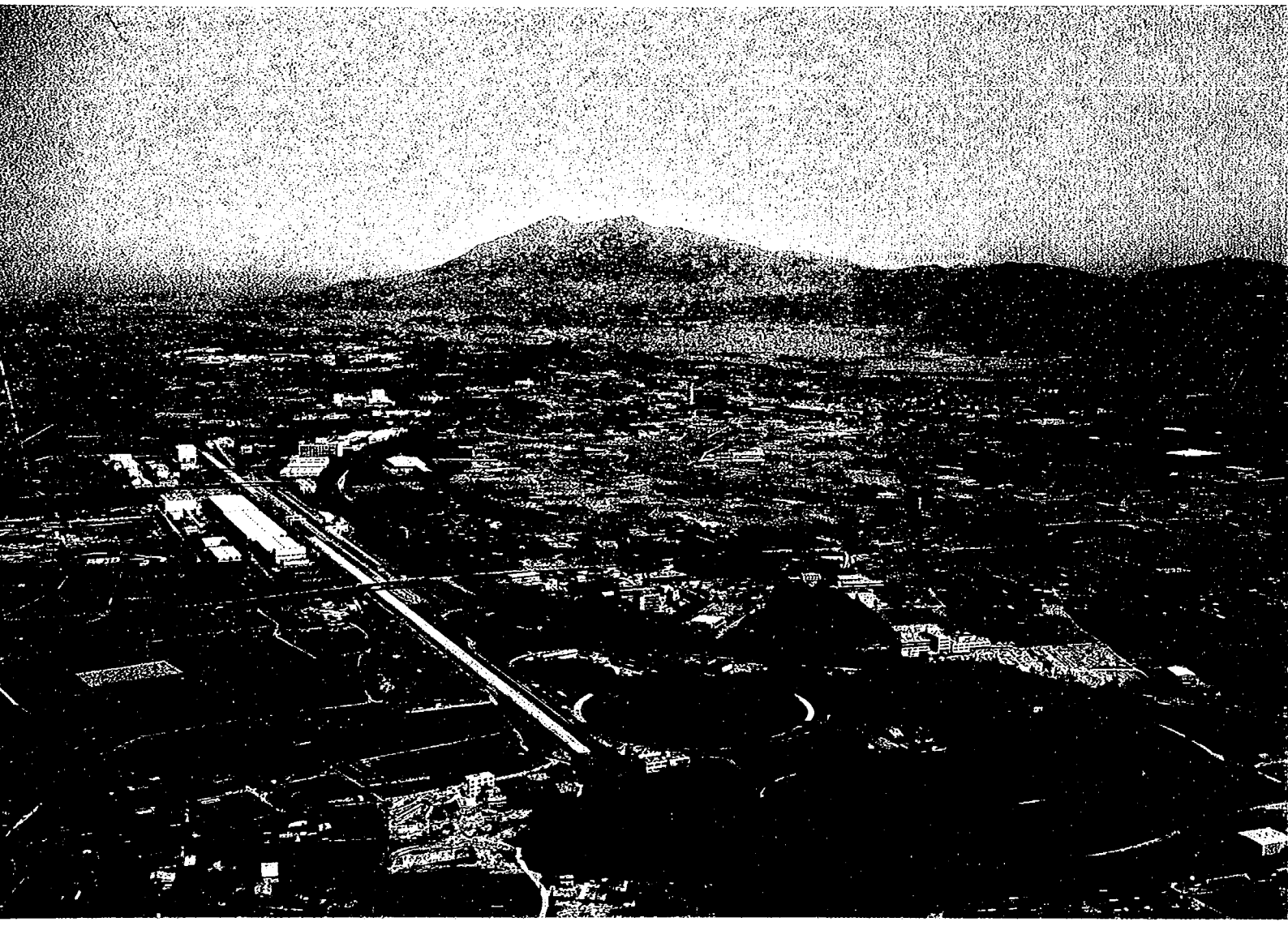
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寒冷地における
先端道路技術に関する
国際ワークショップ

1993年12月6日～11日

つくば市

報告書

1994年3月

建設省土木研究所
カナダ運輸省研究開発局
科学技術庁
(社) 科学技術国際交流センター



ワークショップ参加者



調　印　式



分科会報告

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附属文書

日本国建設省土木研究所とカナダ国運輸省研究開発局間との間の
道路科学技術における協力に関する実施取り決め

1．はじめに

現在，我国では高速自動車国道から市町村道に至るまで，総延長約110万kmの道路ネットワークが構築されている。しかし，その整備水準は急増する交通需要に対し，まだまだ不十分なレベルにとどまっており，深刻な交通渋滞，交通事故の増加，道路交通環境の悪化等が全国各地で顕在化している。国土の均衡ある発展と一体化を図るための高速道路ネットワークだけに着目してみても，その総延長はおよそ5,500km程度であり，将来の計画目標である14,000 km規模に到達できるには，まだまだ長期の年月を要する状況にある。その一方で，道路および道路交通に対する国民のニーズは今後一層高度化，多様化していくものと予想される。これに的確に応えていくためには，着実な道路整備に加え，情報，通信，エレクトロニクス，メカトロニクス，新材料等の先端技術の活用を図り，より安全で快適かつ高品質の道路交通システムの構築を目指していくことが極めて重要であると考えられる。

日本，カナダ両国の関係に目を転じてみると，両国は互いに寒冷地を有し，冬期の道路設計，施工及び管理の面で各々優れた技術水準にある。相互に技術交流を図ることは，両国にとって非常に有意義であることから，1982年から5回にわたって寒冷地の舗装技術に関するワークショップを開催したり，1987年から3年間にわたって耐風耐震構造物に関する共同研究を行って技術交流を図ってきた。その結果，例えば舗装技術においては，寒冷地におけるクラック防止対策，路上再生工法等の新たな技術移転があり，冬期の道路管理あるいは環境保全の面で成果をあげている。

このような状況の中，建設省土木研究所とカナダ運輸省研究開発局との間で道路科学技術に関する本格的な研究協力が開始されたわけである。この研究協力は，1993年12月7日に住吉幸彦建設省土木研究所長とA. E. Pokotylo カナダ運輸省研究開発局長とで署名，文書交換を行った「日本国建設省土木研究所とカナダ国運輸省研究開発局との間の道路科学技術における協力に関する実施取り決め」に基づいて行われる。実施取り決めの協力分野は，従来より技術交流のあった寒冷地舗装及び耐風耐震構造物に，現在世界的な関心を集めている次世代の道路交通システム（IVHS），道路環境及び先端複合材料を加えたものである。より広範囲な分野において体系的に情報交換や人的交流等による技術交流を図り，両国の道路技術の発展をさらに推進することを目的としており，今後，各分野において冬期の道路設計，施工及び管理を中心に新たな技術の移転，開発が期待されている。

今回の寒冷地における先端道路技術に関する国際ワークショップは，この実施取り決めに基づき開催されたものであり，基調講演，研究発表，分科会，プログラム調整委員会等を行うことにより，日加の研究協力の進展を図ろうとするものである。また，ワークショップに合わせて大型風洞の利用に関する発表も同時に行われた。

なお，本ワークショップ及び大型風洞の利用に関する発表は，1991年に科学技術庁において創設された，重点協力分野において開催する国際ワークショップを支援する制度に正式に採択され，財政面の支援を受けて行われたものである。

ワークショップには，日本側から建設省本省，地方建設局，土木研究所，道路関係四公団等の職員が，また，カナダ側からは運輸省及び州政府の行政官および関係機関の研究者が幅広く出席し，実施中の研究活動全般にわたる活発な情報交換が行われた。その結果，今後研究協力を行うべき多くの研究項目及び方法が決定され，さらに次回のワークショップを1996年度にカナダにおいて開催することも決定された。

本報告書はワークショップの記録であり，ワークショップの概要，参加者が採択した最終報告，

現地視察の概要などが掲載されている。また，附属文書として日加間でとりかわされた実施取り決めも掲載されている。

2．ワークショップの概要

1. 目的および意義

本ワークショップは，1993年12月７日に土木研究所において締結された日本国建設省土木研究所とカナダ国運輸省研究開発局との間の実施取り決めに基づいて行われたものであり，その目的は次のとおりである。

a）日加両国の間で寒冷地舗装（ＰＩＣＡ），次世代の道路交通システム（ＩＶＨＳ），耐風耐震構造物，道路環境，先端複合材料（ＡＣＭ）の各分野における最近の研究について情報交換を行うこと

b）将来両国の協力が有益となるであろう分野を探求すること

c）将来の共同計画に合意すること

2. 概要

本ワークショップの本会議は，1993年12月６日～８日に，建設省土木研究所において，約120名の参加者を得て開催された。（付録A　参加者一覧）

本会議は，まず，１日目に５つの分科会に分かれて研究発表，質疑応答及び今後の研究協力の方向等についての討議が行われた。２日目は，「日本の道路行政」，「カナダの道路行政」と題した基調講演及び土木研究所の施設見学が行われた。３日目は，「日本の道路研究」，「カナダの道路研究」と題した研究発表が行われた。引き続き，分科会報告において１日目に行われた各分科会ごとの討議内容の報告が行われた後，議事録起草会議において今回の会議の最終報告の草案が作成され，最後に，プログラム調整委員会において，最終報告の採択が行われた。（付録B　本会議プログラム）

なお，12月７日に行われた土木研究所施設見学及び12月９日～11日に行われた視察旅行の概要を付録Cに示す。

3．ワークショップの報告

以下，それぞれの講演及び会議の内容を報告する。なお，分科会報告は，分科会ごとにその参加者，目的，成果，今後の計画について記述してある。

1．基調講演

日本側，建設省道路局脇国道第二課長は，「日本の道路行政」と題して基調講演を行った。この中で，脇課長は，はじめに日本の地理的概要，自動車の普及状況，交通発達の歴史に触れた後，道路の現況，道路管理者の種類，道路事業の分類について説明した。次に，道路整備の経緯と題して，道路整備の五箇年計画の経緯，道路特定財源，有料道路制度について説明を行った。さらに第１１次道路整備五箇年計画について，その必要性，主要課題，及び整備目標を述べ，この計画の目的は「豊かさとゆとりを実感できる社会」を実現することであり，そのための３つの大きな目標として，生活者の豊かさを支える道路整備の推進，活力ある地域づくりのための道路整備の推進，良好な環境創造のための道路整備の推進があることを述べた。最後に，道路技術五箇年計画の策定を取り上げ，その目的，計画内容，策定のプロセスについて述べ，いくつかの主要技術の具体事例について概要の説明を行った。

カナダ側，運輸省Pokotylo研究開発局長は，「カナダの道路行政」と題して基調講演を行った。この中で，Pokotylo局長は，はじめにカナダの地理的状況，人口分布，道路利用の状況について説明を行った。次に，道路行政システムについて述べ，連邦政府，州政府，市町村政府の役割分担及び３政府の調整機関としてのカナダ運輸協会について説明を行った。また，国道，橋梁の整備状況，道路投資の概要について説明するとともに，連邦の戦略的道路プログラムについて触れた。さらに，カナダにおける道路整備の課題として，自由貿易協定に起因する交通流の変化への対応，維持修繕，新たな財源，技術開発を上げ，説明を行った。最後に，ノースアンバーランド海峡橋の建設プロジェクトについて触れ，その構造，建設費用，資金調達の方法等について紹介を行った。

2．研究発表

土木研究所安崎道路交通総括研究官は，「日本の道路研究」について発表を行った。はじめに，北海道開発局開発土木研究所・日本道路公団試験所・警察庁科学警察研究所・運輸省交通安全公害研究所・日本自動車研究所等によって行われている研究活動について述べた。次に，建設省の行っている道路関係調査は次の４つに分類されることを説明した。それは，交通状態把握のための調査・道路網計画のための調査・道路整備推進のための調査・道路維持管理のための調査である。さらに，土木研究所の調査について触れ，その調査は行政的なニーズに密接に関連し，種々の技術的な基準作成にも大きな役割を果たしていることを指摘した。最後に，先進道路交通システム・新物流システム・長大橋梁・橋梁構造物のハイブリッドコントロールによる耐震設計等の先進技術について述べた。

カナダ運輸省研究開発局Khubchandani氏は，「カナダの道路研究」について発表を行った。はじめに，カナダ国内において調査研究のために支出されている資金の内訳について説明された。カ

ナダの道路に関する年間支出50億ドルのうち，１％程度が関係する研究に支出されているとのことであった。次に，土木関係の調査研究機関の紹介が行われた。財源・調査機関ともにその特徴としては，分散型であることが強調された。次に，現在実施されている調査研究活動の概要の紹介があり，その中で，今回の日加のワークショップで取り上げられている課題に該当する調査研究を行っているカナダ国内の研究機関・現在実施されている主要な研究課題としてのナショナルリサーチアジェンダ1992−1994・カナダにおける国際的な調査研究交流の紹介が行われた。最後に，OECDのレポートをもとにして，1995〜1997年に予定されているカナダにおける道路の調査研究の主要課題がインフラ整備・IVHS・道路安全対策であると述べた。

3・分科会報告

実施取り決めに従い，以下の５つの分科会が編成された：

寒冷地舗装分科会
ＩＶＨＳ分科会
耐風耐震構造物分科会
道路環境分科会
先端複合材料分科会

それぞれの分科会報告は，次の通りである。

3．1　寒冷地舗装

出席者

カナダ側

○*Gerhard J. Kennepohl Manager,*
Pavements & Roadway Office,
Research & Development Branch,
Ontario Ministry of Transportation

日本側

○中村　俊行	建設省土木研究所道路部舗装研究室長
吉田　　武	建設省土木研究所道路部舗装研究室主任研究員
川村　和幸	北海道開発局開発土木研究所維持管理研究室長
七五三野茂	日本道路公団試験研究所舗装試験研究室長
山之口　浩	(財)道路保全技術センター調査部長
桐山　孝晴	建設省土木研究所道路部舗装研究室研究員
久保　和幸	建設省土木研究所道路部舗装研究室研究員

オブザーバー

August E. Pokolylo	*Director General,* *Research and Development* *Transport Canada*
飯島　　尚	建設省土木研究所研究調整官

報告内容

3. 1. 1 目的

この分科会の目的は，低温クラックの防止，冬期路面管理のあり方等，日加両国に共通する寒冷地における舗装について，情報交換，技術者の交流等を行い，研究協力を推進することである。

3. 1. 2 成果

以下の項目について報告がなされた。

「日本における舗装」

中村俊行

日本における舗装の現状に関して，道路の分類，舗装延長の推移，アスファルト舗装の補修原因および補修工法，アスファルト舗装およびコンクリート舗装の構造設計法，排水性舗装，ＲＣＣＰ等の報告があった。これに対して，舗装の破損原因，設計期間等の質疑応答があった。

「カナダにおける舗装」

Gerhard J. Kennepohl

舗装技術の開発，実行，管理に関する報告があった。ここでは，材料，維持・修繕，設計・施工，舗装管理等の項目について，研究テーマの例が示された。また，将来の方向について，環境，健康，社会，政策，技術，経済等に関するキーワードが示された。これに対して，舗装管理システム，パフォーマンスカーブ等の質疑応答があった。

3. 1. 3. 将来計画

3. 1. 3. 1 PICA－6

1）PICA－6の実施

PICA－6の実施について，今年９月にカナダにおいて打合せた内容が確認された。

・PICA－6は，1996年秋に新潟市において開催される
・将来のワークショップは，前進的，計画的に編成されるべきである
・共同事業や人材交流が重要であり，推進されるべきである

2）専門家グループ（ＥWG）の設置

PICA－6においては，従来の論文発表に加えて，特定のテーマについて議論する，５～６個の専門家グループ（ＥWG）を設置する。また，その実施手順について，以下のような提案があり，了承された。

・課題の抽出
・課題選定の基準作り
・ＥWGの設置（会議前に，テーマ，メンバーを決定する）
・ＥWGの実施（その後，全体会議に報告する）

3）課題の提案

ＥWGの課題について，以下のような提案があった。

・ＳＨＲＰ成果の実行
・舗装技術の持続可能な開発（リサイクル等）
・氷雪排除

・供用性の高い舗装
・廃棄物利用の便益と費用
・設計，施工，材料の新技術
・舗装の長期供用性保証の開発
・革新的材料の受入れ手法
・舗装における教育，訓練手法
・舗装管理システム

3. 1. 3. 2 その他

その他の協力として，以下のことを行う。

・情報交換
・人材交流
・共同事業

3. 1. 4 その他

共同事業のテーマとして，アスファルト混合物の配合設計について共通試験を行うことが提案された。

3. 2 IVHS

出席者

カナダ側

○*Milton D. Harmelink*	*Director, Transportation Technology & Energy Branch, Ontario Ministry of Transportation*
Lewis Sabounghi	*Senior Development Officer, Transportation Development Center*

日本側

○中村　亮	建設省土木研究所道路部道路研究室長
松村　哲男	建設省土木研究所道路部総合交通安全研究官
日置　洋平	建設省土木研究所道路部道路研究室主任研究員
平井　節生	建設省土木研究所道路部道路研究室研究員
今長　信浩	建設省土木研究所道路部道路研究室研究員
村田　重雄	建設省土木研究所道路部道路研究室研究員
大石　嗣雄	日本道路公団技術部交通技術課長代理
中井　三夫	首都高速道路公団交通管制部管制技術課長補佐
佐々木　清	阪神高速道路公団業務部交通管制課長補佐
増田芳太郎	(財)道路新産業開発機構技術参与
吉海　達	(財)道路新産業開発機構企画開発部調査役
柴田　正雄	(財)日本デジタル道路地図協会専務理事
飯野　宏	(財)日本デジタル道路地図協会企画調査部長

オブザーバー

August E. Pokotylo *Director General,*
Research and Development, Policy and Coordination
Transport Canada

飯島　尚　建設省土木研究所研究調整官

報告内容

3. 2. 1 目的

本分科会の目的は，ＩＶＨＳに関する実験結果やシステムの導入に対する情報を交換し，ＩＶＨＳの研究開発を促進することにある。

3. 2. 2 成果

日加両国におけるＩＶＨＳの開発状況及び将来計画が両国からの発表を通じて明らかになった。発表は以下のとおり。

日本側からは，

「日本におけるＩＶＨＳ活動の現状」　中村　亮

「道路交通情報通信システム（ＶＩＣＳ）」　増田　芳太郎

「日本におけるデジタル道路地図データベースの現況と今後の計画」

カナダ側からは，

「カナダにおけるＩＶＨＳ活動の現状」　Milton D. Harmelink

「ローコスト多用途ＩＶＨＳインフラストラクチャーをめざして」　Lewis Sabounghi

「トラベルガイドルートナビゲーションシステム」　Milton D. Harmelink

の計６点であった。

ディスカッションにおいては，カナダ側からは日本のＶＩＣＳの普及状況，整備効果，データ収集の方法等について質問がなされたほか，日本側からはカナダのオンタリオ州において実施されている道路交通情報システム（トラベルガイド）の運営組織等について質問がなされたが，個別の技術の点では，

1）交通事故感知システム

2）自動料金徴収システム

3）路車間及び車々間双方向通信システム

の３技術について特に活発に討議がなされた。

3. 2. 3 将来計画

以下の２つの活動が本分科会の当面の主たる活動とされた。

1）資料の送付等の情報交換

2）相手国からの短期間の訪問者の受入れ

また，特に活発に議論がなされた３つの技術についてはそれぞれの技術について両国で以下のコンタクトパーソンを設置して直接に情報交換をすることとした。

1）交通事故感知システム

日本側　阪神高速道路公団業務部交通管理課長補佐　佐々木　清

カナダ側　Milton D. Harmelink, Director, Transportation Technology & Energy Branch, Ontario Ministry of Transportation

2）自動料金徴収システム

日本側　日本道路公団技術部交通技術課長代理　大石　嗣雄

カナダ側　Milton D. Harmelink, Director, Transportation Technology & Energy Branch, Ontario Ministry of Transportation
Lewis Sabounghi, Senior Development Officer, Transportation Development Center

3）路車間双方向通信システム

日本側　建設省土木研究所道路部道路研究室長　中村　亮

カナダ側　Milton D. Harmelink, Director, Transportation Technology & Energy Branch, Ontario Ministry of Transportation
Lewis Sabounghi, Senior Development Officer, Transportation Development Center

3. 2. 4　その他

次回の分科会は次回のワークショップが開催される際に開催することとした。

3. 3　耐風耐震構造物

出席者

カナダ側

○*Michael G. Savage*	*Research Officer,* *Applied Aerodynamics Laboratory,* *Institute for Aerospace Research,* *National Research Council Canada*
Robert L. Wardlaw	*Guest Worker,* *Applied Aerodynamics Laboratory,* *Institute for Aerospace Research,* *National Research Council Canada*
Donald L. Anderson	*Professor,* *Department of Civil Engineering,* *University of British Columbia*
Alan G. Davenport	*Professor,* *Department of Civil Engineering,* *Boundary Layer Wind Tunnel Laboratory,* *The University of Western Ontario*
Hiroshi Tanaka	*Professor,*

	Department of Civil Engineering,
	Uiversity of Ottawa
J. Peter C. King	*Research Associate,*
	Boundary Layer Wind Tunnel Laboratory,
	The University of Western Ontario

日本側

○佐藤　弘史	建設省土木研究所構造橋梁部構造研究室長
川島　一彦	建設省土木研究所地震防災部耐震研究室長
鈴木　周一	本州四国連絡橋公団
（北川　信：本州四国連絡橋公団の代理）	
猪熊　康夫	日本道路公団技術部構造技術課長代理
中村　一平	阪神高速道路公団公務部設計課長補佐
高野　晴夫	首都高速道路公団
（山崎　和夫：首都高速道路公団の代理）	
飯田　裕	建設省土木研究所地震防災部長
大塚　久哲	建設省土木研究所地震防災部振動研究室長
松尾　修	建設省土木研究所地震防災部動土質研究室長
運上　茂樹	建設省土木研究所地震防災部耐震研究室主任研究員
中島　燈	建設省土木研究所地震防災部耐震研究室研究員
岩崎　秀明	建設省土木研究所地震防災部振動研究室研究員
東　拓生	建設省土木研究所地震防災部振動研究室研究補助員
古関　潤一	建設省土木研究所地震防災部動土質研究室研究員
Andrew Taylor	（米国国立標準技術研究所，米国からの招聘研究員）

報告内容

3. 3. 1 目的

この分科会は，構造物の耐風設計，耐震設計に関連する科学的な情報および技術の交換を推進することを目的とする。

3. 3. 2 成果

3. 3. 2. 1 構造物の耐風設計

セミナー形式（場所：研究交流センター，聴衆：約150人）により，下記の論文発表が両国よりなされ，有益な情報交換がなされた。

カナダ側

「長大橋梁の対風応答に及ぼす地形，強風の特性の影響」

Alan G. Davenport

「大型風洞における風工学および非航空力学分野の風洞実験」

Robert L. Wardlaw（カナダ国立研究所）

「斜張橋の架設における風洞実験及び水平偏角の影響」
田中　宏

日本側

「日本の吊形式橋梁の耐風設計」
伊藤　學
「動的空力特性と風環境を考慮した長大橋梁の計画設計法」
白石　成人
「日本の長大橋梁の風洞試験法」
成田　信之
「明石海峡大橋の耐風設計」
宮田　利雄
「明石海峡大橋の大型風洞実験」
佐藤　弘史
「明石海峡大橋上部構造の設計」
北川　信

上記の発表の中で，風洞実験方法，耐風設計方法について振り返るとともに，長大橋梁の風による振動，風の特性が対風応答に及ぼす影響についての解説，耐風設計法に対する提案がなされた。さらに，明石海峡大橋についての研究成果の紹介がなされた。

3. 3. 2. 2　構造物の耐震設計

1）日本及びカナダ両国における現在の研究状況について説明された。

a）土木研究所地震防災部耐震研究室における研究活動：川島一彦

以下の点について重点的に説明された。

・既往の地震による道路橋の地震被害の変遷
・道路橋の耐震設計
・震災を受けた道路橋の復旧方法
・既設道路橋の耐震点検法及び耐震補強法
・道路橋の免震設計及びハイブリッドコントロール
・斜張橋の減衰特性
・地震時の地盤振動特性

b）土木研究所地震防災部振動研究室における研究活動：大塚久哲

以下の点について重点的に説明された。

・強震観測
・近距離地震の距離減衰特性
・地震動の高密度強震観測
・液状化発生の評価方法
・地震危険度ゾーニングのビジュアル情報システム

c）土木研究所地震防災部動土質研究室における研究活動：松尾　修

以下の点について重点的に説明された。

・液状化に対する土構造物の耐震設計法の確立
・液状化に対する土構造物の対策方法の開発

d）カナダにおける橋梁の耐震性に関する研究：Donald L. Anderson 教授

以下の点について重点的に説明された。

・既設鉄筋コンクリート橋の挙動及び耐震補強方法
・鉄筋コンクリート部材の高じん性領域におけるせん断強度の推定法
・せん断強度向上のためのプレストレスの利用法
・コンクリート橋の支承におけるジョイント部の応答
・軟弱地盤の地震動の推定及び土と構造物の動的相互作用
・液状化の推定，液状化による地盤変動の評価，液状化を防ぐための地盤改良方法
・地震時の地盤振動の空間変化特性の解明のための強震記録の活用
・箇所別に異なる地震動を受ける長大橋の応答
・下部構造の耐震性の判定及び耐震補強設計方法
・免震及びエネルギー吸収装置
・既設プレストレス橋の耐震補強法
・斜張橋及び吊橋の解析プログラム
・実橋の動的振動試験
・プレキャスト橋及びジョイントの動的試験
・橋の危険度の評価及び耐震補強の決定方法
・費用便益効果

2）関連する主要な出版物及び参考文献が日本側からカナダ側へ贈られた。

3）日本及びカナダ両国において相互に興味のある研究分野に関する討論が行われた。多くの分野において相互に興味の一致することが明らかになった。

3. 3. 3 将来計画

3. 3. 3. 1 構造物の耐風設計

下記の項目が，今後の共同研究の課題として検討，提案された。これらの項目について論文や各種情報の交換を行なう。研究計画の詳細については両国間で提案，討議することとする。

1）風洞実験方法についての研究

長大橋梁の空力安定性を正確に評価するには，精度の高い風洞実験を実施することが基本である。風洞実験手法の基本的な考え方は世界中で共通であるが，風の発生方法，風洞実験模型の製作方法，非定常空気力の計測方法については各国間で差異がある。このため，両国間で風洞実験方法について研究を実施することは両国にとって有益である。

2）橋梁の桁にかかる非定常空気力のカタログ化

動的空気力学的に優れた推薦される桁断面のリストが作成され，非定常空気力係数，空力アドミッタンスなどの動的空気力学的情報がそれぞれの断面に対応して整備されれば，そのリストは利用価値が高く，耐風設計を解析的に実施することができる。このため，両国間で，橋梁の桁の動的空気力学的情報を交換し，カタログ化してゆくことは両国にとって有益である。

両国の間で情報交換を促進して行く。下記の項目が情報交換の重点項目のいくつかとして提案がなされた。

1）既存橋梁の風による被害に対する脆弱性
2）高速道路上の積雪の吹き溜まりの特性
3）橋梁，高速道路上の車両の風に対する安定性

3. 3. 3. 2 構造物の耐震設計

1）日本及びカナダ両国が強い興味を有する以下の分野の技術情報の交換を行っていくことが提案された。

a）高じん性領域における鉄筋コンクリート部材のせん断強度の推定方法の開発
b）軟弱地盤の地盤振動特性
c）液状化の評価方法，液状化による地盤変動の評価方法，及び液状化防止のための地盤改良方法

2）耐震技術に関する技術情報の交換を行うための場を用意するために，耐震技術に関する第1回日本カナダワークショップを組織することが提案された。第1回ワークショップは，1994年秋の終わり頃に開催することが提案された。日時及び場所については，コンタクトパーソン間で相談することとされた。

3. 4 道路環境

出席者

カナダ側

○*Michael Kent*	*Director, Highway Environment, B. C. Transportation and Highway*

日本側

○石田 稔	建設省土木研究所環境部交通環境研究室長
安藤 淳	建設省道路局企画課道路環境対策室課長補佐
水谷 敏則	建設省土木研究所環境部長
明嵐 政司	建設省土木研究所環境部交通環境研究室主任研究員
上坂 克巳	建設省土木研究所環境部交通環境研究室研究員
西尾 崇	建設省土木研究所環境部交通環境研究室研究員
半田真理子	建設省土木研究所環境部緑化生態研究室長
仲柴二三夫	日本道路公団企画部環境対策課長代理
木村 尚史	日本道路公団企画部環境対策課副参事
高木 武康	首都高速道路公団計画部環境技術課調査役
入谷 良弘	阪神高速道路公団計画部環境対策室専門役
岡部 芳文	本州四国連絡橋公団企画開発部調査課長
村井 逸郎	名古屋高速道路公社計画部環境対策室長補佐

オブザーバー

Shyam Khubchandani	*Chief, Planning and Coordination*

Research and Development
Policy and Coordination
Transport Canada
飯島　尚　　建設省土木研究所研究調整官

報告内容

3. 4. 1 目的

道路環境分科会の目的は，生活環境及び自然環境を対象とした道路環境問題について，双方の知識と理解を深めることである。

3. 4. 2 成果

3. 4. 2. 1 日本側発表概要

まず，日本における道路環境問題の発生の経緯と，それを低減するためにこれまでとられてきた各種の法的制度についての発表が行われた。具体的には，環境基準及び環境影響評価，沿道法が説明された。さらに，現在の道路環境問題の傾向と今後の政策の方向について発表があった。そこでは，地球温暖化の防止と，自然環境との調和，良好な生活環境の保全・形成が重要課題として示された。

また，道路環境技術の概要について網羅的に発表が行われた。環境技術の分野としては，大きく分けて大気，騒音，自然環境の3つがある。大気，騒音については，最近の研究である各種遮音壁，低騒音舗装，高架裏面への吸音板，樹木による大気浄化を含めて説明がなされた。自然環境については，自然環境に配慮した道路づくりの考え方と保全対策のメニューが報告された。

3. 4. 2. 2 カナダ側発表概要

まず，連邦における環境影響評価の法制度とシステム，その効果等について説明がなされ，それがBritish Columbia州で実際に行われる場合の詳細について発表が行われた。さらに，環境影響評価の一つの例として，Coquihalla Projectについて具体的な説明がなされた。

この道路計画は海岸部から内陸部までおよぶ非常に長いものであるために多くの保全対象が存在した。それらは，河川に生息する魚類や，放牧されている家畜，野生のシカやクマなどである。これら自然環境の調査や保全対策，補償対策について説明がなされた。魚類については，多様性に富んだ生活圏を保全・創出する対策がなされ，家畜の移動のために必要な橋やカルバートが設置され，また野生動物に対しては無線追跡装置を用いた影響予測とそれに基づいた動物侵入防止柵の設置，移動路の建設がなされているという報告がなされた。また，それらの対策がうまく機能しているかについての追跡調査の内容も報告された。

3. 4. 2. 3 討議の概要

(1) 両国の研究活動について

以下の点について質疑応答を行った。

・動物の衝突件数の根拠について
・自然環境保全に関するインセンティブについて

・自然環境保全のための予算的問題について
・環境アセスメントの際の民間調査の手続きについて
・事後調査の実施機関について
・建物側の騒音対策手法について
・大気汚染の排出規制，騒音の環境基準について
・道路の排水構造について

(2) 両国の必要とする情報について

日本側は自然環境，生活環境を保全するための技術について興味がある。日本の自然環境保全対策を普及させるにはさらに多くの情報が必要である。生活環境については特に騒音，大気汚染が環境基準との比較で問題が大きい。また，沿道の緑化手法及び環境アセスメントのシステムについても情報交換が必要と考えている。

カナダの自然環境は州によって異なるが，その中には日本と似た環境の地域もあり，十分情報交換の意義があると考えられる。大気汚染については2大都市で問題があるが，騒音については都市の近隣で問題があるほかはあまり問題にされないような状況である。また，除雪剤として使用される塩による汚染も問題がある。緑化についてはマニュアルがあるが，現在でも維持の問題などがある。

3. 4. 3 将来計画

(1) 以下の項目について，文献と情報の交換を行うこととする。
・環境アセスメントに関する制度
・自然環境保全のための調査や対策手法の研究成果と実例
・沿道の大気汚染対策，交通騒音対策に関する各種の研究成果
・緑化に関する各種の調査成果，指針

(2) 追加的に情報交換が必要な場合，上のほかに課題を設定し，情報交換を行う。

(3) 今後の活動を促進するため，国際会議等の他の機会を利用できる。
例えば，1994年に国際環境会議が Vancouver で開催される。

3. 5 先端複合材料

出席者

カナダ側

○*Daniel Vezina*	*Chef de la section des Betons de ciment, Division des produits industriels, Transports Quebec*
Ken W. Neal	*Professor, Department de genie civil, Faculte des sciences appliquees, Universite de Sherbrooke*

日本側

○片脇　清	建設省土木研究所材料施工部化学研究室長

岩崎　泰彦	建設省道路局国道第二課長補佐
池村　雅司	建設省土木研究所材料施工部長
西川　和廣	建設省土木研究所構造橋梁部橋梁研究室長
西崎　　到	建設省土木研究所材料施工部化学研究室研究員
安藤　博文	日本道路公団試験研究所橋梁研究室
前田　良文	日本道路公団試験研究所橋梁研究室主任
丸山真佐雄	首都高速道路公団東京保全部設計課長

報告内容

3. 5. 1 目的

本分科会の開催目的は，ＡＣＭを用いた土木構造物の設計及び利用技術を開発するため必要な，ＡＣＭの利用に関する研究結果や技術動向などについての情報交換を行うことである。

3. 5. 2 成果

3. 5. 2. 1 研究発表

以下の項目について報告がなされた。

1）QuebecにおけるＦＲＰの利用についての経験
2）カナダにおけるＡＣＭの橋梁及び構造物への利用の現状
3）既設構造物の炭素繊維による補強に関する研究
4）炭素繊維補強プラスチック接着によるＲＣスラグの補強
5）ＦＲＰケーブル材料の暴露試験の実施例
6）ＡＣＭの土木構造物への最近の利用例

「QuebecにおけるＦＲＰの利用についての経験」

Daniel Vezina

ケベックにおいて生産されたＦＲＰの評価結果と現場での利用例について発表された。

実験室におけるＧＦＲＰロッドの，特に下記の項目についての試験結果が報告された。

1）物理的性質
2）凍結融解性
3）低温試験
4）引き抜き試験

また，ＧＦＲＰの現場での応用例についての結果についても発表があった。

「カナダにおけるＡＣＭの橋梁及び構造物への利用の現状」

Ken W. Neale

(1) 橋梁や土木構造物へのＡＣＭ応用についてのカナダにおける研究方向について発表があった。

1）海外視察団，2）国際会議，3）カナダ政府及びカナダ土木学会の協力によるネットワーク

(2) 設計基準の動向について発表があった。

1）橋梁設計基準，2）建築物の規格

(3) 応用例が紹介された。

1）Nova scotia のACM橋のプロジェクト，2）カルガリー市中央道路橋でのＡＣＭ利用例，3）ＦＲＣによる橋梁床版補強，4）ＦＲＰ歩道橋，5）コンクリートのカーボンファイバーシートによる補修

「既設構造物の炭素繊維による補強に関する研究」

安藤　博文

日本道路公団で行った炭素繊維を用いた耐震補強方法に関する研究報告を行った。

車と交通容量の増加のために，桁は当初の設計荷重を超えるようになったため，桁の補強が必要になっている。

炭素繊維を用いた場合の付着力，疲労試験を紹介し，炭素繊維を用いることによって曲げ抵抗性について効果的に補強がなされた実験結果を発表した。

これらの結果から，既存構造物の炭素繊維を用いた補強効果が確認された。

「炭素繊維補強プラスチック接着によるＲＣスラブの補強」

丸山　真佐雄

首都高速道路公団では，ＣＦＲＰを接着したＰＣスラブ補強工法を検討している。この方法は，箱桁の場合や障害物があって作業性が劣る場合に有効である。

ＣＦＲＰの使用目的は，過積載によって生じる過剰な載荷力によって生じる鉄筋応力を軽減することである。

静的荷重試験や試験施工がなされたが，これらの実験結果によれば，鉄筋応力の軽減がみられることから，ＣＦＲＰを接着したＰＣスラブ補強工法の有効性が確認された。

「ＦＲＰケーブル材料の暴露試験の実施例」

西崎　　到

土木研究所において行われているＦＲＰの暴露試験の概要が紹介された。

過酷な環境におけるＦＲＰの長期耐久性を研究するため，海上を中心に試験が行われている。暴露試験の結果の一部が報告され，特別な条件下では，いくつかのＦＲＰが劣化を示す例が報告された。

これらの結果から，あらためてＦＲＰの耐久性研究の重要性が確認された。

「ＡＣＭの土木構造物への最近の利用例」

片脇　　清

日本におけるＡＣＭの最近の動向例を発表した。

コンクリート橋の最近の利用例を紹介した。次に最近注目を浴びているグランドアンカーの利用例を紹介した。

ＡＣＭを利用する際の問題点として，

1）ＡＣＭの長期耐久性

2）材料設計技術

が必要であることを示した。

3. 5. 2. 2 討論

プレゼンテーションに引き続き質疑応答とコメントの交換が活発に行われた。

下記の項目について特に意見交換が行われた。

1）橋梁床版防水方法と問題点
　適切な被覆材料について
2）ＦＲＰによる橋梁床版の補強
3）複合材料としてのＦＲＰの種類と性質
4）ＡＣＭ構造物の試験施工計画
5）ＦＲＰによる橋梁桁の補強
6）海塩と凍結防止材による鉄筋コンクリートの腐食
7）ＦＲＰ接着による橋梁床版の補強工法
8）ＡＣＭ利用のための設計基準の動向
9）西川橋梁研究室長から日本の海塩による橋梁損傷についての紹介
10）土木全般へのＡＣＭの設計と用途

3. 5. 3 将来計画

(1) 下記の項目について文献や情報の交換を行う。

1）ＡＣＭの土木分野での用途
2）ＡＣＭを利用した構造物に関する試験研究結果
3）ＡＣＭの研究に関する研究者リスト
4）ＡＣＭ構造物に関する設計基準と試験規格

(2) ＡＣＭを用いた実際構造物の相互視察と共同調査

(3) 長期及び短期の研究機関の相互訪問

(4) 今後の活動を推進するため，他のいろいろな機会を利用する。

4．全体の成果

3日間のワークショップは，両国の最新の情報を共有するのに非常に有益なものであった。また，前記のように同時に開催された5つの分野の分科会では，広く日本の道路関係者の参加も得て日加両国の研究者が様々なテーマに関する知識や意見，論文を交換した。さらに明確な今後の活動方針が確立され，連絡窓口が設定された。

5．将来計画

(1) 両者によって確立された5つの分野に関する研究協力をより効率的に行うため，組織を強化し，活動を継続する。また，両者は予算を確保する努力を行う。

(2) 両者は次の項目に関するさらなる協力を検討することに合意した。

1. 研究施設やコンピューターモデル等の相互利用
2. 研究者交流の拡大
3. 技術の普及

4. ジョイント・デモンストレーション
5. 民間の参加
6. 関連する会議への参加

(3) 両者は，第２回合同委員会を1996会計年度にカナダの主催で開くことに合意した。

4. 大型風洞の利用に関する発表

「寒冷地における先端道路技術に関する国際ワークショップ」の機会を得て，12月６，７日の両日，日本・カナダ両国の風工学の研究者に加え，その他の国の長大橋梁建設プロジェクトに関する風工学の面からの検討を実施されている著名な研究者の方々を交えて，大型風洞の利用に関する発表を通じて，情報交換の場を持った。発表の会場は，つくば市内の「研究交流センター」の国際会議場とし，一般の聴衆も臨席できる形としたため，約１５０人の一般聴衆が発表を聴講した。発表者，発表表題を下記に示す。

日本より

「日本の吊形式橋梁の耐風設計」
伊藤　學　（埼玉大学）

「動的空力特性と風環境を考慮した長大橋梁の計画設計法」
白石　成人　（京都大学）

「日本の長大橋梁の風洞試験法」
成田　信之　（東京都立大学）

「明石海峡大橋の耐風設計」
宮田　利雄　（横浜国立大学）

「明石海峡大橋の大型風洞実験」
佐藤　弘史　（土木研究所）

「明石海峡大橋上部構造の設計」
北川　信　（本州四国連絡橋公団）

カナダより

「長大橋梁の対風応答に及ぼす地形，強風の特性の影響」
Alan G. Davenport　（西オンタリオ大学）

「大型風洞における風工学および非航空力学分野の風洞実験」
Robert L. Wardlaw　（カナダ国立研究所）

「斜張橋の架設における風洞実験及び水平偏角の影響」
田中　宏　（オタワ大学）

その他，海外より

「グレートベルト海峡イースト橋の耐風設計における全橋模型風洞実験の役割」
Timothy A. Reinhold　（米国　クレムゾン大学）

「メッシナ海峡連絡橋の耐風設計のための解析的及び実験的研究」
Giogio Diana　（イタリア　ミラノ工科大学）

「ジブラルタル海峡連絡橋の耐風設計」
Miguel Angel Astiz Suarez　（スペイン　マドリッド工科大学）

上記の発表の中で，風洞実験方法，耐風設計方法について振り返るとともに，最大橋梁の風による振動，風の特性が対風応答に及ぼす影響についての解説，耐風設計法に対する提案がなされた。さらに，明石海峡大橋についての研究成果の紹介がなされた。

付　　録

参加者一覧

〔Transport Canada〕 Place de Ville－Tower C－, Area B,
Ottawa, Ontario K1A ON5

Mr. A. E. Pokotylo
Director General, Research and Development, Policy and Coordination
TEL：613－991－6036 FAX：613－991－6045

Mr. Shyam Khubchandani
Chief, Research Coordination, Research and Development, Policy and Coordination
TEL：613－991－6036 FAX：613－991－6045

〔Ontario Ministry of Transportation〕 1201 Wilson Avenue, Downsview, Central Building, Ontario M3M 1J8

Dr. Gerhard J. Kennepohl
Head, Pavements and Roadway Office, Research & Development Branch
TEL：416－235－4701 FAX：416－235－4872

Mr. Milton D. Harmelink
Director, Transportation Technology and Energy Branch
TEL：416－235－5040 FAX：416－235－4936

〔B.C. Transportation and Highway〕 940 Blanshard Street, Victoria, B.C. V8W 3E6

Mr. Michael Kent
Director, Highway Environment
TEL：604－387－3208 FAX：604－387－3736

〔Transports Quebec〕 2700 rue Einstein, Sainte－Foy, Quebec G1P 3W8

Mr. Daniel Vezina
Chef de la section des Betons de cirnent Division des produits industriels
TEL：418－643－3178 FAX：418－646－6692

〔National Research Council Canada〕 Bldg. M－2, Montreal Road, Ottawa, Ontario K1A OR6

Mr. Michael G. Savage
Research Officer, Applied Aerodynamics Laboratory, Institute for Aerospace Research
TEL：613－991－1144 FAX：613－957－4309

Mr. Robert L. Wardlaw　Guest Worker, Applied Aerodynamics Laboratory
Institute for Aerospace Research
TEL : 613-749-5919　FAX : 613-957-4309

〔University of Ottawa〕　161 Louis Pasteur,
Ottawa, Ontario K1N 6N5
Prof. Hiroshi Tanaka　Professor, Department of Civil Engineering
TEL : 613-564-3432　FAX : 613-564-9860

〔The University of Western Ontario〕　London, Ontario N6A 5B9
Prof. Alan G. Davenport　Director and Professor, Boundary Layer Wind Tunnel Labo.
TEL : 519-661-3338　FAX : 519-661-3339

J. Peter C. King　Research Associate, Boundary Layer Wind Tunnel Labo.
TEL : 519-661-3338　FAX : 519-661-3339

〔University of British Columbia〕　2017-2324 Main Mall
Vancouver, B.C. V6T 1Z4
Prof. Donald L. Anderson　Professor, Department of Civil Engineering
TEL : 604-822-2637　FAX : 604-822-6901

〔Universite de Sherbrooke〕　Sherbrooke, Quebec J1K 2R1
Prof. Ken W. Neale　Professor, Department de genie civil
Faculte des sciences appliquees
TEL : 819-821-7752　FAX : 819-821-7974

〔Transportation Development Center〕　Guy-Favreau Complex, 200 Rene-Levesque
Blvd W, West Tower Suite 601,
Montreal, Quebec H2Z 1X4
Dr. Lewis Sabounghi　Senior Development Officer
TEL : 514-283-0029　FAX : 514-283-7158

〔カナダ大使館〕　〒100 東京都港区赤坂7-3-38
TEL : 03-3408-2101
Mr. Donald W. Campbell　大使
Mr. Stuart Wilson　参事官（科学技術）
鈴木　弘子　技術情報官
阿部のり子　科学技術室科学技術調査官

〔建設省〕

〒100　東京都千代田区霞が関２－１－３
TEL：03－3580－4311

藤井　治芳	技監
安藤　　淳	道路局企画課道路環境対策室課長補佐
脇　　雅史	道路局国道第二課長
岩崎　泰彦	道路局国道第二課課長補佐
村上　真幸	建設経済局国際課海外協力官

〔建設省土木研究所〕

〒305　茨城県つくば市大字旭１番地
TEL：0298－64－2211

住吉　幸彦	所長
都丸　徳治	次長
飯島　　尚	研究調整官
田口　　仁	総務部長
田村　正秀	企画部長
水谷　敏則	環境部長
池村　雅司	材料施工部長
藤原　　稔	構造橋梁部長
飯田　　裕	地震防災部長
大石龍太郎	企画部国際研究協力官
安崎　　裕	道路部道路交通総括研究官
松村　哲男	道路部総合交通安全研究官
高橋　庄三	総務部会計課長
森　　望	企画部企画課長
石田　　稔	環境部交通環境研究室長
明嵐　政司	環境部交通環境研究室主任研究員
上坂　克巳	環境部交通環境研究室研究員
西尾　　崇	環境部交通環境研究室研究員
半田真理子	環境部緑化生態研究室長
中村　　亮	道路部道路研究室長
日置　洋平	道路部道路研究室主任研究員
平井　節生	道路部道路研究室研究員
今長　信浩	道路部道路研究室研究員
村田　重雄	道路部道路研究室研究員
中村　俊行	道路部舗装研究室長
吉田　　武	道路部舗装研究室主任研究員
桐山　孝晴	道路部舗装研究室研究員
久保　和幸	道路部舗装研究室研究員
片脇　　清	材料施工部化学研究室長
西崎　　到	材料施工部化学研究室研究員

佐藤　弘史	構造橋梁部構造研究室長
西川　和廣	構造橋梁部橋梁研究室長
大塚　久哲	地震防災部振動研究室長
岩崎　秀明	地震防災部振動研究室研究員
東　　拓生	地震防災部振動研究室研究補助員
川島　一彦	地震防災部耐震研究室長
運上　茂樹	地震防災部耐震研究室主任研究員
中島　　燈	地震防災部耐震研究室研究員
松尾　　修	地震防災部動土質研究室長
古関　潤一	地震防災部動土質研究室研究員

〔建設省北陸地方建設局〕　〒951 新潟県新潟市白山浦1－425－2
TEL：025－266－1171

日野　祐滋	道路調査官

〔北海道開発局開発土木研究所〕　〒062 北海道札幌市豊平区平岸1－3
TEL：011－841－1111

清崎　昌雄	所長
川村　和幸	維持管理研究室長

〔科学技術庁〕　〒100 東京都千代田区霞が関2－2－1
TEL：03－3581－5271

小倉伸一郎	科学技術振興局国際課長
堀口　彰一	科学技術振興局国際交流推進室調査員

〔日本道路公団〕　〒100 東京都千代田区霞が関3－3－2
TEL：03－3506－0111

栗原　光二	技術部交通技術課長
大石　嗣雄	技術部交通技術課長代理
猪熊　康夫	技術部構造技術課長代理
仲柴二三夫	企画部環境対策課長代理
木村　尚史	企画部環境対策課副参事

〔日本道路公団試験研究所〕　〒194 東京都町田市忠生1－4－1
TEL：0427－91－1621

市川　義博	所長
前田　良文	橋梁研究室主任
安藤　博文	橋梁研究室技師
七五三野茂	舗装試験研究室長

〔首都高速道路公団〕

〒100 東京都千代田区霞が関1－4－1
TEL：03－3502－7311

一桝　久允	工務部設計技術課長
山崎　和夫	工務部調査役
中井　三夫	交通管制部管制技術課長補佐
高木　武康	計画部環境技術調査役
丸山真佐雄	東京保全部設計課長

〔阪神高速道路公団〕

〒541 大阪府大阪市中央区久太郎町4－1－3
TEL：06－252－8121

佐々木　清	業務部交通管制課長補佐
中村　一平	工務部設計課長補佐
入谷　良弘	計画部環境対策室専門役

〔本州四国連絡橋公団〕

〒105 東京都港区虎ノ門5－1－5
TEL：03－3434－7281

森　　章	企画開発部調査役
岡部　芳文	企画開発部調査課長
鈴木　周一	設計部設計第一課長代理

〔名古屋高速道路公社〕

〒460 愛知県名古屋市中区丸の内1－16－15
TEL：052－211－1445

村井　逸郎	計画部環境対策室長補佐

〔（社）科学技術国際交流センター〕

〒102 東京都千代田区麹町2－12－6
TEL：03－3288－0970

石川　智子	主事

〔（財）道路新産業開発機構〕

〒105 東京都中央区築地7－17－1
TEL：03－3545－6633

増田芳太郎	技術参与
吉海　　達	企画開発部調査役

〔（財）日本デジタル道路地図協会〕

〒102 東京都千代田区平河町1－3－13
TEL：03－3222－7990

柴田　正雄	専務理事
飯野　　宏	企画調査部長

〔（財）土木研究センター〕

〒305 茨城県つくば市西沢2－2
TEL：0298－64－2521

市原　　薫	理事長

〔（財）道路保全技術センター〕

〒103 東京都中央区日本橋久松町9－9
TEL：03－5695－2711

山之口　浩　　調査部長

〔（財）道路環境研究所〕

〒102 東京都千代田区紀尾井町3－30
TEL：03－3234－5326

松村　　保　　常務理事

本会議プログラム

第一日目　12月6日（月）

9：30～10：00　受付け　（8F会議室）

10：00～12：00　分科会

A：寒冷地舗装分科会（PICA）　（526会議室）

10：00～10：30　研究発表　「日本における舗装」
建設省土木研究所　舗装研究室長　中村　俊行

10：30～10：50　討議

10：50～11：10　休憩

11：10～11：40　研究発表　「カナダにおける舗装」
Gerhard J. Kennepohl
Manager, Pavements & Roadway Office,
Research & Development Branch,
Ontario Ministry of Transportation

11：40～12：00　討議

B：IVHS分科会　（627会議室）

10：00～10：30　研究発表　「日本におけるIVHS活動の現状」
建設省土木研究所　道路研究室長　中村　亮

10：30～11：00　研究発表　「カナダにおけるIVHS活動の現状」
Milton D. Harmelink
Director,
Transportation Technology & Energy Branch,
Ontario Ministry of Transportation

11：00～11：15　休憩

11：15～11：45　研究発表　「道路交通情報通信システム（VICS）」
（財）道路新産業開発機構　技術参与　増田芳太郎

11：45～12：00　討議

C：耐風耐震構造物分科会　（8F国際会議室）

10：00～10：45　研究発表　「日本における耐震設計に関する研究活動の現況」
建設省土木研究所　耐震研究室長　川島　一彦
振動研究室長　大塚　久哲
動土質研究室長　松尾　修

10：45～11：30　研究発表　「カナダにおける橋梁の耐震性に関する研究」
Donald L. Anderson
Professor, Department of Civil Engineering,
University of British Columbia

11：30～12：00　討議

D：道路環境分科会　（532会議室）

10：00～10：40　研究発表　「日本における道路環境」
建設省道路局企画課道路環境対策室課長補佐　安藤　淳
「日本における道路環境に関連する技術」
建設省土木研究所　交通環境研究室長　石田　稔

10：40～11：20　研究発表　「カナダにおける道路環境に関する研究」
Michael Kent
Director, Highway Environment,
B.C. Transportation and Highway

11：20～11：30　休憩

11：30～12：00　両国のR＆D活動についての討議

E：先端複合材料分科会（ACM）　（534会議室）

10：00～10：50　研究発表　「QuebecにおけるFRPの利用についての経験」
Daniel Vezina
Chef de la section des Betons de ciment,
Division des produits industriels,
Transports Quebec
「カナダにおけるACMの橋梁及び構造物への利用の現状」
Ken W. Neale
Professor, Department of Civil Engineering,
Faculty of Applied Science, University of
Sherbrooke

10：50～11：00　休憩

11：00～12：00　研究発表　「既設構造物の炭素繊維による補強に関する研究」
日本道路公団試験研究所　橋梁研究室　安藤　博文
「炭素繊維補強プラスチック接着によるRCスラグの補強」
首都高速道路公団　東京保全部設計課長　丸山　真佐雄
「ACMの土木構造物への最近の利用例」
建設省土木研究所　化学研究室長　片脇　清
「FRPケーブル材料の暴露試験の実施例」
建設省土木研究所　化学研究室研究員　西崎　到

12：00～13：30　昼食　（土木研究所外）

13：30～17：00　分科会　同　上

A：寒冷地舗装分科会（ＰＩＣＡ）　（526会議室）

13：30～14：00　PICA－5とPICA－6の方向に関する報告

Gerhard J. Kennepohl
Manager, Pavements & Roadway Office,
Research & Development Branch,
Ontario Ministry of Transportation

14：00～14：45　討議

14：45～15：00　結論

建設省土木研究所道路部　舗装研究室長　中村　俊行

15：00～15：30　休憩

15：30～16：00　今後の協力活動の方向に関する報告

建設省土木研究所道路部　舗装研究室長　中村　俊行

16：00～16：30　討議

16：30～17：00　結論

建設省土木研究所道路部　舗装研究室長　中村　俊行

B：ＩＶＨＳ分科会　（627会議室）

13：30～14：00　研究発表　「ローコストで多目的な路車間通信」

Lewis Sabounghi
Senior Development Officer,
Transportation Development Center

14：00～14：30　研究発表　「日本におけるデジタル道路地図データベースの現況と今後の計画」

（財）日本デジタル道路地図協会　専務理事　柴田　正雄

14：30～14：45　「トラベルガイド経路誘導システム」

Milton D. Harmelink
Director,
Transportation Technology & Energy Branch,
Ontario Ministry of Transportation

14：30～15：00　討議

15：00～15：15　休憩

15：15～17：00　今後の協力活動の方向に関する討議

C：耐風耐震構造物分科会　（８Ｆ国際会議室）

13：30～14：30　実験施設視察

14：30～17：00　今後の協力活動の方向に関する討議

D：道路環境分科会　（532会議室）

13：30～14：45　今後の協力活動の方向に関する討議
14：45～15：00　休憩
15：00～16：00　分科会報告執筆
16：00～17：00　土木研究所内の道路環境実験施設見学

E：先端複合材料分科会（ＡＣＭ）　（534会議室）

13：30～15：00　今後の協力活動の方向に関する討議
15：00～15：15　休憩
15：15～17：00　分科会報告執筆

第二日目　１２月７日（火）

9：30～12：00　土木研究所施設見学
（舗装走行実験施設，ガイドライト実験施設，試験走路，
大型風洞実験施設，大気汚染実験施設，材料構造共同実験棟）

12：00～13：30　昼食　（１Ｆ会議室）
13：30～14：00　調印式　（８Ｆ会議室）
14：00～14：30　開会式　（８Ｆ会議室）
14：30～14：45　写真撮影
14：45～15：00　休憩
15：00～16：00　基調講演　（８Ｆ会議室）
（司会　建設省土木研究所　環境部長　水谷　敏則）
「日本の道路行政」
建設省道路局国道第二課長　脇　雅史
16：00～17：00　「カナダの道路行政」
カナダ運輸省研究開発局長　August E. Pokotylo
18：00～20：00　土木研究所長招待レセプション（ホテルサンルートつくば）

注）11:30～13:30　調印式・開会式参加者受付け　（８Ｆ会議室）

第三日目　１２月８日（水）

9：00～9：45　研究発表　（８Ｆ会議室）
（司会　建設省土木研究所　材料施工部長　池村　雅司）
「日本の道路研究」
建設省土木研究所　道路交通総括研究官　安崎　裕
9：45～10：30　「カナダの道路研究」
カナダ運輸省　研究開発局　Shyam Khubchandani

10：30～10：45	休憩	
10：45～11：45	分科会報告	（8Ｆ会議室）
11：45～13：00	昼食	
13：00～15：30	議事録起草会議	（8Ｆ会議室）
15：30～15：45	休憩	
15：45～16：30	日加プログラム調整委員会	（8Ｆ会議室）
16：30～16：40	休憩	
16：40～17：10	閉会式	（8Ｆ会議室）
18：00～20：00	カナダ側返礼レセプション（研究交流センター）	

調 印 式

1. 日 時 ： 平成5年12月7日（火） 13時30分～14時

2. 場 所 ： 建設省土木研究所 8階 会議室

3. 開会式 ： （司会 建設省土木研究所 企画部長 田村 正秀）

開 会

調 印 日本側調印者（建設省土木研究所長） 住吉 幸彦

カナダ側調印者 August E. Pokotylo

挨 拶 建設省土木研究所長 住吉 幸彦

カナダ側代表 August E. Pokotylo

閉 会

開 会 式

1. 日　　時 ： 平成5年12月7日（火）　14時～14時30分

2. 場　　所 ： 建設省土木研究所　8階　会議室

3. 開 会 式 ： （司会　建設省土木研究所　研究調整官　　飯島　　尚）

開　　会

挨　　拶　　建設省技監　　藤井　治芳

カナダ大使館大使　　Donald Wilfred Campbell

科学技術庁科学技術振興局国際課長　小倉伸一郎

参加者紹介

閉　　会

4. 記念撮影 ： 14時30分～14時45分

・場所　正面玄関前（1階）

閉 会 式

1. 日 時 ： 平成5年12月8日（水） 16時40分～17時10分

2. 場 所 ： 建設省土木研究所 8階 会議室

3. 閉会式 ： （司会 建設省土木研究所 総務部長 田口 仁）

開 会

挨 拶 カナダ側コーディネーター Shyam Khubchandani

日本側コーディネーター 飯島 尚
（建設省土木研究所 研究調整官）

記念品贈呈

閉 会

現地視察の概要

参加者は，ワークショップの本会議の期間に土木研究所の施設見学を行い，ワークショップの本会議終了後に視察旅行を行った。これらの視察により，道路研究及び道路等社会資本の整備の進展のために日本で行われている様々な活動を理解する機会を得た。

1. 土木研究所施設見学

1993年12月7日，参加者は土木研究所の施設見学を行った。

見学した施設は，舗装走行実験施設，ガイドライト実験施設，試験走路，大型風洞実験施設，大気汚染実験施設及び材料構造共同実験棟である。

参加者は，現在，土木研究所においてこれらの施設を用いて，新しい舗装材料・工法，次世代道路交通システム，道路構造，路面のすべり，長大橋梁の耐風安定性，排気ガスの拡散，新素材・新材料の建設分野への利用等に関する研究が行われている旨の説明を受けた。

2. 視察旅行

視察旅行は，1992年12月9日から11日までの3日間，関西方面で行われた。視察した施設は，明石海峡大橋，関西新空港，阪神高速道路湾岸線，交通管制センター，名神高速道路である。耐震耐風分科会の委員は途中で他の分科会のグループと別れ，明石海峡大橋を更に詳細に視察した他，瀬戸中央道（瀬戸大橋）を視察した。

〔明石海峡大橋〕

明石海峡大橋においては，アンカレイジ1Aの上部に上がり，明石海峡大橋の全景及びケーブル架設の状況などを視察した。

次に展示館に移り，これまでの明石海峡大橋の建設の資料を視察すると共に，以下のような説明を受けた。明石海峡大橋は，神戸市垂水区舞子と淡路島との間の明石海峡（幅約4㎞）に架かる橋である。橋長3,910m，中央支間長1,990mの3径間2ヒンジ補剛トラス吊橋であり，完成すれば世界一の長大吊橋となる。主塔の高さは海面上約300m，下部工建設にあたっては，コンクリート約142万㎥，鋼材約20万㌧を必要とするなど非常に大規模であり，また毎秒80mの暴風や，マグニチュード8.5クラスの激震など厳しい自然環境に耐えられる様に設計されているとのことだった。

〔関西新空港〕

関西新空港（正式名称：関西国際空港）の建設現場に上陸して現地を見学しながら，以下のような説明を受けた。

関西新空港は，泉州沖約5㎞の海上に，1994年夏頃に供用の予定で建設が進められている。新空港の埋め立ては既に完了しているが，埋め立てによる海底地盤の沈下は現在も進行しており，空港施設については不等沈下が起きないようにバランスさせることにより，その供用性を維持するとのことであった。

このあとほぼ完成している人口島内の連絡橋，滑走路及び誘導路，内装工事の進む旅客ターミナルビルの視察を行った。

〔阪神高速道路湾岸線〕

阪神高速道路湾岸線をバスにて通行しながら視察した。以下のような説明を受けた。

阪神高速道路湾岸線は泉佐野市りんくう往来北から神戸市垂水区名谷町までの全長80㎞を結ぶ自動車専用道路である。この湾岸線は，大阪湾地域に点在する諸都市を相互に結ぶことで，これらの地域の交通需要に対応すると共に，泉佐野市で，関西国際空港と連絡し，神戸市垂水区にて本州四国連絡橋と連絡しているように，開発が進む様々なプロジェクトを有機的に結び付け，京阪神を総合的に発展させていくための，基盤施設としての役割も担っているとのことであった。

〔阪神高速道路交通管制センター〕

阪神高速道路公団交通管制センターにおいて以下のような説明を受けた。交通管制システムは1969年に採用されて以来，改良拡張が行われ，世界でももっとも進んだ交通管制システムとなっている。160箇所に設置されたテレビカメラや，20箇所に設置された車両番号自動読み取り装置などからの情報を管制センターのコンピュータにより情報処理し，道路情報板，道路情報ラジオなどにより提供しているとのことであった。参加者から情報処理の方法などについて活発な質問があった。このあと交通管制センター内の施設の視察を行った。

〔名神高速道路〕

名神高速道路をバスにて通行しながら視察した。以下のような説明を受けた。

名神高速道路（京都南－吹田間）は，約30年前に我が国初の高速道路として誕生した栗東－尼崎間の中間部に位置しており，京阪地区の大動脈として経済文化の発展を支えてきた。しかし経済的発展と共に利用量は当初の予想を大きく上回り，道路の損傷や交通渋滞が恒常化している。このため交通需要に見合った交通容量を確保するため，この区間を4車線から6車線に拡幅する事業を実施しているとのことだった。

〔明石海峡大橋〕

耐風耐震分科会の委員は，他の分科会委員のグループと分かれ，12月10日（金）の午前に再度，明石海峡大橋の建設現場を訪問した。この日は，本州四国連絡橋公団・垂水工事事務所・保田雅彦所長の案内で，本州側（2P）の塔頂まで上がった。2Pは鋼製の塔柱だけで287m，塔頂は水面上，約297mの塔であり，平成5年春に完成，同年11月にパイロットロープ（吊橋の主ケーブル架設のために，最初に架けるロープ）が架設されたばかりである。パイロットロープ渡海にヘリコプターを使用したこと，現在，ロープを太くする作業中であること，ロープを塔頂サドルの所定の位置に調整するために塔頂部ではロープの引張力を抜く仕組みがあることなどの説明を受けた。

〔瀬戸中央道（瀬戸大橋）〕

耐風耐震分科会の委員は，本州四国連絡橋公団・第二管理局の古屋信明計画課長の案内を得て，本線上，および海上から瀬戸大橋を視察した。瀬戸大橋は昭和63年4月に供用を開始した本州と四国を結ぶ連絡道であり，吊橋3橋，斜張橋2橋，その他トラス橋，高架橋よりなり，海峡部は約10㎞におよぶ。道路・鉄道併用橋であり，長大吊橋としては初めて本格的な鉄道を通した。1日平均で，約12,000台の自動車交通と，135便（貨物含む）の列車交通を支えている。

大型風洞の利用に関する発表：プログラム

会場：つくば研究交流センター

平成5年12月6日（月）

9：30　開会式

（司会　土木研究所　藤原　稔　構造橋梁部長）

挨拶　土木研究所　住吉　幸彦　所長

本州四国連絡橋公団　遠藤　武夫　理事

10：00　セッション1

（司会　土木研究所　藤原　稔　構造橋梁部長）

10：00　日本の吊形式橋梁の耐風設計

Wind resistant design of cable supported bridges in Japan

埼玉大学　伊藤　學　教授

10：40　休　憩

11：00　セッション2

（司会　本州四国連絡橋公団　多田　和夫　設計部長）

11：00　橋梁の対風応答に及ぼす地形，強風の特性の影響

The influence of topography and storm structure on long span bridge behavior in wind.

カナダ　ウェスタンオンタリオ大学

ダベンポート教授

11：40　動的空力特性と風環境を考慮した長大橋梁の計画設計法

Feasible design methods of long-span bridge based on its aerodynamic characteristics and wind environments

京都大学　白石　成人　教授

12：20　昼食

13：20　セッション3

（司会　土木研究所　藤原　稔　構造橋梁部長）

13：20　大型風洞における風工学および非航空力学分野の風洞実験
Wind engineering and other non-aeronautical experiments in a large wind tunnel
カナダ　国立研究所
ワードロー　応用空気力学研究所前所長

14：00　日本の長大橋梁の風洞試験法
Wind tunnel testing methods of long-span bridges in Japan
東京都立大学　成田　信之　教授

14：40　休憩

15：00　セッション4

（司会　本州四国連絡橋公団　多田　和夫　設計部長

15：00　明石海峡大橋の耐風設計
Wind resistant design considerations for the Akashi Kaikyo Bridge
横浜国立大学　宮田　利雄　教授

15：40　明石海峡大橋の大型風洞実験
Experiments for the Akashi Kaikyo Bridge in a large boundary layer wind tunnel
土木研究所　佐藤　弘史　室長

16：20　明石海峡大橋上部構造の設計
Design considerations for superstructures of the Akashi Kaikyo Bridge
本州四国連絡橋公団　北川　信　課長

17：00　終了

17：30　懇親会

（司会　土木研究所　佐藤　弘史　構造研究室長）

挨拶　本州四国連絡橋公団　萩原　浩　総裁
カナダ　ウェスタンオンタリオ大学
ダベンポート教授

乾杯　埼玉大学　伊藤　學　教授

〃　京都大学　白石　成人　教授

平成５年１２月７日（火）

９：００　セッション５

（司会　土木研究所　藤原　稔　構造橋梁部長）

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９：４０　グレートベルト海峡イースト橋の耐風設計における全橋模型風洞実験の役割
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（司会　本州四国連絡橋公団　多田　和夫　設計部長）

挨拶　　土木研究所　　都丸　徳治　次長

附属文書

日本国建設省土木研究所とカナダ国運輸省研究開発局との間の道路科学技術における協力に関する実施取り決め

IMPLEMENTING ARRANGEMENT BETWEEN THE PUBLIC WORKS RESEARCH INSTITUTE OF THE MINISTRY OF CONSTRUCTION OF JAPAN AND THE RESEARCH AND DEVELOPMENT DIRECTORATE OF THE DEPARTMENT OF TRANSPORT OF CANADA CONCERNING COOPERATION IN HIGHWAY SCIENCE AND TECHNOLOGY

The Public Works Research Institute (PWRI) of the Ministry of Construction of Japan and the Research and Development Directorate (R&DD) of the Department of Transport of Canada, hereinafter referred to as "the Parties",

Desiring to promote and enhance the development and transfer of technology with respect to highway transportation between Japan and Canada; and

Desiring to proceed with cooperative activities pursuant to and governed by all the provisions of the Agreement between the Government of Japan and the Government of Canada on cooperation in Science and Technology (the Agreement) signed in Tokyo on May 7, 1986;

Have decided on the following Implementing Arrangement (the Arrangement) in accordance with Article III of the Agreement:

Article I
Scope and Objectives

The purpose of this Arrangement is to provide for a program of mutually beneficial cooperative activities to be undertaken by both the Parties in the field of highway transportation research and technology including, but not limited to, the following topics:

1. Paving in Cold Areas (PICA)
2. Intelligent Vehicle Highway Systems (IVHS)
3. Wind Resistant and Seismic Structures
4. Road Environment
5. Advanced Composite Materials (ACM)

Article II
Cooperative Activities

Cooperation may be pursued through several means, including but not limited to:

1. Exchange of technical information, reports,

data bases and publications;
2. Exchange visits by technical experts on short term assignments;
3. Joint workshops and symposia on topics of mutual interest; and
4. Joint research.

Article III
Participating Agencies

Both the Parties, as appropriate in the cooperative activities, may allow the participation of other agencies, outside their own organizations. Such agencies, to be referred to as the Participating Agencies, may be drawn from all sectors of research establishment, including other levels of governments, universities, national laboratories, and the private sector. The Parties will act as coordinating bodies for all the cooperative activities including those of the Participating Agencies.

Article IV
Program Coordination

The Parties designate their following officers as overall Program Coordinators for implementing this Arrangement:

PWRI: Assistant Director-General

R&DD: Chief, Planning and Coordination

The Program Coordinators will be responsible for:

1. Designating a Contact Person for each individual topic under this Arrangement;
2. Selecting cooperative activities;
3. Preparing periodic status and progress reports;
4. Arranging meetings, workshops and exchange visits;
5. Meeting periodically to review the cooperation and resolve any difficulties.

Article V
Implementation

The cooperative activities will be implemented in accordance with the following terms and conditions:

1. Funding arrangements, wherever required, will be agreed upon on a case-by-case basis;
2. In connection with the exchange of reports, data and other material, each Party will respect any conditions or limitations on further dissemination as may be

proposed by the other;

3. The Party transmitting information, while making every effort to ensure its accuracy, will not be held liable for the content or use of such information;
4. In case of joint projects, both the Parties will decide in advance on the tasks to be performed by each and the dissemination of results.

Article VI
Intellectual Property

Scientific and technical information of a non-proprietary nature resulting from the cooperative activities under this Arrangement may be made available to the public through customary channels and in accordance with the normal procedures of the Participating Agencies.

The intellectual property created or any proprietary information furnished in the course of cooperative activities under this Arrangement will be protected and managed by both the Parties in accordance with prior decision in each individual case and both the Parties will consult with each other for this purpose as necessary.

Article VII
Duration

This Arrangement will come into effect upon signature and will remain in force for five years. Either Party may terminate this Arrangement at any time upon six months' written notice to the other. The Arrangement may be extended and amended at any time by written confirmation by both the Parties as long as it is in force. The termination of this Arrangement will not affect the carrying out of any cooperation activities undertaken under this Arrangement and not fully executed at the time of the termination of this Arrangement.

DONE in Tsukuba, this 7th day of December, 1993,

For the Public Works Research Institute of the Ministry of Construction of Japan

Yukihiko Sumiyoshi
Director-General
Public Works Research Institute

For the Research and Development Directorate of the Department of Transport of Canada

A. E. Pokotylo
Director General
Research and Development

日本国建設省土木研究所とカナダ国運輸省研究開発局との間の道路科学技術における協力に関する実施取り決め（仮訳）

日本国建設省土木研究所（ＰＷＲＩ）とカナダ国運輸省研究開発局（Ｒ＆ＤＤ）、以下「両当事者」という、はカナダ日本間の道路交通に関する技術の開発および移転の推進と向上を図るため１９８６年５月７日東京において日本国政府とカナダ国政府との間で締結された科学技術協力に関する協定（以下、「協定」）の規定によった技術協力を始めるため協定の第Ⅲ条にしたがって、以下の実施取り決め（以下、「取り決め」）に合意する。

第Ⅰ条　範囲と目的

本取り決めの目的は、相互に有益な協力活動のプログラムを規定することである。ここでいう協力活動は道路交通研究および技術の領域で両当事者により着手されるもので以下の課題を含んでいる、ただしこれに限定されるものではない：

１．寒冷地舗装（ＰＩＣＡ）
２．路車間情報システム（ＩＶＨＳ）
３．耐風耐震構造物
４．道路環境
５．先端複合材料（ＡＣＭ）

第Ⅱ条　協力活動

協力は以下のいくつかの方法により遂行される、ただしこれに限定されるものではない。

１．技術情報、報告書、データベースおよび出版物の交換
２．短期間の技術専門家の交換訪問（exchange visit）
３．相互に興味を有する課題に関する共同ワークショップ
　あるいはシンポジウム
４．共同研究

第Ⅲ条　参加機関

両当事者は、適当な場合には、協力活動への、他の機関（両機関を除く）による参加を認めることができる。参加機関としては、すべての分野における研究機関（地方行政府、大学、国立研究所および民間部門を含む）があげられる。両当事者は参加機関の活動を含めたすべての協力活動に関する調整機関として機能するものとする。

第Ⅳ条　プログラム　コーディネーション

両当事者は、本取り決めを実施するために、以下の職員をプログラムコーディネーターに任命する：

PWRI:　Assistant Director-General

R&DD:　Chief,Research Coordination

プログラムコーディネーターは、以下の事項に対して責任をもつ

1．本取り決めの下の個別の課題におけるコンタクトパーソンを任命すること
2．協力活動を選定すること
3．定期報告（periodic status ）および進捗報告（progress reports）を準備すること
4．会議、ワークショップおよび交換訪問（exchange visit）をアレンジすること
5．協力状況を吟味し、問題点を解決するために定期的に会合すること

第Ⅴ条　実施

協力活動は以下の条件により実施される。

1．費用負担について、必要な場合にはいつでも、ケースバイケースで協議し、取り決める。
2．報告書、データおよび他の資料の交換に関連して、各当事者は相手から資料の取扱い（dissemination ）について申し入れのあった場合には、いかなる条件あるいは制限も遵守する。
3．情報を提供した当事者は、情報の正確さを高めるあらゆる努力をしなければならないが、その資料の内容と使用についての責任を負うものではない。
4．共同プロジェクトの場合には、両当事者はあらかじめ各々の義務と結果の取扱い（dissemination ）について合意しておく。

第Ⅵ条　知的所有権

本取り決めの下の協力活動から派生した所有権のない科学技術情報は、通例のルートにより、あるいは参加機関の通常の手続きにより、公共の用に供することができる。

本取り決めの下の協力活動の過程で生まれた知的所有権あるいは供給された所有権のある情報は、両当事者により、個々のケースにおける事前の決定により、保護され、管理される。また、両当事者は、必要に応じ、この目的のために、協議する。

第Ⅶ条　存続

本取り決めは署名により発効し、協定が効力を有しているという条件の下で、５年間効力を有する。各当事者は、相手方に６か月前に書面により通知することによって、本取り決めの効力を随時停止することができる。本取り決めは、協定が効力を有している限り、両当事者の書面による合意により、随時延長し、修正することができる。本取り決めの効力の停止は、本取り決めの下で着手されており、本取り決めの効力の停止の時点で完全には達成されていない活動に影響を与えない。

日本国建設省	カナダ国運輸省
土木研究所所長	研究開発局長
日付：	日付：

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Proceedings of the International Workshop on the Advanced Highway System in Cold Area

December 6-11, 1993
Tsukuba, Japan

March, 1994

Public Works Research Institute, Ministry of Construction, Japan
Research and Development Directorate, Transport Canada

Preface

The road network in Japan now has a length of 1.1 million kilometers including all classes from municipal roads to expressways. But the improvement of these roads has not kept pace with the rapidly increasing traffic. Consequently, serious traffic congestion, increase of traffic accidents, deterioration of road environments have become problems in everywhere. While the expressway network, whose objective is to enhance balanced development throughout Japan, has arrived at the length of about 6,100 kilometers, it will take a long time to achieve the planned network of 14,000 kilometers.

The people's needs for road traffic are expected to continue growing and to diversify. To respond appropriately to the future requirements, it is extremely important to create a safer, more comfortable, higher quality road traffic system at the same time with steady development of roads. And to do this, we need to make full use of advanced technologies such as telecommunications, electronics, mechatronics and new materials.

The highway network in Canada stands at total of 840,000 kilometers and the governments have invested about 5 billion dollars per year on road improvement during last 5 years. Now, the main issues in road improvement are the changes in the traffic flow as a result of North America Free Trade Agreement, necessity of rehabilitation and technical development in highway engineering.

Both Japan and Canada have cold areas. And both countries possess sophisticated technologies used to design, construction and maintenance of roads in cold areas. Since the exchange of technology is essential for both countries, Japan and Canada have held workshops on paving technology in cold areas five times since 1982, and have conducted researches on wind resistant and seismic structures for three years since 1987. Through these activities, we have exchanged technologies against clacking of pavements and In-place Recycling Method which improved road maintenance and environment protection in both countries.

In this time, the new full-scale research cooperation program in the field of road technology has been launched on these background. This cooperative activity will be conducted on the basis of the "Implementing Arrangement Between the Public Works Research Institute of the Ministry of Construction of Japan and the Research and Development Directorate of the Department of Transport of Canada concerning Cooperation in Highway Science and Technology." On December 7, this arrangement was signed and exchanged by myself representing the Public Works Research Institute and by Mr. August E. Pokotylo, Director General of the Research and Development Directorate of the Department of Transport of Canada.

The cooperation covered by this arrangement includes the topics which have already been treated in Japan-Canada cooperation: Paving in Cold Areas, Wind Resistant and Seismic Structures. And we added new topics: advanced transport system or the Intelligent Vehicle Highway System (IVHS), Road Environments and Advanced Composite Materials which now attract world-wide interests. The arrangement is intended to encourage the development of road technology in both countries by exchanging technology through systematic exchanges of information and personnel concerning broader range of topics. We expect that this workshop will result in the exchange and the development of new technologies related to the design, construction, and maintenance of roads in cold areas.

The present International Workshop on the Advanced Highway System in Cold Areas was held based upon this arrangement. The keynote speech, task committee meeting, and the program coordination meeting all contributed to the promotion of cooperative activities by Japan and Canada.

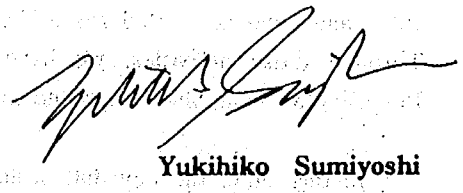
This workshop was officially backed up by the Special Coordination Funds for Promoting Science and Technology established by the Science and Technology Agency in 1991.

Japan side was composed of officials of the Road Bureau, Regional Construction Bureaus and the Public Works Research Institute of the Ministry of Construction, Japan Highway Public Corporation, Metropolitan Expressway Public Corporation, Hanshin Expressway Public Corporation and Honshu-Shikoku Bridge Authority. The Canadian delegation included officials of the Department of Transport and provincial governments and researchers from related organizations. The participants engaged in a lively exchange of information on research activities and as a result agreed upon research items and methods that are to be dealt with in future cooperative activities. We also agreed to hold the next workshop in Canada in fiscal year 1996–1997.

This report is the official record of the workshop. It contains, the minutes of discussion adopted by the participants of the task committee meetings, and the summary of the field trip. It also contains the arrangement signed at the workshop. I hope that this report contributes to the development of highway technology in Japan and Canada to improve road traffic systems in both countries.

I would like to express my sincere thanks to the Canadian Embassy, the Science and Technology Agency, the Japan International Science and Technology Exchange Center, the Ministry of Construction, Japan Highway Public corporation, Metropolitan Expressway Public Corporation, Hanshin Expressway Public Corporation and Honshu-Shikoku Bridge Authority for their help for the workshop.

March 1994



Yukihiko Sumiyoshi
Chairman of Japan Side,
Cooperation in Highway Science and Technology
between Japan and Canada
Director-General
Public Works Research Institute

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ANNEX 1

IMPLEMENTING ARRANGEMENT BETWEEN THE PUBLIC WORKS RESEARCH INSTITUTE OF THE MINISTRY OF CONSTRUCTION OF JAPAN AND THE RESEARCH AND DEVELOPMENT DIRECTORATE OF THE DEPARTMENT OF TRANSPORT OF CANADA CONCERNING COOPERATION IN HIGHWAY SCIENCE AND TECHNOLOGY 339

ANNEX 2

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1. Record of the Discussion of the Japan-Canada Workshop on Advanced Highway Systems in Cold Areas

Record of the Discussion of the Japan – Canada Workshop on Advanced Highway Systems in Cold Areas

The Japan – Canada Workshop on Advanced Highway Systems in Cold Areas was held at the Public Works Research Institute, Ministry of Construction in Tsukuba City from December 6 to December 8, 1993. The Workshop was held in accordance with the Implementing Arrangement concluded between the Public Works Research Institute of the Ministry of Construction of Japan, and the Research and Development Directorate of the Department of Transport of Canada on December 7, 1993 at the Public Works Research Institute. The objectives of the Workshop are as follows:

a)Exchange information between Japan and Canada on the latest research in the areas of Paving in Cold Areas (PICA), Intelligent Vehicle Highway Systems (IVHS), Wind Resistant and Seismic Structures, Road Environment, and Advanced Composite Materials (ACM).

b)Seek areas where cooperation between Japan and Canada may be beneficial in the future.

c)Agree on future joint programs.

1. Keynote Topics

Mr. Waki, the Director of the National Highway Second Division, Road Construction Bureau, Ministry of Construction of Japan, made a keynote speech entitled "*The Road Administration in Japan*". In his speech, Mr. Waki first touched upon the geographic condition, automobile use and history of transportation development in Japan. He then described the current status of the roads, types of road administrators and classification of roads. Next, under the theme of the past history of road improvements, Mr. Waki explained the past Five-Year Road Improvement Program by describing its necessity, major issues and development targets. He also mentioned that the purpose of this program is to realize "a society where affluence and comfort can be felt", and that to realize this purpose, three major objectives are set out; namely, promotion of road improvement to support affluent consumer life, promotion of road improvement to make vital community and promotion of road improvement to establish human and nature friendly environment. Lastly, Mr. Waki discussed the development of the Five-Year Road Technology Program, its aims, contents and planning process. He also spoke about specific examples of some of the major technologies under the program.

Mr. Pokotylo, Director General of the Research and Development Directorate of

Transport Canada, gave a keynote speech entitled "*Road Administration System in Canada*". In his speech, Mr. Pokotylo first spoke about the geographic conditions, population distribution and the use of roads in Canada. Next, he described the road administration system and the jurisdictions of the Federal Government, Provincial Governments and Municipal Governments and the coordinating role played by the Transportation Association of Canada. Furthermore, Mr. Pokotylo discussed the status of the roads and bridges and the outline of the road investment. At the same time, he also discussed the Federal Strategic Highway Program. He then spoke about the issues in road improvement in Canada; namely, measures against the changes in the traffic flow caused by free trade agreements, rehabilitation, new financing options and technology development. Lastly, Mr. Pokotylo introduced the Northumberland Straits Bridge construction project, describing such points as its structure, construction cost and funding arrangement.

2. Presentation on Road Research

Mr. Anzaki, Research coordinator for Road Traffic of the Road Department of the Public Works Research Institute, made a presentation on road related research activities in Japan. At the outset, he touched upon research activities conducted by the Civil Engineering Research Institute of the Hokkaido Development Bureau, the Research Institute of Japan Highway Public Corporation, the National Research Institute of Police Science of the National Police Agency, the Traffic Safety and Nuisance Research Institute of the Ministry of Transport, and the Japan Automobile Research Institute. Then, he explained roadrelated surveys carried out by the Ministry of Construction, which can be classified in to four categories; that is, surveys to ascertain traffic conditions, surveys to make road network plans, surveys to promote road improvement, and surveys for road maintenance. Further, he spoke about the research activities in the Public Works Research Institute and pointed out that PWRI is carrying out research closely related to administrative needs and that PWRI plays an important role in establishing various technical standards. Finally, he talked about new highway technologies such as Advanced Road Transportation Systems, New Urban Freight Transport Systems, Long Bridges, and Hybrid Control of Seismic Response of Bridge Structures.

Mr. Khubchandani, the Chief of the Planning and Coordination of the Research and Development Directorate of Transport Canada gave a presentation entitled "*Highway Research in Canada*." First, the breakdown of the expenditure on research within Canada was described. Of the total annual expenditure of 5 billion dollars on highways in Canada, about 1% is spent on related research. Next, research organizations in highway area were introduced. It was stressed that the funding and the organization of the research institutions are decentralized. The outline of the research activities currently in place followed, in which Canadian research organizations that conduct the research on the topics also discussed in this Workshop were cited. Some major research topics under the National Research Agenda 1992–1994 and international research exchange in Canada were also discussed. Lastly, based on the OECD report, major research topics in Canada planned for 1995–1997 were identified as being infrastructure improvement, IVHS and road safety.

3. Reports of Task Committees

Following five task committees were organized in accordance with the provisions of the Implementing Arrangement.

Paving in Cold Areas (PICA)
Intelligent Vehicle highway Systems (IVHS)
Wind Resistant and Seismic Structures
Road Environment
Advanced Composite Materials (ACM)

Summary record of discussion of each task committee is described in following sections.

3.1 PAVING IN COLD AREAS

Attendees:

Canada side

○ *Gerhard J. Kennepohl, Manager, Pavements & Roadway Office, Research & Development Branch, Ontario Ministry of Transportation*

Japan side

○ *Toshiyuki Nakamura, Head, Pavement Division, Road Department, PWRI*
Takeshi Yoshida, Chief Researcher, Pavement Division, Road Department, PWRI
Kazuyuki Kawamura, Head,Maintenance and Management Section, Civil Engineering Research Institute, Hokkaido Development Bureau
Shigeru Shimeno, Head,Pavement Section, Research Institute, Japan Highway Public Corporation
Hiroshi Yamanokuchi, Director, Investigation Department, Road Management Technology Center
Takaharu Kiriyama, Researcher, Pavement Division, Road Department, PWRI
Kazuyuki Kubo, Researcher, Pavement Division, Road Department, PWRI

Observer

August E. Pokotylo, Director General, Research and Development, Transport Canada
Takaahi Iijima, Assistant Director-General, PWRI

MISSION STATEMENT

3.1.1 Objective

The objective of this subcommittee is a promotion of research cooperation through exchange of information and engineers, concerning pavement in cold areas which is a common issue between Japan and Canada, for example, prevention of thermal cracking and road management in the winter.

3.1.2 Accomplishment

Following issues were reported.

Pavement in Japan

Toshiyuki Nakamura

Concerning present situation of pavement in Japan, classification of road, increase of pavement length, cause and method of asphalt pavement rehabilitation, structural design of asphalt and concrete pavement, drainage asphalt pavement, RCCP are reported. After that, cause of pavement damage and design period are discussed.

Pavement in Canada

Gerhard J. Kennepohl

Overview of development, implementation and management of pavement technology were reported. Examples of research topics about materials, maintenance / rehabilitation, design / construction, pavement management were shown here. Key issues about environment, health, social, policy, technical and economic were shown concerning future direction. After that, pavement management system and performance curve were discussed.

3.1.3 Future Plans

3.1.3.1 PICA-6

1)Implementation of PICA-6

Concerning implementation of PICA-6, the program proposed in Canada in September this year was confirmed.

- PICA-6 will be held in Niigata City in the fall of 1996.
- Future workshops should be structured as forward looking, planning-type fora.
- Joint projects and staff exchanges are important and should be encouraged.

2)Expert Working Group

At PICA-6, in addition to the ordinary session, 5-6 Expert Working Groups (EWG) which discuss special issue will be established. The proposed procedure for EWG includes

- Identification of topics
- Development of guidelines and criteria for selecting topics
- Establishment of EWG (topics and members are decided before workshop)
- Implementation of EWG (Report from EWG to plenary session)

3)Proposal of topics

- SHRP product implementation
- Sustainable development in pavement technology
- Snow and ice mitigation
- High performance pavement
- Benefits and costs in using waste materials
- New technology in design, construction and materials
- Development of specific long term performance guarantees for pavement work

- Procedure for acceptance of innovative materials
- Education and training program for pavement technology
- Pavement management system

3.1.3.2 Other areas of cooperation

As other areas of cooperation, following items will be done.
- information exchanges
- staff exchanges
- Joint projects

3.1.4 Miscellaneous

As a theme for a joint project, common tests for the design of rut resistant asphalt mixture was proposed.

3.2 INTELLIGENT VEHICLE HIGHWAY SYSTEMS

Attendees:

Canada side

○ *Milton D. Harmelink, Director, Transportation Technology & Energy Branch, Ontario Ministry of Transportation*
Lewis Sabounghi, Senior Development Officer, Transportation Development Center

Japan side

○ *Makoto Nakamura, Head, Traffic Engineering Division, Road Department, PWRI*
Tetsuo Matsumura, Research Coordinator for Traffic Safety, Road Department, PWRI
Yohei Hioki, Chief Researcher, Traffic Engineering Division, Road Department, PWRI
Setsuo Hirai, Researcher, Traffic Engineering Division, Road Department, PWRI
Nobuhiro Imatyo, Researcher, Traffic Engineering Division, Road Department, PWRI
Shigeo Murata, Researcher, Traffic Engineering Division, Road Department, PWRI
Tsuguo Oishi, Assistant Manager, Traffic Engineering Division, Engineering Department, Japan Highway Public Corporation
Mitsuo Nakai, Deputy Director, Traffic Control Engineering Division, Traffic Control Department, Metropolitan Expressway Public Corporation
Kiyoshi Sasaki, Assistant Manager, Traffic Control Section, Management Division, Hanshin Expressway Public Corporation
Yoshitaro Masuda, Technical Counselor, Highway Industry Development Organization
Toru Yoshikai, Senior Associate Manager,

Highway Industry Development Organization
Masao Shibata, Executive Managing Director,
Japan Digital Road Map Association
Hiroshi Iino, Director, Planning Department,
Japan Digital Road Map Association

Observer
August E. Pokotylo, Director General, Research and Development,
Policy and Coordination, Transport Canada
Takashi Iijima, Assistant Director-General, PWRI

MISSION STATEMENT

3.2.1 Objective

The objectives of the Task Committee are to exchange information on experiments and implementation of IVHS and to encourage R&D of IVHS.

3.2.2 Accomplishments

Present states and plans in Japan and Canada were recognized through the presentations.

- Presentations of Japan

Present State of IVHS in Japan
Makoto Nakamura
Vehicle Information & Communication System -VICS-
Yoshitaro Masuda
Preparation and Application of Digital Road Map in Japan
Masao Shibata

- Presentation of Canada

Present State of IVHS in Canada
Milton D. Harmelink
Towards a Universal Low-Cost Multi-Application IVHS Infrastructure
Lewis Sabounghi
Travelguide Route Navigation Systems
Milton D. Harmelink

In the discussion, questions about the Japanese VICS such as the marketability of the system, the effect of utilization and the method and type of data gathering were asked by the Canadian representatives.

Japanese representatives asked questions about the traffic information system "Travelguide" which is experimented in the state of Ontario. Concerning the specific technologies, especially the following three technologies were intensively discussed.

1)Traffic and Incident Detection Systems
2)Automatic Toll Collection Systems
3)2Way-Communication System between vehicles and infrastructures, and vehicle

to vehicle

3.2.3 Future Plans

The following two activities were recognized as the present principal activities of the Task Committee.

1)Exchange of information such as sending materials about IVHS

2)Welcoming short term visitors from the other country

About the three technologies intensively discussed, the two countries have agreed to name contact person(s) for each technology as follows and to exchange information directly between the contact persons.

1)Traffic and Incident Detection Systems

Japan side : Kiyoshi Sasaki, Assistant Manager, Traffic Control Section, Management Division, Hanshin Expressway Public Corporation

Canada side: Milton D. Harmelink, Director, Transportation Technology & Energy Branch, Ontario Ministry of Transportation

2)Automatic Toll Collection Systems

Japan side : Tsuguo Oishi, Assistant Manager, Traffic Engineering Division, Engineering Department, Japan Highway Public Corporation

Canada side: Milton D. Harmelink, Director, Transportation Technology & Energy Branch, Ontario Ministry of Transportation
Lewis Sabounghi, Senior development Officer, Transportation Development Center

3)2Way-Communication System between vehicles and infrastructures

Japan side : Makoto Nakamura, Head, Traffic Engineering Division, Road Department, PWRI

Canada side: Milton D. Harmelink, Director, Transportation Technology & Energy Branch, Ontario Ministry of Transportation
Lewis Sabounghi, Senior development Officer, Transportation Development Center

3.2.4 Miscellaneous

The two countries have agreed to hold the next Task Committee Meeting when the next workshop is held.

3.3 WIND RESISTANT AND SEISMIC STRUCTURES

Attendees:

<u>*Canada side*</u>

○ *Michael G. Savage, Research Officer, Applied Aerodynamics Laboratory, Institute for Aerospace Research, National Research Council Canada*

Robert L. Wardlaw, Guest Worker, Applied Aerodynamics Laboratory, Institute for Aerospace Research, National Research Council Canada

Donald L. Anderson, Professor, Department of Civil Engineering,
University of British Columbia
Alan G. Davenport, Professor, Department of Civil Engineering,
Boundary Layer Wind Tunnel Laboratory,
The University of Western Ontario
Hiroshi Tanaka, Professor, Department of Civil Engineering,
University of Ottawa
J. Peter C. King, Research Associate,
Boundary Layer Wind Tunnel Laboratory,
The University of Western Ontario

Japan side

○ *Hiroshi Sato, Head, Structure Division, Structure and Bridge Department, PWRI*
Kazuhiko Kawashima, Head, Earthquake Engineering Division, Earthquake Disaster Prevention Department, PWRI
Shuuichi Suzuki, Honshu-Shikoku Bridge Authority (proxy for Makoto Kitagawa)
Yasuo Inokuma, Assistant Manager, Structure Engineering Division, Engineering Department, Japan Highway Public Corporation
Ippei Nakamura, Assistant Manager, Design Division, Engineering Department, Hanshin Expressway Public Corporation
Haruo Takano, Metropolitan Expressway Public Corporation (proxy for Kazuo Yamazaki)
Yutaka Iida, Director, Earthquake Disaster Prevention Department, PWRI
Hisanori Otsuka, Head, Ground Vibration Division, Earthquake Disaster Prevention Department, PWRI
Osamu Matsuo, Head, Soil Dynamics Division, Earthquake Disaster Prevention Department, PWRI
Shigeki Unjoh, Chief Researcher, Earthquake Engineering Division, Earthquake Disaster Prevention Department, PWRI
Tomoru Nakajima, Researcher, Earthquake Engineering Division, Earthquake Disaster Prevention Department, PWRI
Hideaki Iwasaki, Researcher, Ground Vibration Division, Earthquake Disaster Prevention Department, PWRI
Takuo Azuma, Ground Vibration Division, Earthquake Disaster Prevention Department, PWRI
Junichi Koseki, Researcher, Soil Dynamics Division, Earthquake Disaster Prevention Department, PWRI
Andrew Taylor (NIST, USA, currently staying at PWRI as a Visiting Researcher from the USA)

MISSION STATEMENT

3.3.1 Objective

The objective of this Task Committee is to encourage the exchange of scientific information and technology related to wind resistant design and seismic design of structures.

3.3.2 Accomplishment

3.3.2.1 Wind Resistant Design of Structures

The following papers were presented from both countries in the seminar format at the Tsukuba Center for Institutes with participants of about 150 people, and useful information was exchanged.

Canada Side

The influence of topography and storm structure on long span bridge behaviour in wind
Alan G. Davenport

Wind engineering and other non-aeronautical experiments in a large wind tunnel
Robert L. Wardlaw

Wind tunnel tests of cable-stayed bridges at their erection stage and effects of wind yaw angles
Hiroshi Tanaka

Japan Side

Wind resistant design of cable supported bridges in Japan
Manabu Ito

Feasible design methods of long-span bridge based on its aerodynamic characteristics and wind environments
Naruhito Shiraishi

Wind tunnel testing methods of long-span bridges in Japan
Nobuyuki Narita

Wind resistant design considerations for the Akashi Kaikyo Bridge
Toshio Miyata

Experiments for the Akashi Kaikyo Bridge in a large boundary layer wind tunnel
Hiroshi Sato

Design considerations for superstructures of the Akashi Kaikyo Bridge
Makoto Kitagawa

In the above presentations, wind tunnel testing methods and wind resistant design methods were reviewed. The wind induced vibrations of long span bridges, and the effect of wind properties on the responses of bridges were explained. Some suggestions on wind resistant design were presented. Also in the lectures, what have been studied on the Akashi Kaikyo Bridge were introduced.

3.3.2.2 Seismic Design of Structures

1) Current research activities were presented from the both countries:

a)*Current Research Activities Conducted at the Earthquake Engineering Division, PWRI*
Dr. Kazuhiko Kawashima
These included the following issues:

- History of damage to highway bridges caused by past earthquakes
- Seismic design of highway bridges
- Repair methods for highway bridges damaged by earthquakes
- Seismic inspection and strengthening methods for existing highway bridges
- Seismic isolation and hybrid control systems for highway bridges
- Damping characteristics of cable-stayed bridges
- Ground vibration characteristics during earthquakes

b)*Current Research Activities Conducted at the Ground Vibration Division, PWRI*

Dr. Hisanori Ohtsuka

These included the following issues:

- Strong motion observations
- Attenuation characteristics of near-source ground motions
- Dense instrument array observations of strong earthquake motions
- Assessment of soil liquefaction potential
- Visual information system for seismic ground hazard zoning

c)*Current Research Activities Conducted at the Soil Dynamics Division, PWRI*

Mr. Osamu Matsuo

These included the following issues:

- Establishment of seismic design methods for earth structures susceptible to soil liquefaction
- Development of remediation measures for earth structures to resist soil liquefaction

d)*Seismic Bridge Research in Canada*

Professor Donald L. Anderson

These included the following issues:

- Behavior of existing reinforced concrete bridge structures and retrofitting methods
- Reliable methods for estimating the shear capacity of reinforced concrete members in regions of high ductility
- Use of prestressing to increase shear capacity
- Joint response in concrete bridge supports
- Ground motion estimates at sites with deep soft soil layers and soil-structure interaction at soft sites
- Prediction of liquefaction, the estimation of ground displacement caused by liquefaction, and methods to improve soils to prevent liquefaction
- Use of strong motion data to characterize variations in earthquake ground motions
- Response of long bridges subjected to different ground motions
- Vulnerability of substructures and retrofit design details
- Base isolation and energy dissipation mechanisms
- Strengthening of existing prestressed segmental bridges
- Specialized software for analysis of cable-stayed and suspension bridges
- Dynamic testing of bridges
- Precast modular bridges and dynamic testing of joints
- Methods of estimating risk and decision making for bridge retrofit

- Cost benefit studies

2) Major publications and references on the relevant subjects were delivered from the Japan side to the Canada side.

3) Discussion was made for the subjects of mutual interest. It was found that there are many areas in which both sides have a strong interest.

3.3.3 Future Plans

3.3.3.1 Wind Resistant Design of Structures

Following items were examined and proposed as collaborative research themes in the future. The exchange of papers and various information shall be made about these items, and the details of the research plan shall be proposed and discussed between both countries.

1) Study on wind tunnel testing methods

The accuracy of wind tunnel testing is essential to achieve accurate evaluation of aerodynamic stability of long-span bridges. Although the basic concept of wind tunnel testing is almost same all over the world, there are differences between countries in method of wind generation, method of model production, and method of aerodynamic force measurement. Therefore, it is mutually beneficial to study on wind tunnel testing methods between Canada and Japan.

2) Cataloguing of aerodynamic forces on bridge deck

If there is a list of recommended cross-sections of bridge deck which have excellent aerodynamic characteristics, and if the aerodynamic data such as aerodynamic derivative and aerodynamic admittance are associated to the list, the list will be conveniently used and wind resistant design can be made through analysis. Therefore, it is mutually beneficial to exchange aerodynamic data of bridge deck between Canada and Japan and to catalogue them.

Information exchange shall be promoted between two countries. Following items are proposed as some of major themes of information exchange.

1)Vulnerability of existing bridges to disasters due to wind.

2)Characteristics of snow drifting on highway.

3)The stability of vehicles on bridge and highway in high wind.

3.3.3.2 Seismic Design of Structures

1) It is proposed to initiate the exchange of relevant technical information from the following areas in which the both side have strong interests.

a)Development of methods to estimate the shear capacity of reinforced concrete members in regions of high ductility

b)Ground motions at deep and soft soil sites

c)Assessment of soil liquefaction, estimation of ground movements caused by liquefaction, and remedial methods to improve soils to prevent liquefaction

2) To provide a platform for exchange of relevant technical information in earthquake engineering, it is proposed to organize the First Japan–Canada Workshop on Earthquake Engineering. It is tentatively proposed to hold it in late fall, 1994. The date and place will be discussed between the contact persons.

3.4 ROAD ENVIRONMENT

Attendees:

Canada side

○ *Michael Kent, Director, Highway Environment, B.C.Transportation and Highway*

Japan side

○ *Minoru Ishida, Head, Traffic Environment Division, Environment Department, PWRI*
Jun Ando, Assistant Director, Road Environment Research Section, Planning Division, Road Bureau, MOC
Toshinori Mizutani, Director, Environment Department, PWRI
Seishi Meiarashi, Chief Researcher, Traffic Environment Division, Environment Department, PWRI
Katsumi Uesaka, Researcher, Traffic Environment Division, Environment Department, PWRI
Takashi Nishio, Researcher, Traffic Environment Division, Environment Department, PWRI
Mariko Handa, Head, Landscape and Ecology Division, Environment Department, PWRI
Fumio Nakashiba, Assistant Director, Environment Measure Division, Planning Department, Japan Highway Public Corporation
Takashi Kimura, Senior Engineer, Environment Measure Division, Planning Department, Japan Highway Public Corporation
Takeyasu Takagi, Advisory Manager, Environment Engineering Division, Planning Department, Metropolitan Expressway Public Corporation
Yoshihiro Iritani, Special Officer, Environment Studies Office, Planning Division, Hanshin Expressway Public Corporation
Yoshihumi Okabe, Deputy, Research Division, Planning & Development Department, Honshu–Shikoku Bridge Authority
Itsuro Murai, Assistant Manager of Office, Environment Studies Office, Planning Division, Nagoya Expressway Corporation
Masahiko Ito, Research Director, Road Environment Laboratory

Observer

Shyam Khubchandani, Chief, Planning and Coordination, Research and Development, Policy and Coordination, Transport Canada

Takashi Iijima, Assistant Director-General, PWRI

MISSION STATEMENT

3.4.1 Objective

The objective of the road environment task group was to enhance knowledge and understanding regarding roadside environment including living environment and natural environment.

3.4.2 Accomplishments

3.4.2.1 Outline of the presentations from Japan side

The first part was the history of the road environment problem in Japan. Up to now, several laws were established to eliminate such problem. They were environmental quality standards, environmental impact assessment, and roadside law. Then, latest trends of the road environment problem and future policy were stated. The main targets were the countermeasures for the greenhouse effect, harmony with natural environment, and conservation and creation of a roadside living environment.

Next, the outline of technology on road environment was explained comprehensively. Environmental technology was divided into 3 parts: air pollution, noise pollution, and natural environment. As for air and noise pollution, recent technology was explained such as various types of noise barriers, low noise pavement, absorptive panel on the reverse face of viaduct, and air purification by plants. As for the last, list of mitigation and compensation measures and adequate thinking in consideration of natural environment were discussed.

3.4.2.2 Outline of the presentation from Canada side

The first part of the presentation was the explanation of the federal legislation of the environmental impact assessment and its effects. Besides, the detail of this system in the province of British Columbia was reported. Next, an example of the environmental process with regard to the Coquihalla Project was explained concretely.

There were a number of natural species to be conserved in this project area since this road was very long and it passed through various types of areas such as coast and inland. They were several kinds of fishes in narrow valleys, cattle moving back and forth, and wildlife with large populations of moose, deer, and bear. In consideration with these natures, the mitigation and compensation research works were explained. As for fishes, variety of compensation measures to recreate fishery habitat were carried out in building the highway. In dealing with cattle, culverts were placed with corrals. The migration routes of wild Unimals were researched by radio tracking equipment. This information helped locate pathway and exclusion fencing. The post-construction monitoring were also reported.

3.4.2.3 Outline of the discussion

(1)Research activities in both sides

There were questions and answers on the following points.

- the estimate of the number of collisions involving animals
- incentives to protect the natural environment

- budget or funding for natural environment protection
- public study procedures involved in environmental impact assessments
- the party responsible for post-construction monitoring
- sound-proof measures on the buildings
- emission standards for air pollution and environmental standards for noise
- highway drainage structure

(2)Necessary information for future

Japan is interested in the technologies to preserve the natural and living environments. More information is needed to widely implement natural environment protection measures in Japan. With regard to the living environment, noise and air pollution are serious problems not meeting environmental standards. There was a request of information on roadside planting and environmental impact assessment system of Canada.

The natural environment in Canada is different from jurisdiction to jurisdiction, but there are some regions whose climates are similar to that of Japan, therefore, it is certainly significant to exchange information. As to the auto emission, it is a problem in two cities. As for the noise, it is a problem in the surrounding areas of the cities but not in other areas. In addition, the salt used to melt snow causes contamination. Regarding planting, there is a manual, but a problem of maintenance still remains.

3.4.3 Future plans

(1)Papers and information on the following items shall be exchanged.

- Environmental impact assessment system
- Studies on natural environment protection and research results and actual cases of the countermeasures
- Various research results on roadside air pollution mitigation and traffic noise mitigation
- Various study results and guidelines on planting

(2)Should additional exchange of information become necessary, topics other than the topics above shall be identified and the relevant information shall be exchanged.

(3)To promote future activities, various opportunities such as international conferences might be utilized. For example, an international environment conference will be held in Vancouver in 1994.

3.5 ADVANCED COMPOSITE MATERIALS

Attendees:

Canada side

○ *Daniel Vezina, Chef de la section des Betons de ciment, Division des produits industriels, Transports Quebec*

Ken W. Neale, Professor, Department of Civil Engineering, Faculty of Applied Science, University of Sherbrooke

Japan side

○ *Kiyoshi Katawaki, Head, Chemistry Division,*

Materials and Construction Method Dep., PWRI, MOC
Yasuhiko Iwasaki, Assistant Director, National Highway Second Division
Road Bureau, MOC
Masashi Ikemura, Director, Materials and Construction Method Dep.,
PWRI, MOC
Kazuhiro Nishikawa, Head, Bridge Division, Structure and Bridge Dep.,
PWRI, MOC
Itaru Nishizaki, Researcher, Chemistry Division,
Materials and Construction Method Dep., PWRI, MOC
Hirofumi Ando, Bridge Section, Research Institute,
Japan Highway Public Corporation
Yoshifumi Maeda, Bridge Section, Research Institute,
Japan Highway Public Corporation
Masao Maruyama, Manager, Design Division, Tokyo Maintenance Department,
Metropolitan Expressway Public Corporation

MISSION STATEMENT

3.5.1 Objective

The objective of this Task Committee is to exchange the information about the application techniques of ACM and to develop these techniques.

3.5.2 Accomplishments

3.5.2.1 Presentation

Status reports were presented on the following issues.

1) First Experience with FRP in Quebec
2) ACM in Bridges and Structures in Canada
3) A Study on the Strengthening with Carbon Fiber Sheets of Existing Structures
4) RC Slabs Strengthened by Bonded Carbon FRP
5) Recent Applications of ACM in Civil Engineering Field in Japan
6) Examples of Exposure Tests on FRP cables

First Experience with FRP in Quebec

Daniel Vezina

The result of the evaluation of the FRP manufactured in Quebec and the application of FRP in the field was presented.

The result of laboratory testing of GFRP rods especially listed below was presented.

1) Mechanical properties
2) Freezing and thawing
3) Low temperature test
4) Pull out tests

The result of field use of GFRP was also presented.

ACM in Bridges and Structures in Canada

Ken W. Neale

(1) An overview of current activity in Canada on the use of ACM in bridges and structures was presented.

1) Study mission to Europe and Japan
2) International conference
3) Network supported by Canadian government and Canadian Society for Civil Engineering

(2) Design codes

1) Bridge design codes work
2) Standards for buildings

(3) Examples of application

1) ACM Demonstration Bridge Project in Nova Scotia
2) Use of ACM for Center Street / Beddington Trail Bridge in City of Calgary
3) FRC deck slabs using inert fibers
4) FRP Pedestrian bridge
5) Carbon fiber sheets for repair

A Study on the Strengthening with Carbon Fiber of Existing Structure

Hirofumi Ando

Strengthening method with carbon fiber against earthquake examined by Japan Highway Public Corporation was presented.

Because of increasing weight of cars and growing traffic volume, loads on superstructures often exceed the design value, so strengthening of superstructures has become necessary. Fatigue tests which used beam model bonded with carbon fiber was presented and its result was that members with carbon fiber improved bending resistance. From these results, the effect of the carbon fiber strengthening method was confirmed.

RC Slabs Strengthened by Bonded Carbon FRP

Masao Maruyama

RC slabs strengthening by bonded carbon FRP was presented by the Tokyo Metropolitan Expressway. It is effective to apply to box girders or where there are obstructions. The aim of CFRP strengthening is to reduce the reinforcing bar stress caused by excessive wheel loads. Investigations on CFRP applicability to strengthening work through static loading and work efficiency tests were conducted, and it can be concluded from the foregoing that reinforcing bar stress intensity can be reduced, confirming the possibility of strengthening.

Examples of Exposure Tests on FRP cables

Itaru Nishizaki

An outline of exposure tests of FRP conducted by PWRI was introduced. FRP is tested mainly on shore in order to investigate the long term durability of FRP under severe environment.

Some results of these exposure tests were also reported, and it was shown that there are some cases that some FRP become damaged under specific conditions.
The importance of the investigation on the durability of FRP was confirmed.

Recent Applications of ACM in Civil Engineering Field in Japan

Kiyoshi Katawaki

Recent applications of ACM which have been developed in Japan was reported. Recent application examples and trends to concrete bridges were introduced. Application of ACM to ground anchor was introduced. Problems of ACM to be solved were discussed, and main items needing further study are:

1) Long term durability of ACM
2) Materials Design Techniques

3.5.2.2 Discussion

On the basis of the presentations, questions and answers and the exchange of comments were made actively on the following items

1) The method of bridge deck water proofing and its problems Comments on the coating materials were exchanged
2) Bridge deck strengthening with FRP
3) Properties and variety of FRP as composite materials
4) Demonstration projects of ACM structures
5) Bridge beam strengthening with FRP
6) Corrosion of reinforced concrete with sea salt and deicing salt
7) The method of strengthening of bridge decks with adhesion of FRP
8) Trends of design codes for ACM applications
9) Short presentation of bridges damaged by sea salt in Japan was made by Mr. Nishikawa.
10) Design and application with ACM in civil engineering field

3.5.3 Future Plans

(1) The exchange of papers and various information shall be made on the items listed below:

1) Applications of ACM in civil engineering
2) Research and testing results on the application of ACM
3) Identification of individuals conducting researches on ACM
4) Design codes and testing standards

(2) Mutual visits to actual structures using ACM shall be encouraged.
(3) Short and long term visit to research centers
(4) Any other opportunities shall be utilized to improve cooperation.

4. Overall Accomplishments

The three day Workshop proved to be highly productive in the sharing of current information from both sides. During the concurrent task committee meetings addressing the five topics previously mentioned, members of the Japan/Canada research staffs shared ideas, opinions and published information of various topics. They were joined by members of the greater highway community of Japan. Specific actions for follow-up were identified and contact points were established.

5. Future Directions

(1) In order to promote research cooperation efficiency in the five topics identified by both the parties, organization should be strengthened and activities should be continued. Both the parties shall make efforts to obtain a budget.

(2) Both the Parties agreed to examine increased cooperation through several means, such as:

1. Mutual use of each others' laboratory facilities, computer models, etc.
2. Increased researcher exchange
3. Technology dissemination
4. Joint demonstrations
5. Industry involvement
6. Participation in associated conferences

(3) Both the parties agreed that the second Joint Panel meeting will be hosted by Canada in fiscal year 1996-1997.

2. Keynote Topics

Road Administration in Japan

Masashi Maki
Director, National Highway Second Division,
Road Bureau, MOC

Contents

1. General description of Japan

2. General description of road condition
   ① Road classification and present condition
   ② Road administrators
   ③ Classification road project

3. History of road improvement
   ① History of Five-year Road Improvement Program
   ② Special fund for road improvement
   ③ Toll road system

4. The 11th Five-year Road Improvement Program
   ① Present road condition and necessity of road improvement
   ② Major subjects
   ③ Target of road improvement

1. General description of Japan

60% of Japanese land is mountainous. The population is concentrated in the district of Kanto, Chubu and Kinki.

Figure.1

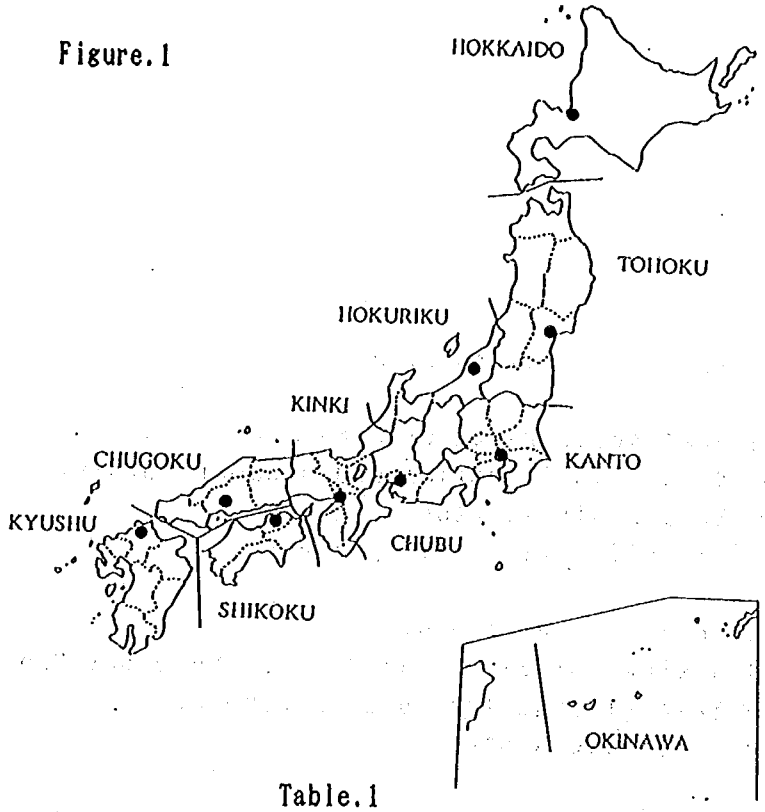


Table.1

Districts	Area (10^3 Km^2)	Percentage of mountainous terrain	Population (million)	Population density (per Km^2)	Per capita gross product in the districts (million yen per person)
Hokkaido	83.4(22.1%)	49%	5.6(4.6%)	67	2.95
Tohoku	66.9(17.7%)	62%	9.8(7.9%)	147	2.88
Kanto	36.9(9.8%)	46%	39.4(31.9%)	1,068	4.34
Metro. and 3 prefectures	13.5(3.6%)	---	31.7(25.6%)	2,348	4.55
Hokuriku	21.0(5.6%)	62%	4.8(3.9%)	228	3.29
Chubu	42.9(11.3%)	73%	16.4(13.3%)	382	3.80
Kinki	31.5(8.3%)	65%	21.0(17.0%)	667	3.65
Chugoku	31.8(8.4%)	74%	7.7(6.3%)	242	3.36
Shikoku	18.8(5.0%)	80%	4.2(3.4%)	223	2.79
Kyushu	42.2(11.2%)	65%	13.3(10.8%)	315	2.86
Okinawa	2.3(0.6%)	24%	1.2(1.0%)	522	2.31
Total	377.7(100%)	61%	123.6(100%)	327	3.64

1) Population : end of March 1992 2) Per capita gross product : 1990 fiscal year

60% of Japanese land is snowy or cold area.

Figure.2 Snowy or Cold Areas

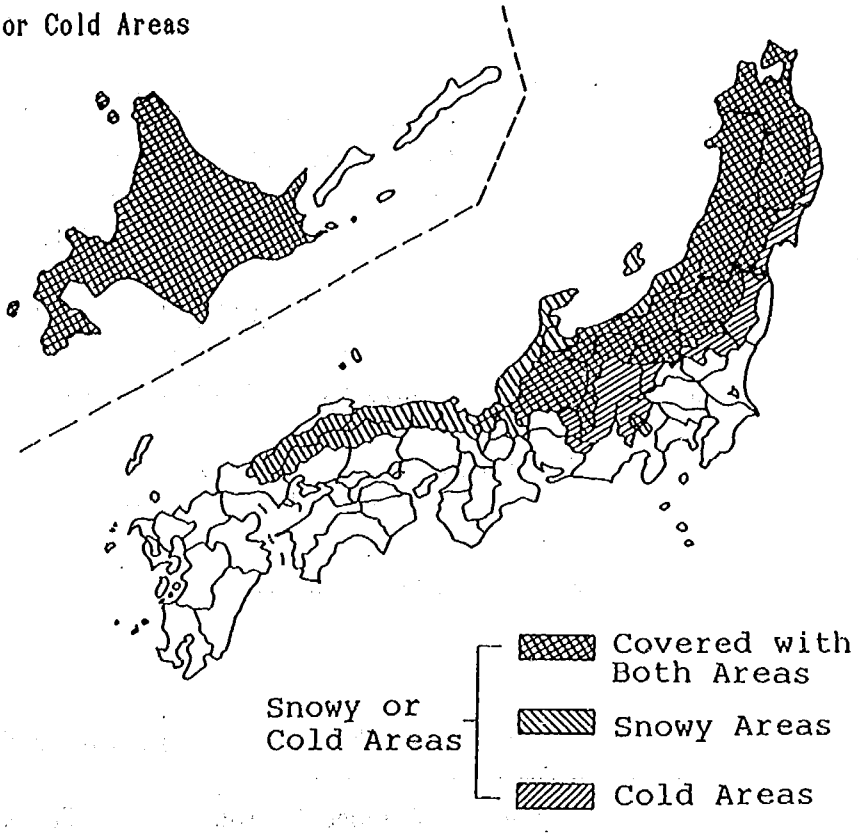


Table.2

	Number of Cities, Towns, and Villages	Area (km^2)	Population (million)
Snowy areas ※ 1	1,048 (32.2%)	200,018 (53.7%)	21.8 (18.0%)
Cold areas ※ 2	988 (30.4%)	193,280 (51.8%)	21.0 (17.4%)
Snowy or Cold areas	1,332 (41.0%)	227,603 (61.1%)	27.5 (22.8%)

Definition

※ 1 : The mean value (more than five years in the past) of maximum snow depth in February greater than 50cm.

※ 2 : The mean value more than five years in the past of average temperature in January lower than 0°C.

Car is main transportation mode in Japan

Table.3 Trend of Number of Vehicle License Holders
(unit : million persons, million vehicles)

Item \ Year	1970 (A)	%	1992 (B)	%	Ratio B/A
Number of license holders	26.5	25.3	64.2	51.6	2.4
Number of vehicles	18.2		57.7		3.2

% : for population
Source : National police agency

Table.4 Trend of Share of Transportation Mode

	Passenger Transportation			Freight Transport		
	Vehicle	Railway	Air	Vehicle	Marine	Railway
1955	17%	82%	0.1%	12%	36%	53%
1990	60%	35%	5%	50%	45%	5%

2. General description of road condition

① Road classification and present condition

The Road Law classifies roads into 4 categories according to the share on the road network: National expressways, National highways, Prefectural roads and Municipal roads.

Table.5 Improvement of Roads

(Values as of April 1,1992)

(Unit: km, %)

Classification	Actual extension	Maintenance made		Pavement made		Improvement		More than 4 lanes	
		Extension	Rate	Extension	Rate	Extension	Rate	Extension	Rate
National expressway	5,054	—	—	5,054	100.0	5,504	100.0	4,653	92.1
National highways	47,033	25,805	54.9	41,465	88.2	41,523	88.3	4,813	10.2
Designated sections	20,671	10,521	50.9	20,342	98.4	20,603	99.7	3,704	17.9
Other than designated sections	26,362	15,284	58.0	21,124	80.1	20,920	79.4	1,110	4.2
Prefectural roads	129,284	60,949	47.1	63,823	49.4	74,334	57.5	3,711	2.9
Municipal roads	943,472	426,311	45.2	144,115	15.3	426,311	45.2	4,096	0.4
Total	1,124,844	—	—	254,458	22.6	547,223	48.6	17,273	1.5

Note: 1. Extension and rate for "Maintenance made" refers to the extension of the roads having a width of 5.5m or more, improvement made and a congestion degree less than 1, and the values given are those according to the 1990 Road Traffic Census.
2. Extension and rate for "Pavement made" are the values precluding the sections of law-cost pavement.
3. Extension and rate for "Improvement" are the values of the roads having a width of 5.5m or more of Prefectural roads and higher-level roads than that, and are the values of all roads of Municipal roads.
4. Extension and rate for "More than 4 lanes" are the values ofds having a width of 13.0m or more.

② Road administrators

* General Categories

National expressways	Minister of Construction
National highways (Designated sections)	Minister of Construction
National highways (Non-designated sections)	Prefectural governor (or mayor of designated city)
Prefectural roads	Prefectures(or designated city)
Municipal roads	municipalities

* Special Cases (example)

New construction and reconstruction of National expressways are allocated to the jurisdiction of the Japan Highway Public Corporation by the Minister of Construction.

③ Classification road project

Road Works are classified according to undertakers as follows:

Figure.1 Types of Projects according to undertakers

Road Projects

Ordinary road projects

- Projects under direct control

  The government directly executes these projects through Regional Construction Bureaus, Hokkai-do Development Bureau and Okinawa General Office.

- Subsidized Projects

  Local public bodies executes the projects with subsidies from the government.

Toll road projects

Public corporations and authorities executes these projects with loans, road development fund loans and government and local public bodies' financial investment.

Local independent projects

Local public bodies executes the projects based on their own authorities.

Table.6 Investment scale of road projects

(Unillion Yen)

Classification	11th 5-Year Program (Fiscal 1993 ~ 1997)	Fiscal 1993		Fiscal 1992	
		Project cost(A)	Progress rate %	Project cost(B)	Ratio (A)/(B)
Ordinary road projects	288,000	48,028	18.8	46,085	1.04
Toll road projects	206,000	36,332	17.9	32,627	1.11
Sub-total	494,000	84,360	18.4	78,712	1.07
Local independent projects	252,000	44,600	17.7	40,382	1.10
Total	764,000	128,960	18.2	119,094	1.08
Contingency	14,000	—	—	—	—
Grand total	760,000	128,960	17.9	119,094	1.08

values in ( ):included national fund

NOTE:1.The values in fiscal 1992 and 1993 are planned initially.
2.Ordinary road projects include works concerning Housing Land(General Account and Road Improvement Special Account) and Urgent local road works
3.The values of local independent projects since fiscal 1991, are expected.

3. History of road improvement

It was since the establishment of the first Five-Year Road Improvement Program 1954 that Japan began to make great strides in road improvement. Thereafter, it has been forwarded with the Special Road Financial Source of Road Funds System and the Toll Road System, the two main systems which are closely connected with each other.

① History of Five-year Road Improvement Program

Table.7 History of the Five-Year Road Improvement Programs

the 1st - the 4th (1954 - 1966)	* Main subjects of road works were primary reconstruction of the national highways and the extension of paved sections * Improvement of the national expressways and the urban expressways was linear
the 5th - the 7th (1967 - 1977)	* It began to improve the national expressways like as "network", taking the decision of the planned routes of national development arterial express ways (7,600km July, 1966) * Traffic Safety Facilities Improvement Program was established in 1966
the 8th - the 9th (1978 - 1987)	* The early days of this period, the critical opinions for improvement for roads, particularly national expressways, were major * To get the understanding of a nation widely, and to improve the roads efficiently according to plans, "The targets of road improvement" was confirmed
the 10th (1988 - 1992)	* Necessity of road improvement, which was propounded in nation-wide plans of land development and economy such as The fourth Comprehensive National Development, increased * The long-term target of the national expressway network was revised, after 20 years intervals, since establishment of the extension(7,600km) by Law for Construction of Arterial Motorways for National Land Development, 1966 * The fundamental policy of nation-wide trunk road network at the 21st century was determined * Various kinds of Contrivances were essential for the promotion of the urgent improvement such as a ring road in Metropolitan area

The 10th Five-Year Road Improvement Program ends in fiscal 1992. From fiscal 1993, Road Improvement will be promoted by the 11th Five-Year Program(1993 - 1997).

② Special fund for road improvement

Table.8 Tax Rates for Special Source of Road Funds

(Unit:1,000 million Yen)

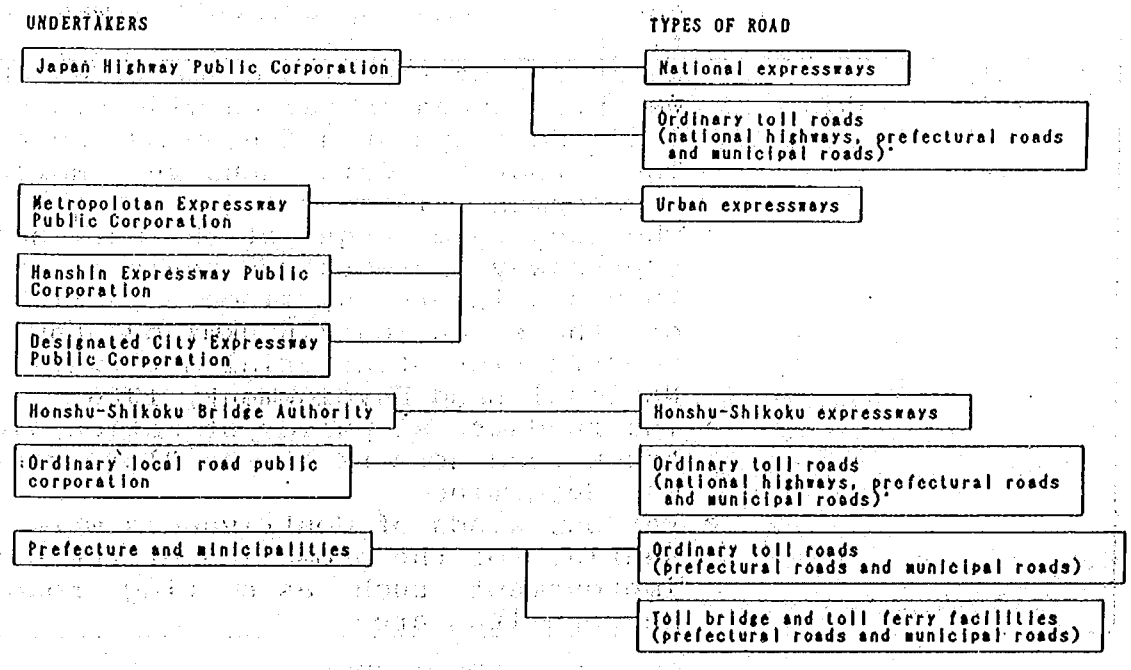
	Taxes	Rates of taxes	Tax revenues in Fiscal 1993
National	Gasoline Tax	45.6 Yen/litre (until 11/30/'93) 48.6 Yen/litre (from 12/01/'93)	22,565 (22,910)
	LPG Tax	17.5 Yen/kg	160 (144)
	Motor vehicle tonnage Tax	ex.private vehicle 6,300 Yen/0.5ton·year	5,636
	Sub-total		28,261 (28,690)
Local	Local road Transfer Tax	6.2 Yen/litre (until 11/30/'93) 5.2 Yen/litre (from 12/01/'93)	3,822
	LPG Transfer Tax	17.5 Yen/kg	160
	Motor vehicle Tonnage Transfer Tax	ex.private vehicle 6,300 Yen/0.5ton·year	2,301
	Diesel fuel Transaction Tax	24.3 Yen/litre (until 11/30/'93) 32.1 Yen/litre (from 12/01/'93)	10,243
	Motor vehicle Purchase Tax	5% of retail price (private) 3% of retail price (commercial and light)	6,385
	Sub-total		21,911
Total			51,172 (51,501)

NOTE 1.The revenues are written by initially planned budget and the Regional Finaces Plan in fiscal 1993, and the values in ( ) including the adjusted amount for settlement of accounts.

2.Revenues of the Motor vehicle Tonnage Transfer Tax, correspond to about 80% of national revenues.

③ Toll road system

Figure.4 Undertakers and Types of Toll road projects



Limited to the national highways, prefectural roads, and designated city roads in the case of Japan Highway Public Corporation.
Limited to the prefectural and municipal roads in the case of prefecture and municipalities.

4. The 11th Five-year Road Improvement Program

① Present road condition and necessity of road improvement

(1) People's lives and the Japanese economy have been improved with the development of a automobile society.

(2) Roads, as the basis of social and economical activities, contribute to improvement of life, such as the supply of houses and housing land, as well as the automobile traffic.
Road Works have been carried out with utilization of Special Road Financial Source System and Toll Road System, based on the Five-Year Road Improvement Programs.

(3) However, road improvement on a full scale only began in 1954, '30 years ago, when the First Five-Year Road Improvement Program started.
The speed of urbanization and development of automobile society have exceeded that of road.

Table.9 Development of Automobile Society

	1955	1990	2010
Running vehicle-kilometers (100 million vehicle-kilometers)	121	6,286	8,973
Passenger transport by automobile (100 million person-kilometers)	275	6,628	9,169
Freight transport by automobile (100 million ton-kilometers)	95	2,722	3,861
Number of driver's licenses retained (10,000 persons)	378	6,100	9,400
Number of motor vehicles retained (10,000 vehicles)	92	5,800	7,300
GNP (100 billion Yen)	44	410	760

(4) The level of road improvement in Japan is approximately only half the level of Europe and U.S.

Table.10 INTERNATIONAL COMPARISON OF THE LEVELS OF EXPRESSWAY

Countries	Service Extension	Service Extension / National land Area km/10,000km²	Service Extension / Population km/10,000 persons	Service Extension/√(Area·Population) km/√(10,000persons·10,000km²)	Service Extension/Number of vehicles retained km/10,000vhcls	Year Average of newly('86-'89) served Extension km/year
JAPAN	5,929	157.0	0.48	8.67	0.99	260
UNITED STATES	72,857	77.7	2.88	14.97	3.82	501
former WEST GERMANY	8,959	360.4	1.40	22.44	2.68	181
UNITED KINGDOM	2,903	118.9	0.51	7.76	1.09	
FRANCE	7,450	135.1	1.31	13.28	2.81	200
ITALY	6,767	224.6	1.19	16.32	2.20	

NOTE 1. Expressway Service Extension values as of the end of 1990, according to "World Road Statistics"(IRF)
2. For France, it is the values as of the end of 1991. For Italy, it is the values as of the end of 1989. For United States, it is the value as of December 31,1991 in "Highway Statistics". The Japanese value is the road extension of high-graded trunk roads in the end of 1992 by Road Bureau.
3. The year average of newly served extension for former West Germany, is the average of '86 -'87.
4. United States plans for new 155,000miles(app.248,000km) as NHS(National Highway System) ,in its Six-Year New Road Improvement starting since 1992.

(5) In order to be a nation in which people's lives are enriched, realizing "the society in which affluence and comfort are felt" being backed up by vigorous economic growth, urgent measures are needed, answering to people's dissatisfaction with road improvement, laying stress on the public's view point, and creating vital communities and a good environment.

(6) Road improvement are indispensable for unified activation of suburban and urban areas, as the basis for the promotion of all projects which vitalize local communities.

(7) Further improvement of road network is needed to ease traffic jams, rejuvenate local communities, aid a good urban environment and form a multipolar nation before Japan becomes a society in which the ratio of the aged to the population becomes high in the 21st century.

It is desired that the level of road improvement in Japan be raised to the European and American levels, however working expenses of over 400 trillion yen are needed for that achievement.

② Major Subjects

The Eleventh Five-Year Road Improvement Program

Based on a survey of over 10,000 people from all sectors of Japan, the Eleventh Five-Year Road Improvement Program (comprehensive investment of 76 trillion yen for the FY 1993-1997) was enacted (May 1993 Cabinet decision). Rapid systematic road improvement is being promoted based on this program.

Figure.5 Basic policy on road improvements

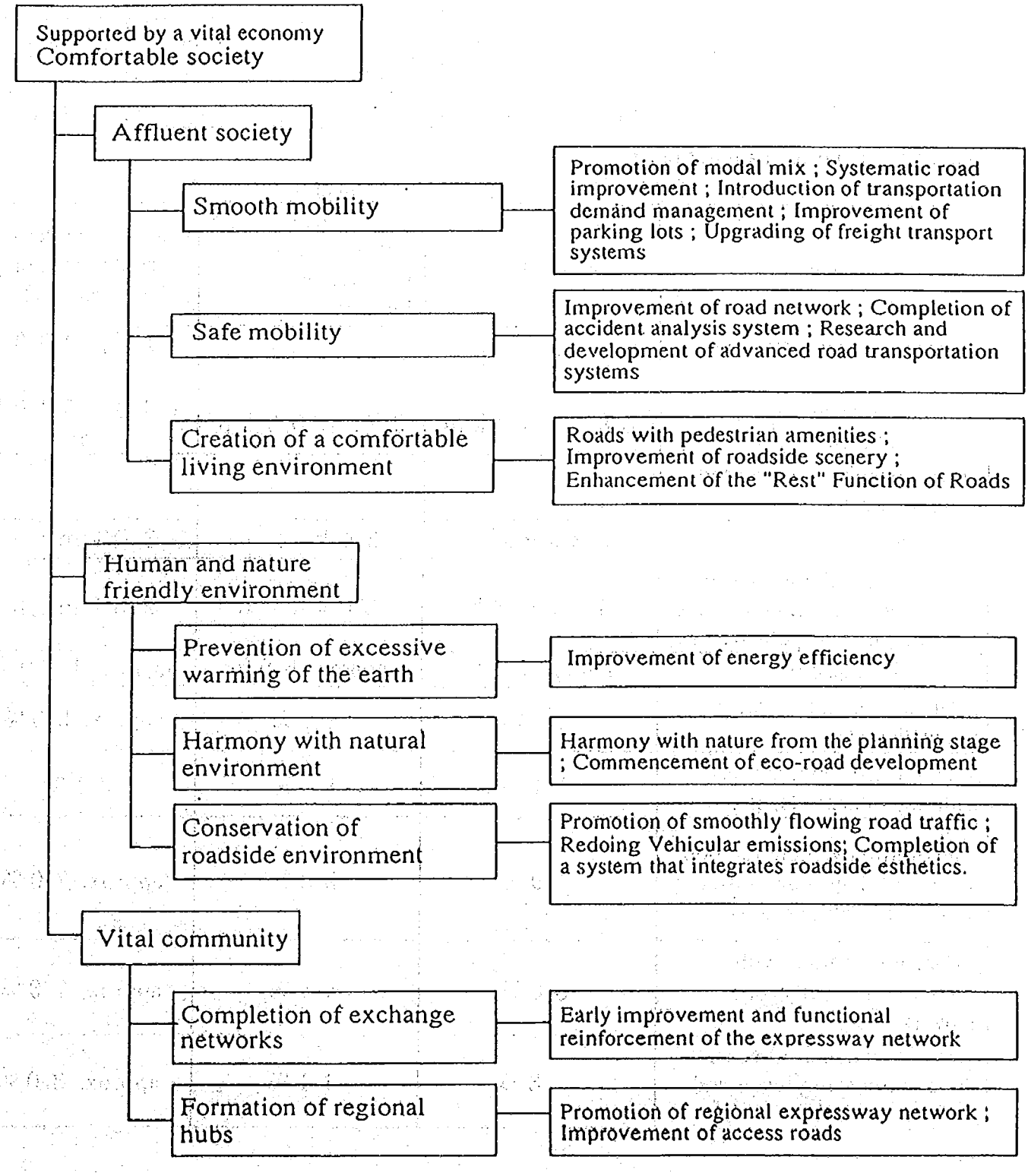


Table.11 The Eleventh Five-Year Road Improvement Program (1993-1997) Unit: 100 million yen

Area	Tenth Five-Year Plan		Eleventh Five-Year Plan		
	Program amount (1)	Total rate of progress	Progress amount (2)	Increase rate (2)/(1)	Average increase rate, beginning of FY 1992
General road projects	238,000	95.1	288,000	1.21	1.08
Toll road projects	140,000	101.7	206,000	1.47	1.08
Subtotal	378,000	97.6	494,000	1.31	1.08
Independent regional projects	139,000	127.1	252,000	1.81	1.08
Total	517,000	105.5	746,000	1.44	1.08
Adjustment expenses	13,000	—	14,000	1.08	—
Aggregate total	530,000	102.9	760,000	1.43	1.08

③ Target of road improvement

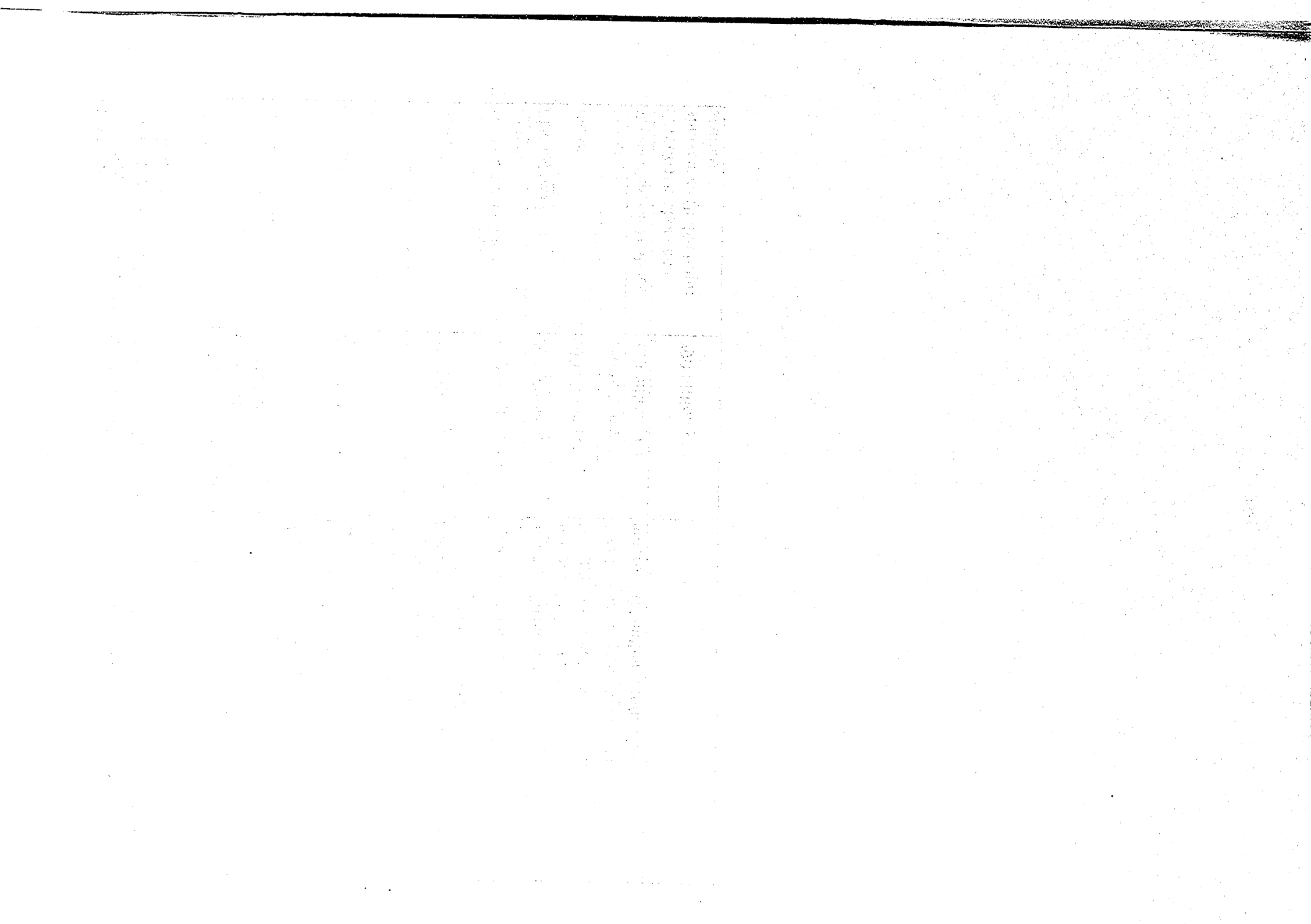
Table.12 Aims of road improvements

Item	End of FY 1992	Aims of the Eleventh Five-Year Road Improvement Program	Aims of long-term concepts (beginning of 21st. century)
Expansion of high-standard main roads in service	5,929km	7,806km	14,000km
National highways and prefectural roads	88,880km	97,100km	138,540km
Travel speed in morning and evening in cities			
Regional cities	22km／h	24km／h	30km／h
Areas of demographic concentration in the three major metropolitan areas	18km／h	20km／h	25km／h
Parking lot capacity	approx. 50%	approx. 65%	approx. 100%
Establishment rate of wide sidewalks, etc.	12%	15%	approx. 50%
Rate of traffic on main roads with high standards, etc.	11%	13%	21%
Rate of improvement for loop roads with high standards, etc. which form city frameworks	19%	28%	approx. 70%
Proportion of areas with improved inner-city road network	38%	44%	approx. 70%
Rate of creation of Greenbalts along national highways and prefectural roads	8%	11%	approx. 30%

Table.13

Related projects within the Eleventh Five-Year Road Improvement Program for access road projects alone, which are directly related to other main infrastructure improvements, exceed 10 trillion yen.

Area	Related road projects within period of Five-Year Plan	Remarks
Housing	5.4 trillion yen	approx. 1.6 million yen/house Total number of houses supplied is 3.3 million. Over 40% of these, 1.5 million, were provided through land readjustment projects. (Land readjustment and access roads)
Schools	370 billion yen	approx. 1.3 billion yen/school (New facilities for junior high schools, high schools and universities)
Welfare and cultural facilities	1.023 trillion yen	approx. 700 million yen/facility
Medical facilities	203 billion yen	approx. 700 million/facility
Parks	960 billion yen	About 2.3 billion/facility (Establishment of large-scale parks)
Sewerage	740 billion yen	100% of sewer pipes under roads
Waste disposal facilities	220 billion yen	approx. 700 million yen/facility
Airports, harbors and shinkansen (bullet train) stations	790 billion yen	—



Enactment of Five-Year Road Technology Program
~Challenging Possibilities in the 21st. century ~

(1) Aims

Based on advancements in the technologies which have supported road improvements thus far, a program should be enacted for the development and implementation of major technologies in fields which must be newly challenged. Also, active efforts should be made to promote the development, implementation and dissemination of new road technology and comprehensive management of technology. Through these changes, this program aims to promote more efficient roads and to respond appropriately to basic issues such as traffic congestion and traffic safety, problems related to the environment and energy conservation, and new demands for affluence and beauty.

(2) Content of program

① This program includes 74 topics which cover new long-term road improvement concepts and main technologies supporting the development of major tasks in the Eleventh Five-Year Road Improvement Program.

② Based on the aim to develop and implement these technologies in the long term, programs will be enacted to develop, implement and disseminate such technologies within the period of the Eleventh Five-Year Road Improvement Program.

(3) Placement of the program

① This program is designed to promote more efficient road improvement through the development and application of new road technology.

② Based on consideration of the research and development of construction technology by the entire ministry, the Road Bureau will enact policies reflecting a wide-range of opinions and proposals.

③ This program will be promoted through cooperation between universities and the private sector.

(4) Special characteristics

① The Road Bureau has enacted this technology policy in light of the inauguration of the Eleventh Five-Year Road Improvement Program.

② Evaluation of the roles and results of the major technologies that have supported road improvements thus far.

③ Deterioration of major road technologies which should be improved, the results of those technologies, and development aims for the five-year period.

④ Use of visual aids1 and other technologies to make concrete images of technology as accessible as possible.

⑤ Policies which should be addressed in order to promote the development and implementation of

new road technology.

(5) Opinion survey

① Deliberation on priority road technology at the New Technology for Roads Conference (Established in September 1991, Chairman: Hideo Nakamura, University of Tokyo professor)

② Survey on the priority of new road technology conducted on 560 experts nationwide (October 1992)

③ Survey of opinions and proposals on policy enactment conducted on 750 experts nationwide (May 1993)

(6) Structure

Chapter 1 Development of Japan's road technology

Chapter 2 Major road technologies which have supported the development of modern road projects

Chapter 3 Five-Year Program for Road Technology
～Striving toward new possibilities in the 21st. century～
1. Basic policy on road technology development
2. Program for the development and implementation of major technology topics
3. Policies for promoting the development and implementation of road technology

(7) Basic policy on road technology development

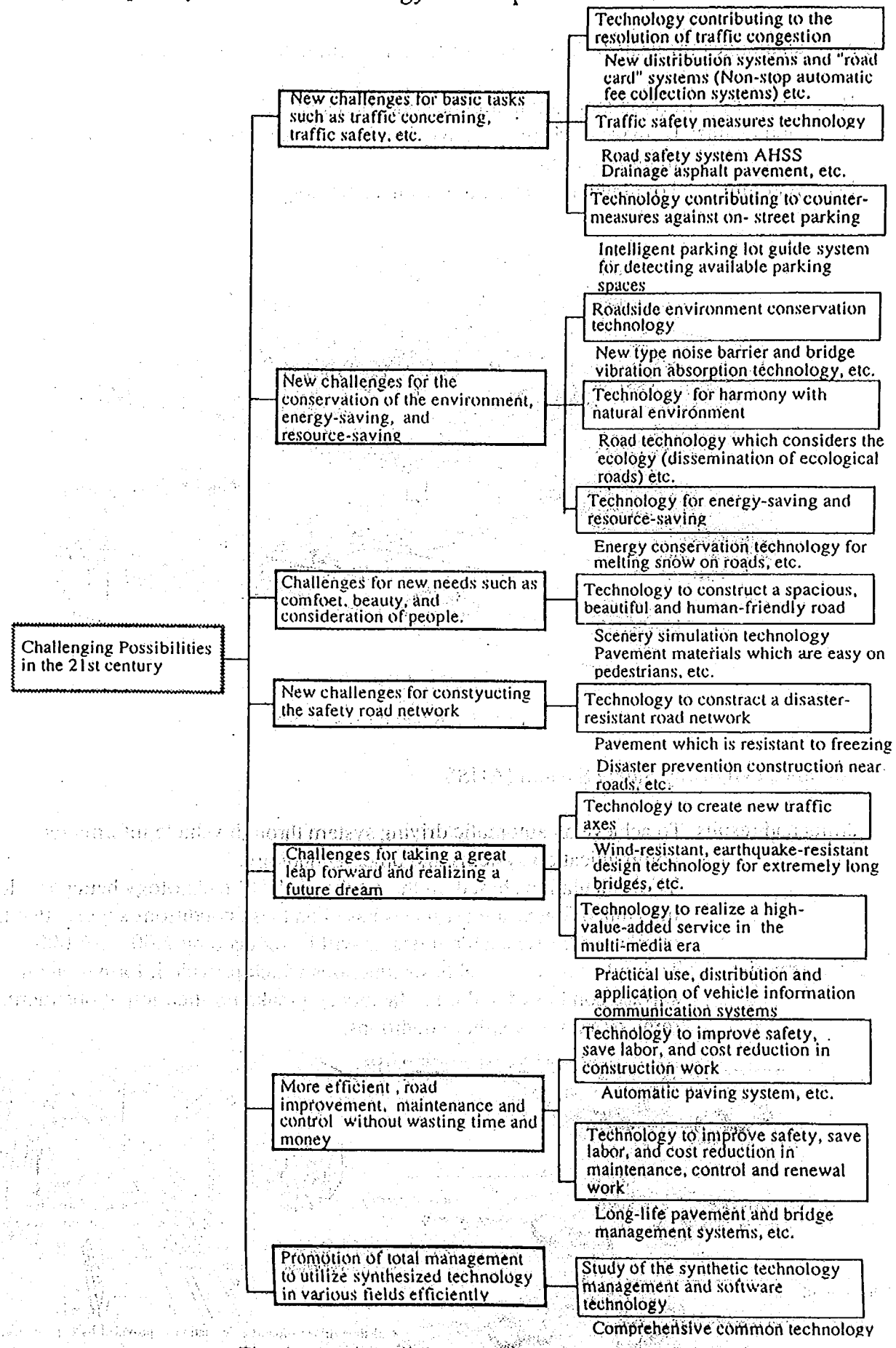


Fig. 1 Basic policy on road technology development

(8) Examples of major technologies

① New challenges for basic tasks such as traffic concerning, traffic safety, etc.

a. "Road card" system (Non-stop automatic fee collection system)

Aims and results: To make roads more convenient by eliminating toll station traffic congestion and the use of cash

Five-year aim : Trial implementation of system technology

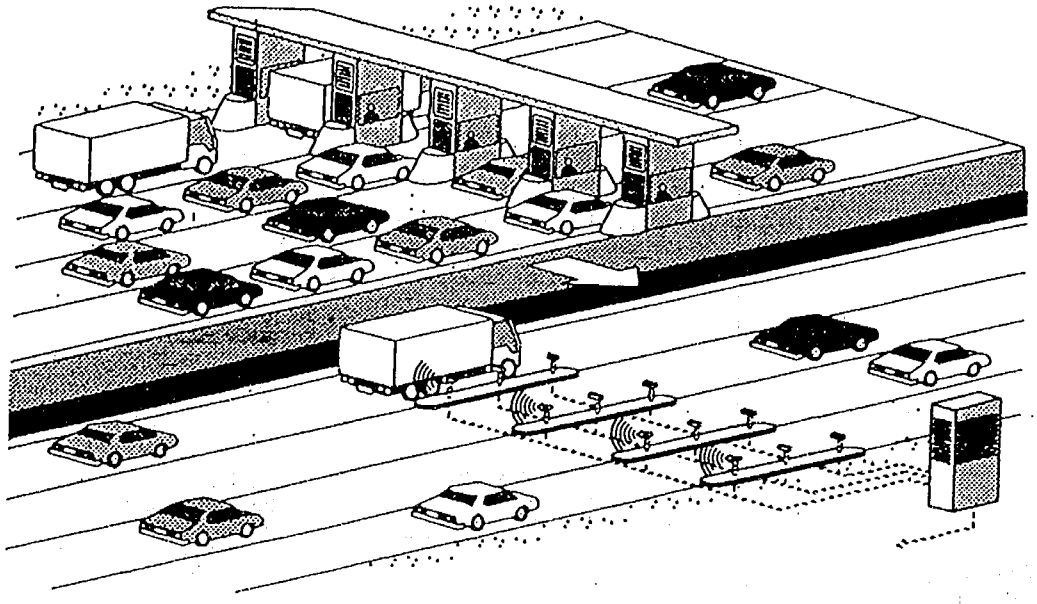


Fig. 2 Road card system

b. Advanced Highway Safety System (AHSS)

Aims and results: To achieve an automatic driving system through vehicle information communication systems and other technology.
Trial calculations based on the results of IVHS technology being developed in the United States and estimates based on these conditions suggest that the number of traffic accident deaths will be reduced by 2,000 to 3,000.

Five-year aim : To implement on a trial basis functions which provide information on road surface conditions and other factors and make notification of obstructions under rainy or snowy weather conditions.

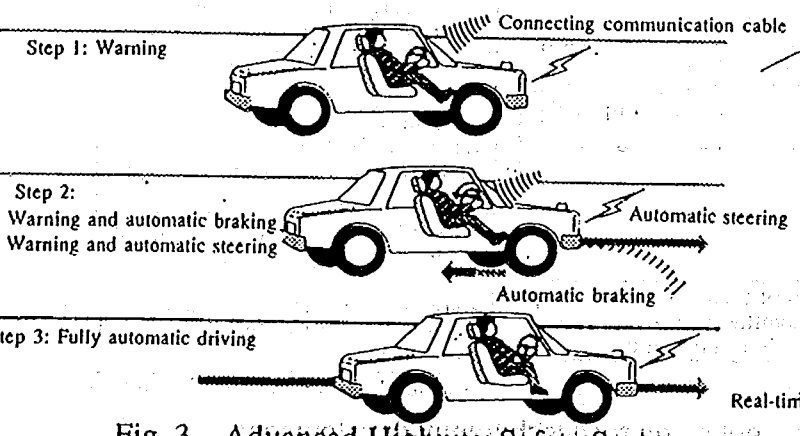


Fig. 3 Advanced Highway Safety System

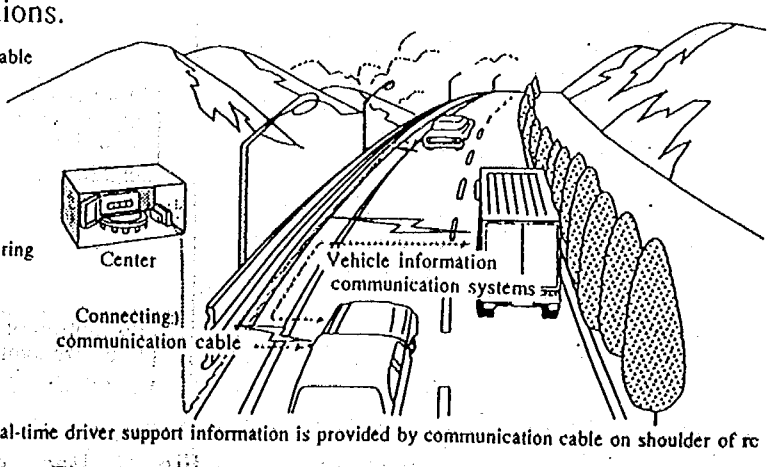


Fig. 4 Full Automatic Driving system

② New challenges for the conservation of the environment, energy-saving, and resource-saving

a. Road technology which considers the ecology (spread of ecological roads)

Aims and results: To make road improvements in environmentally Sensitive areas and which consider the living environment of plants and animals and interaction with nature.

Five-year aims : Development and dissemination of ecological road guidelines (implementation about 200 locations along main roads where improvements will be made to national park areas and other regions abundant in nature).

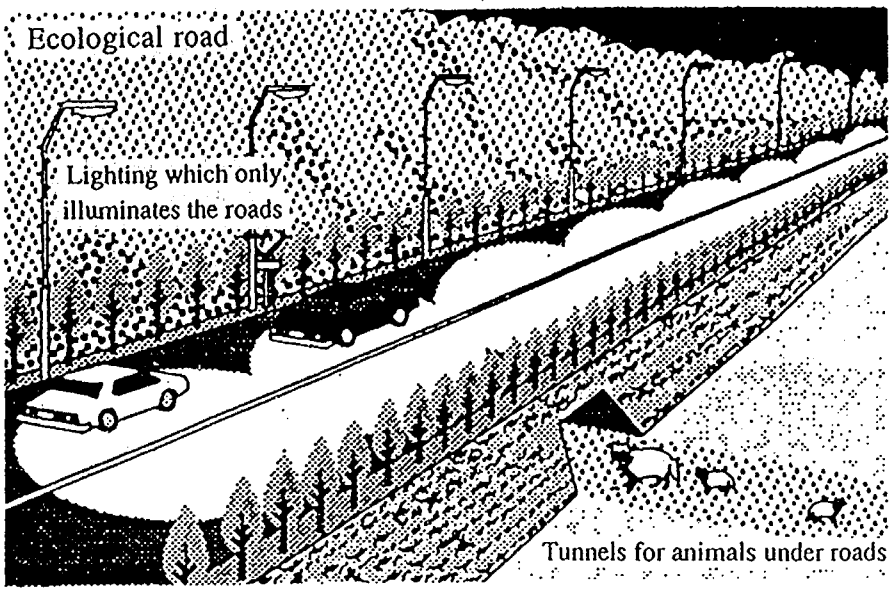


Fig. 5 Ecological road

b. Energy conservation technology for melting snow on roads

Aims and results: To reduce cost for melting snow on roads through the use of solar heating and underground heated water (running consumption will be reduced to about one-third of those when using oil).

Five-year aims : To implement on a trial basis and conduct a practical application.

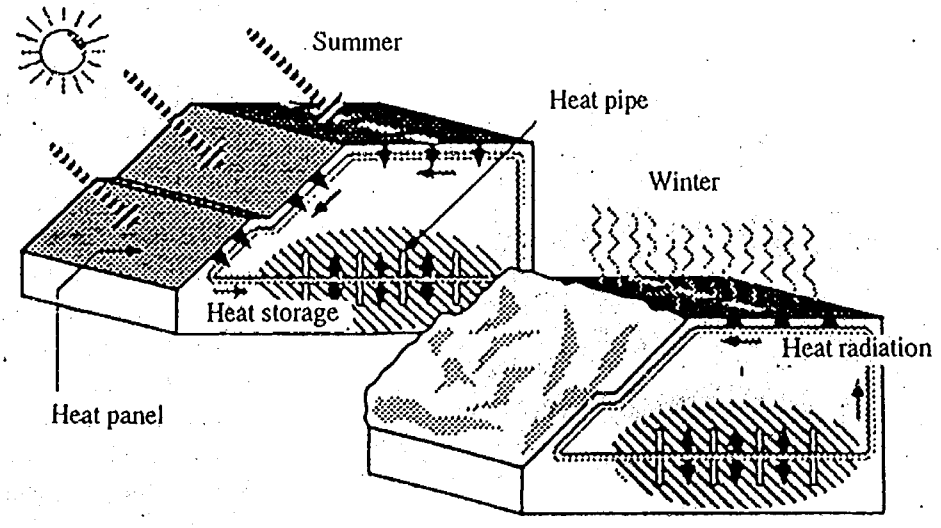


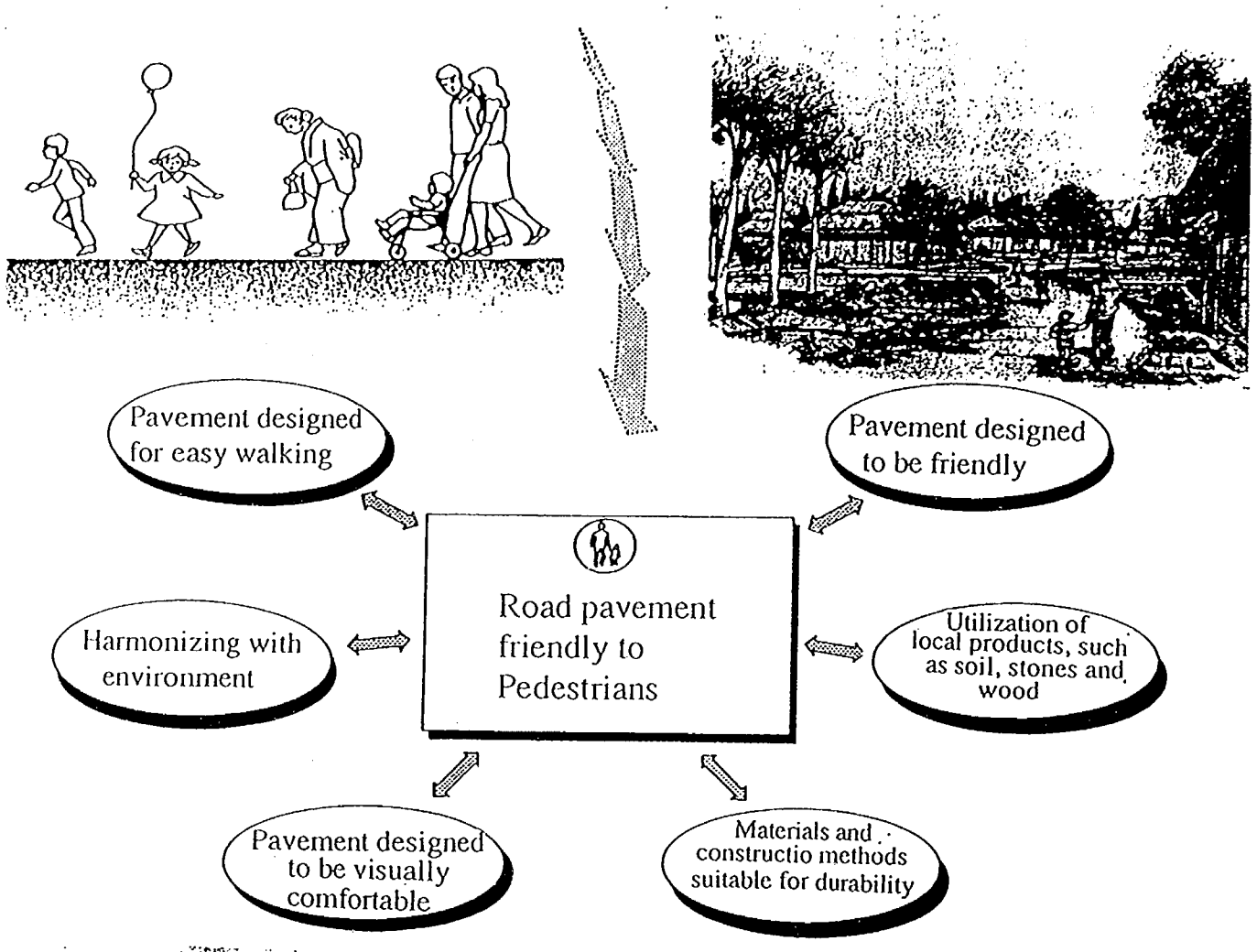
Fig. 6 System for melting snow through under ground heat storage

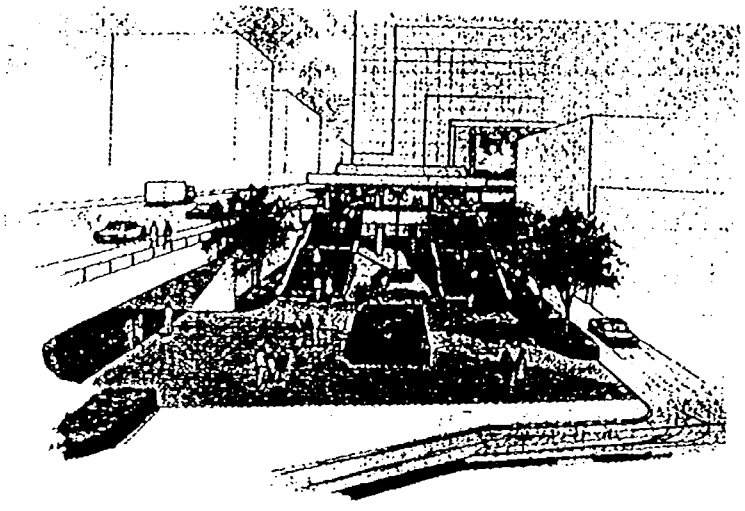
③ Challenges for new needs such as comfort, beauty, and consideration of people

a. Pavement materials which are easy on pedestrians

Aims and results: To use natural materials to develop a highly functional pavement for pedestrians which is easy on the knees, conducive to walking and pleasant to look at.

Five-year aim : To operate on a trial basis, make manual preparations, and apply and disseminate the pavement technology.





Examples of high-performance, pedestrian pavement materials

Colored water-permeable pavement
Elastic water-permeable pavement
Pavement with natural soil
Improved soil pavement
Colored concrete pavement
Elastic tile pavement
Natural stone-plate pavement
Pavement with wooden chips
Wooden tile pavement

Fig. 7 Road pavement friendly to pedestrians

④ New challenges for constructing the safety road network

a. Pavement resistant to freezing

Aims and results: To reduce accidents from slipping by making the pavement itself resistant to freezing.

Five-year aims : To develop pavement materials which are resistant to freezing and to conduct tests, create technology standards and disseminate the technology.

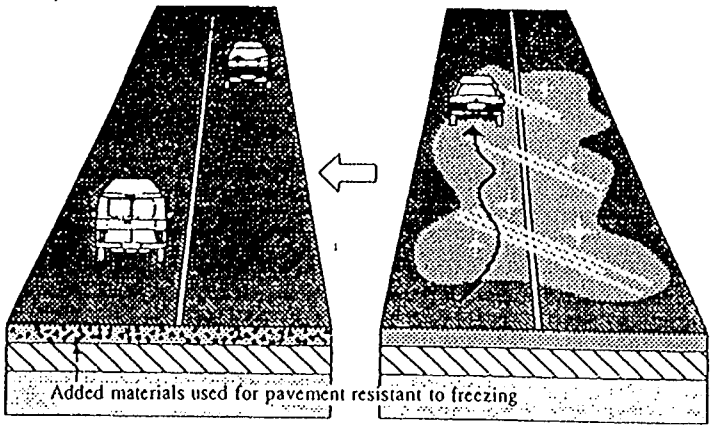


Fig. 8 Freezing Prevention Pavement

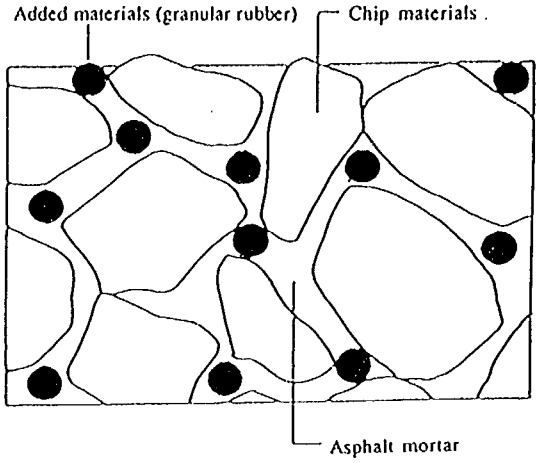


Fig. 9 Conceptual drawing of freezing prevention pavement (Example of granular rubber addition)

⑤ Challenges for taking a great leap forward and realizing a future dream

a. Wind-resistant, earthquake-resistant design technology for extremely long bridges

Aims and results: To develop a new traffic system through the use of bridges which exceed the length of conventional bridges.

Five-year aims : To experiment with wind-resistance of bridges by using a wind tunnel. To develop new types of suspension bridges and cable systems.

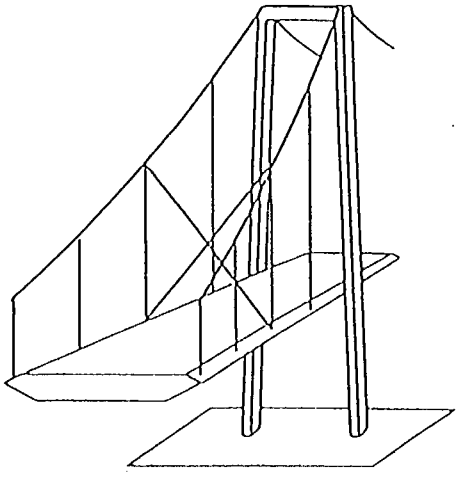


Fig. 10 Cross hanger
(Improvements in rigidity)

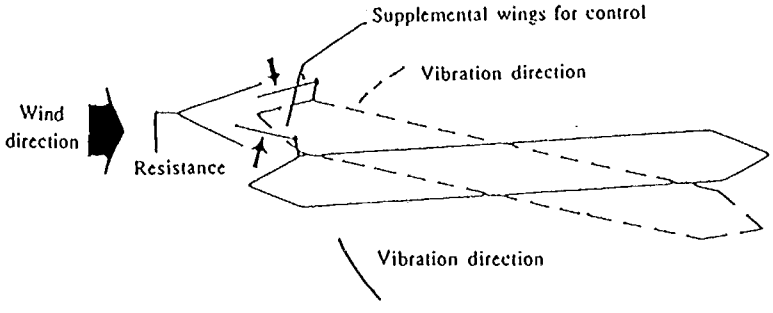
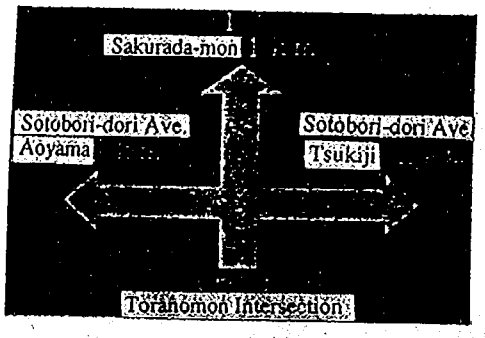


Fig. 11 Active control
The force exerted on girders by the wind is reduced through the movement of the supplemental wings.

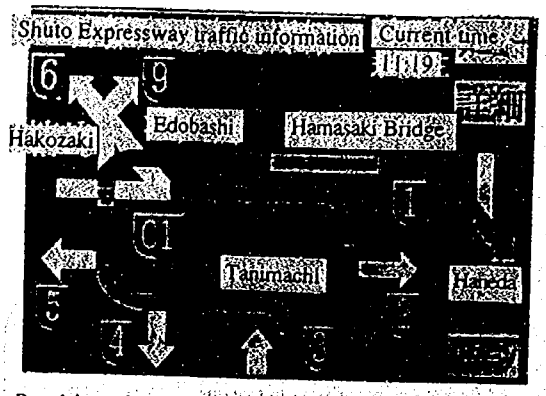
b. Practical use, dissemination and application of the Vehicle Information Communication System (VICS)

Aims and results : Saving resulting from providing traffic information on all areas of expressways and national roads and on 80% of main regional roads are projected to reach about 5 trillion yen over 10 years. Saving resulting from guidance through best routes is projected to reach about 8 trillion yen over 10 years.

Five-year aim : To provide 12,000 information transmitting devices (beacon) which use radio waves on the sides of roads.



Provision of static information (name of region displayed)
Even if the driver misses the road signs, the name of the regions can be confirmed within the vehicle.



Provision of changing information (traffic jam information display)
Accidents, traffic jams and other information are displayed real time within the car.

Fig. 12 Display equipped on vehicles

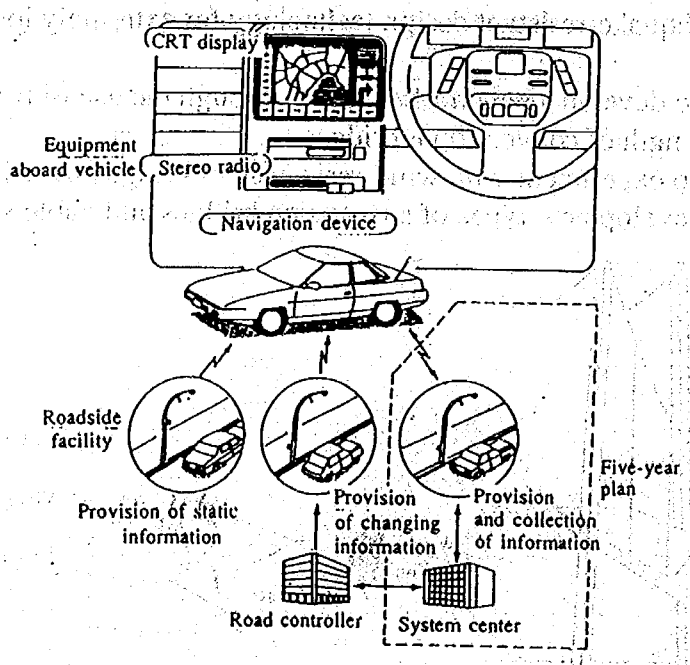


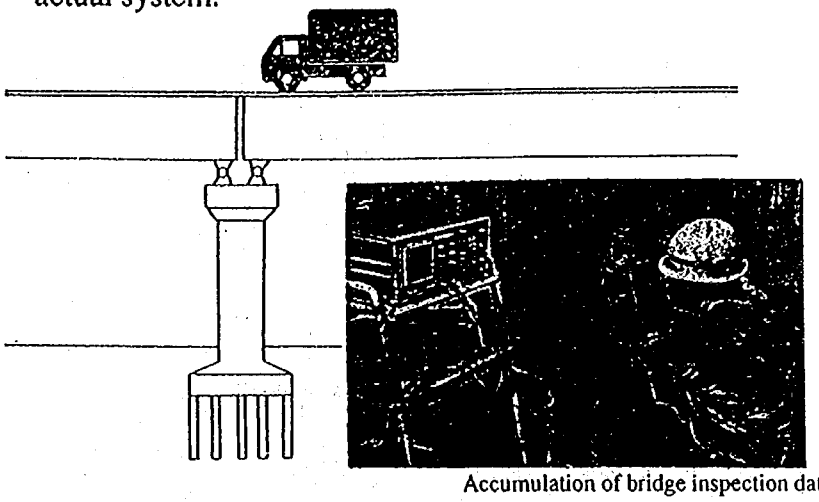
Fig. 13 System structure

⑥ More efficient , road improvement, maintenance and control without wasting time and money

a. Bridge management system

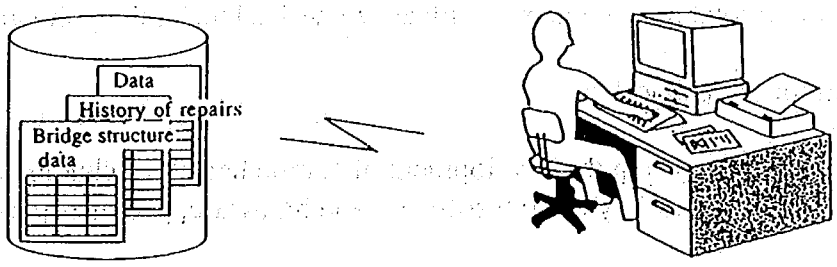
Aims and results : To provide a type of expert system which evaluates bridge inspection data and bridge conditions and supports technical decisions on repair needs and methods.

Five-year aims : Development and improvement of pilot system and practical application of actual system.



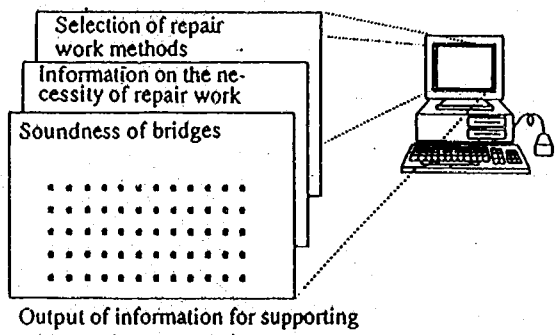
Accumulation of bridge inspection data

Bridge management system



Database

Bridge management system



Output of information for supporting bridge maintenance and management

Fig. 14 Flow of Work from Bridge Inspection to Repair using the Bridge Management System

b. Automatic paving system

Aims and results: To conserve power and require less skill during operation (measured time: number of days → number of minutes)

Five-year aims : To conduct trial operations and develop the technical standards

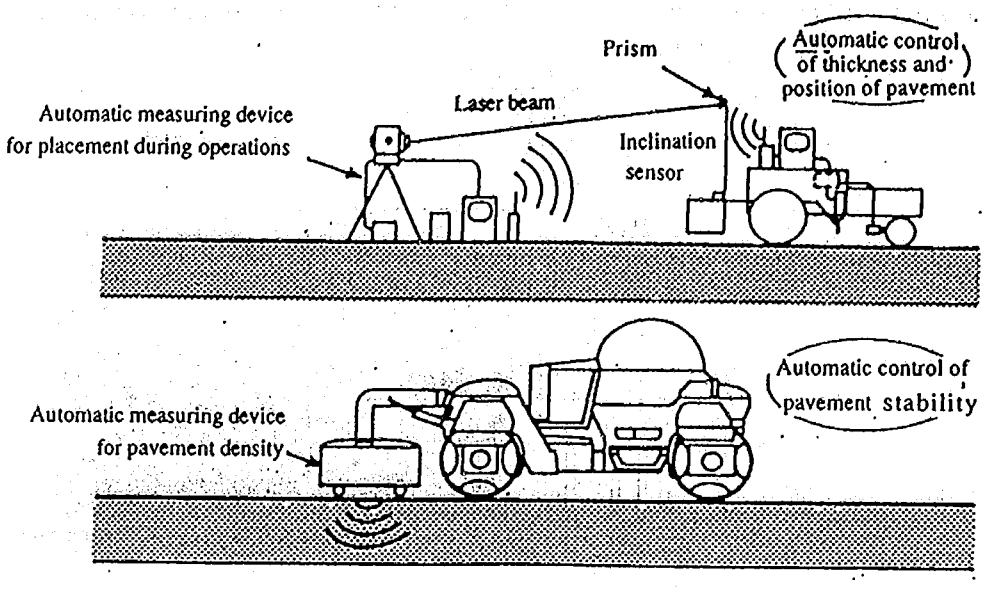


Fig. 15 Automatic paving system

⑦ Promotion of total management to utilize synthesized technology in various fields efficiently

a. Common for all technology

Further improvements in the development of comprehensive technology management which systematically links a variety of both software and hardware, and incorporates this technology into projects.

(9) Structure of Advanced Road Transportation Systems

VICS

This system provides real-time information on traffic accident conditions as well as information on the best alternative routes, availability of parking and events being held in the area.

Road safety system

AHSS

This system provides driver support, including vehicle operation, through the use of information communication devices installed in vehicles and along roads concerning road surface conditions and road alignment.

Vehicle operation control system

ATES

In order to achieve the safe, economical and efficient movement of freight vehicles and buses, this system analyze the traffic conditions and guides vehicles to the most appropriate routes.

(10) Examples of major technologies supporting road improvements thus far

○ An example of technologies which made previously impossible operations possible
- Technologies which made it possible to construct bridges, such as Akashikaikyo Ohashi, which join Honshu and Shikoku.

Earthquake-resistant and wind-resistant design technology
Material technology (High-strength cable materials: Tensile strength: 160kgf/mm→ 180kgf/mm)
Construction technology (control of vibrations in main tower, the construction of larger integrated components, deeper drilling of girders)
Machine technology (Large grab dredgers and unmanned submarines for surveying ocean floor)
→ Various technological developments have been combined to make bridges between Honshu and Shikoku possible.

○ An example of technologies which have greatly improved economic efficiency
- The electrical dust collector greatly improved the economic efficiency of long tunnels

-- Used for air ventilation --

A comparison of the overall expenditures for the Enasan Tunnel (length: 8.6km) during the second stage of construction shows that installation of electrical dust collectors decreased construction costs to approximately 80% of those for conventional methods , Operational costs for electric power for ventilation were reduced approximately 30%.

○ An example of technologies which have contributed to improved construction safety
- Excavating technology greatly improved safety in the construction of tunnels in mountainous regions.

As a result of the implementation of the new Austrian tunneling method of construction in which the surface of the tunnel is blasted with concrete immediately after excavation and lock bolts are set on the surface of the tunnel like quills, the number of accidents resulting from fallout during construction decreased. The number of tunnel construction deaths decreased by about 40% beginning in 1980 when this technology was implemented.

(11) Policy for promoting development and implementation of road technology

○ Promotion of research and development
- An increase in the research and development budget related to road technology and the development of organizational structure.
- Consideration to policies for assigning research and development to universities and other institutions.
- Improvement of the system for offering the experimental facilities of the Ministry of Construction's civil engineering research center to the private sector.

○ Promoting implementation and dissemination of technology
- By setting up a new technology registration system for roads and implementing projects to implement new technologies (leading projects in road technology), projects for applying developed technology are to be implemented and applied technologies disseminated rapidly.

○ Improvement of structures and information bases

- The New Technology for Roads Conference should be further improved and a follow-up study of development and implementation conditions based on this program should be promoted together with the discovery of new technology needs.
- A communications conference should be set up to provide close cooperation between information, communication, automobile and other sectors.
- A library of new information on road technology using JACIC networks and other services should be built.

Transport Canada
Policy and Coordination

Research and Development

Transports Canada
Politiques et coordination

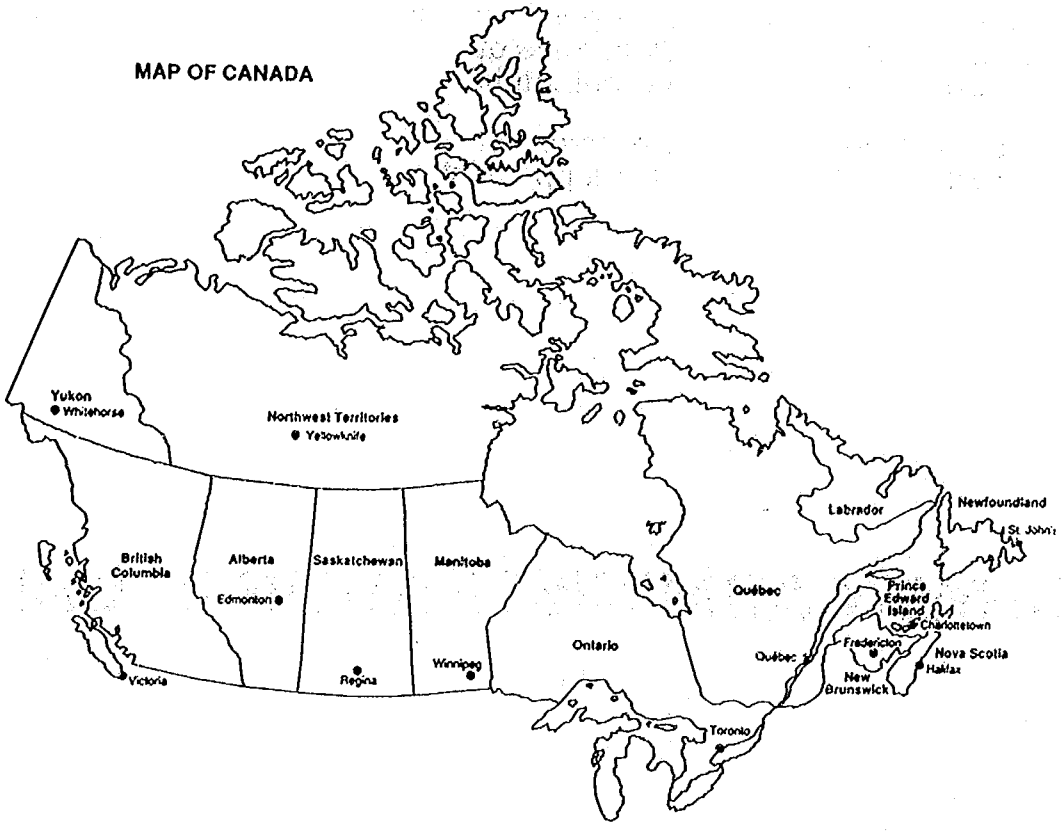
Recherche et développement

Canada

HIGHWAY ADMINISTRATION IN CANADA

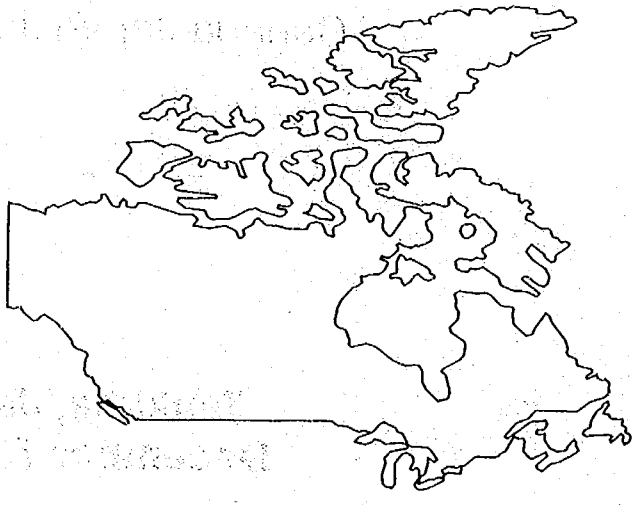
Presentation
to the
Canada-Japan Joint Panel

Tsukuba, Japan
December 7, 1993



(No.1)

CANADA



Geography

- Area — 10 million sq. km
  90% has no permanent settlement
- Distance — 5 500 km East to West

Government

- Federal State; 10 provinces; 2 territories

(No.2)

CANADIAN POPULATION





- Total 27 million
- Density 2.7 per km^2
- Habitation 60% in cities over 100 000
  70% along East-West corridor within 150 km of U.S. border
- Cities 3 over 1 million
  30 over 100 000

(No.3)

HIGHWAY USAGE

Licensed drivers

18 million

Licensed vehicles

	Number in Millions	%
• Automobiles	13	74
• Trucks	4	23
• Buses, motorcycles, others	0.5	3
	17.5	100

- New sales 1.2 million/yr

Average Distance Travelled

- Automobiles 21,000 km/yr
- Trucks 35,000 km/yr
- Tractor-trailers 80,000 km/yr

(No.4)

HIGHWAY JURISDICTION

- Mainly under provincial and municipal jurisdictions (Constitution Act of 1867)
- Federal Involvement
  - Direct responsibility for *federal highways* within its jurisdictions (national parks, Native reserves, national capital, Alaska Highway)
  - Selected funding support for elements of the *National Highway System*
  - Standards setting through a national body — *Transportation Association of Canada*

(No.5)

TRANSPORTATION ASSOCIATION OF CANADA

- Federally chartered, non-profit organization; $4.5 million annual budget
- 550 members including all levels of government, industry and academia
- Provides a forum for discussion of all transportation issues and a technical focus in the highways area
- Works through seven councils and their standing and project committees:
  - Infrastructure Council
  - R&D Council (IVHS Canada - a standing committee)
  - Multimodal Council
  - Urban Transportation Council
  - Member Services Council
  - Safety Coordinating Council
  - Environmental Advisory Council
- Provides secretariat to the Council of Ministers

(No.6)

EXECUTIVE BODY

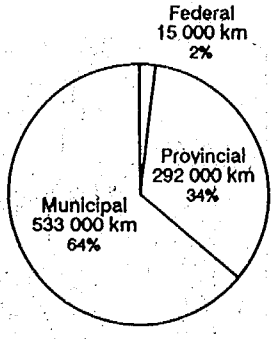
Council of Transport Ministers

- Policy and executive body dealing with federal/provincial highway matters
- Responsible for national highway policy and programs such as C-SHRP
- Incorporates:
  - Council of Transport Deputy Ministers
  - Canadian Council of Motor Transport Administrators

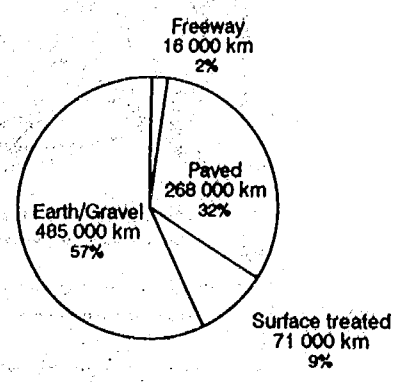
(No.7)

CANADIAN HIGHWAY SYSTEM

Jurisdiction



Type



(No.8)

Total length: 840,000 km (0.31 km/capita)

NATIONAL HIGHWAY SYSTEM

Total length

- 25 000 km (Federal 1 200 km)

Includes major:

- Interprovincial links (Trans-Canada Highway)
- International links (Windsor-Detroit, HWY 401)
- Intercity links (Calgary-Edmonton, HWY 2)
- Intermodal links (Halifax-Sydney ferry link)

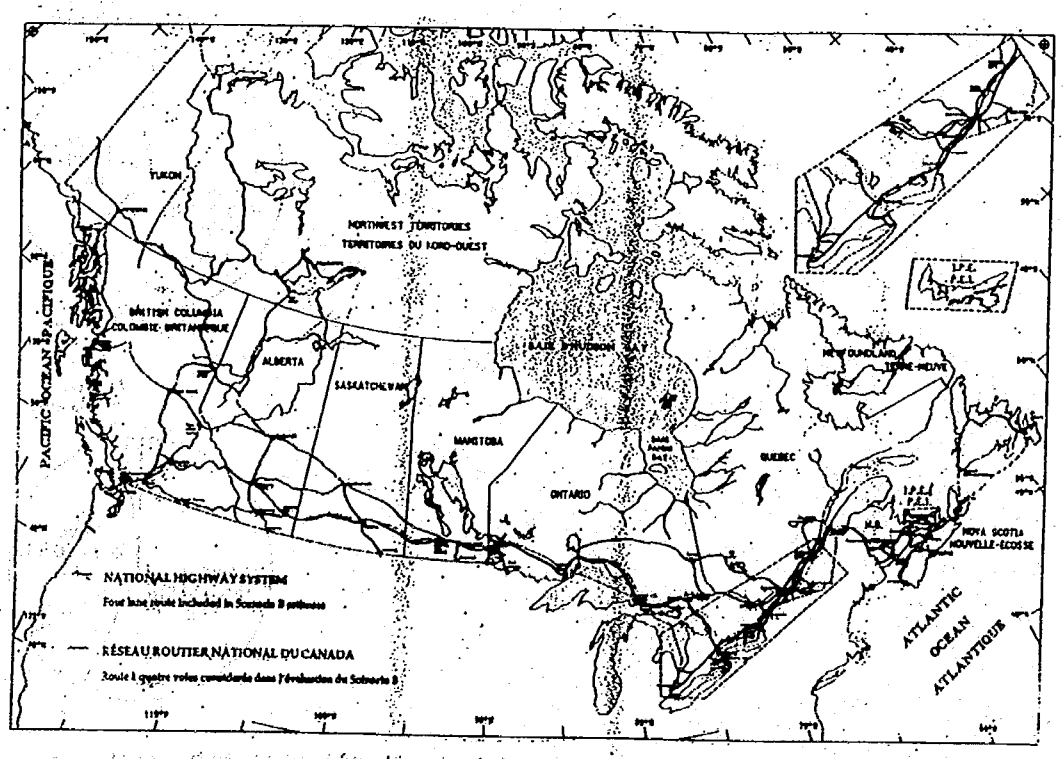
Condition

- Estimated cost of rehabilitation: $14 billion

(No.9)

HIGHWAY ADMINISTRATION IN CANADA *7 December 1993*

(No.10)



BRIDGE INVENTORY

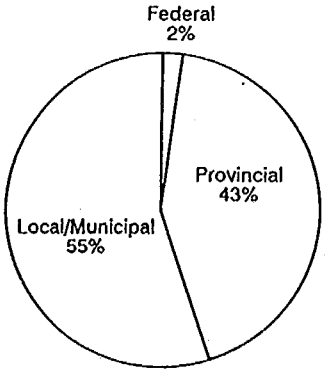
Federal	700
Provincial	25 900
Municipal	21 900
TOTAL	**48 500**

National Highway System	3 600*
International Bridges	23

* 22% require major rehabilitation

(No.11)

HIGHWAY FUNDING



Total investment: $200 billion

Average funding during last 5 years: $5 billion/year

(No.12)

HIGHWAY FUNDING

Federal Strategic Highway Program

- Commenced 1993-94
- $795 million over 5 years
- Provincial projects cost-shared 50:50
- Improvements to Atlantic Expressway ($200 M)
- Individual agreements with provinces

(No.13)

HIGHWAY ISSUES

Free trade implications

- Increased North-South traffic
- Increased long-distance trucking
- Harmonization of weights and dimensions

Rehabilitation

- Major on some stretches

Financing options

- Tolls
- Weight-distance user fees
- Dedicated fuel taxes

Technology

- Infrastructure
- IVHS
- Heavy vehicle weights & dimensions

(No.14)

NORTHUMBERLAND STRAIT BRIDGE

Total length

- 13 km (One of the world's longest)

Spans

- 44 main spans; each 250 metres long

Navigation channel

- 250 metres long; 55.6 metre clearance

Estimated cost

- $840 million (1992 dollars)

Completion date

- May 31, 1997

Funding arrangement

- Private company (SCDI) to build, own, operate for 35 years; then transfer to the Federal Government (BOOT)
- Federal Government to make annual payments to SCDI of $41.9 million (1992 dollars) for 35 years
- SCDI to collect tolls; first year same as cost of ferry crossing; increase in subsequent years limited to 75% of inflation

(No.15)

3. Presentation on Road Research

ROAD RESEARCHES IN JAPAN

Yutaka Anzaki
Research Coordinator for Road Traffic,
Public Works Research Institute,
Ministry of Construction, Japan

1. Introduction

The Public Works Research Institute (PWRI) of the Ministry of Construction and the Civil Engineering Research Institute (CERI) of the Hokkaido Development Bureau are the main governmental civil engineering institutes in Japan.

In Japan, the PWRI is the largest civil engineering institute, which conducts comprehensive researches on highway science and technology. As a research institute of the Hokkaido Development Bureau, which oversees overall development of Hokkaido, the CERI prosecutes studies to overcome various problems due to severe weather conditions in snow and cold areas. It is located in the most northern region of Japan.

Additionally, Regional Construction Bureaus of Ministry of Construction, local governments and road-related public corporations also conduct various surveys/researches on roads. In particular, the Nihon Doro Kodan Research Institute of the Japan Highway Public Corporation conducts various research related to the construction and management of expressways.

Apart from organizations which are related to the Ministry of Construction, various institutes also pursue studies on road traffic with their own distinctive features. For example, the National Research Institute of Police Science in the National Police Agency conducts researches from the view point of traffic regulation and safety. The Traffic Safety and Nuisance Research Institute in the Ministry of Transport conducts researches on traffic safety and pollution on the vehicle side.

A private organization, the Japan Automobile Research Institute, also pursues various experiments and studies mainly focusing on automobile mechanisms.

Table 1 through Table 5 show the outlines of research subject of these research institutes.

The following Section 2 describes subjects on road administration, which are premises for the conduction of research on roads, and the relation with the road-related survey structure of the Ministry of Construction, and the research themes in the PWRI. Section 3 describes the organization and the research subjects of the PWRI. Section 4 introduces some examples of new technological researches.

2. Subjects on Road Administration and Research Themes

It is important to improve and maintain highways for promoting the Fourth Comprehensive National Development Plan, which aims to activate each region and to form a multi-polar nation through promoting communication-network concept. Today, when road transportation has become the main transportation method in the surface transportation, peoples' expectations toward road improvement and maintenance are great and diverse.

Therefore, following subjects have become important in road administration.

Promotion of the national principal road network improvement;

Urban and rural road improvement for activating regional development;

Intensification of measures against traffic congestion and traffic safety;

Improvement of humane road environment;

Improvement of maintenance and management.

Figure 1 demonstrates the road-related survey scheme which is executed by the Ministry of Construction. Various investigations directly connected to a particular project's operation are mainly conducted at the work offices of the Regional Construction Bureaus, the project operation organizations.

The PWRI principally conducts research on subjects common nation wide, subjects of which are deeply engaged in road projects' operation.

As an organization researching common subjects within Regional Construction Bureaus, a technology work office exists in each Bureau. Each technology word office, in concert with the PWRI, is in charge of researches with regionally distinctive features and also a regional part of national research, which is promoted by the Institute.

The PWRI, answering to the aforementioned extensive administrative demands, conducts wide ranging research activities from fundamental subjects to subjects closely related to field problems, covering all fields of road improvement, such as planning, design, execution and maintenance.

Present research themes concerned with aforementioned subjects on road administration are arranged as follows:

(1) Promotion of the national principal road network improvement

Researches on Highway planning, such as estimation methods of holiday and sightseeing traffic demands and prediction of

future traffic volume, etc.

Researches on planning and designing for large-scale projects, such as wind resistant design for super-long-span highway bridges, access plan for express ways, ventilation methods for long tunnels, structural design and construction methods for large-scale tunnels, methods for foundations in deep water, seismic design for super multi-span continuous girder bridges, etc.

Researches on disaster prevention, such as evaluation methods for the degree of danger of debris flows on mountainous roads, evaluation methods for stability of slopes, evaluation of aseismicity of road facilities with consideration of ground flowage, and evaluation methods for aseismicity of slopes, etc.

Researches on traffic security during winter time, such as evaluation methods for anti-avalanche facilities and prediction methods for frozen and compacted snow on road surfaces, etc.

(2) Urban and rural road improvement for activating regional development

Researches on new transportation systems, such as planning and adaptability of new urban freight transport systems, which replace and supplement trucking transportation, etc.

Researches on design methods for urban road structures, such as ventilation methods for long urban tunnels, seismic design for urban tunnels on soft ground, wind resistant design for urban bridges, and noise characteristics in complicated design sections, etc.

Researches on regional plan, such as promoting regional development through improving road networks, etc.

Researches on mountainous roads, such as design for earth-retaining structure on mountainous roads and design for reinforced retaining walls on slope, etc.

(3) Intensification of measures against traffic congestion and for traffic safety

Researches on traffic planning, such as relation between parking vehicles and traffic capacity, estimation of traffic congestion and counter measures, etc.

Researches on measures for traffic safety, such as analysis of traffic accidents, investigation on development of safety facilities which correspond to high speed traffic, utilization of accident data bases, guiding methods at a complex intersection, and measures against right turn accidents, etc.

Researches on driving characteristics, such as simulation analysis of vehicle maneuver, relation between driving and sur-

face characteristics, characteristics of aged drivers, and decipherability and operatability of in-car display units, etc.

(4) Improvement of humane road environment

Researches on road planting technology, such as new technologies of road planting and planting methods of street trees, etc.

Researches on road traffic environment, such as measures against traffic noise, and estimation of traffic air pollution, etc.

(5) Improvement of maintenance and management

Researches on pavement, such as rehabilitation methods for asphalt and concrete pavement, technology for recycling pavement waste, and application methods for a pavement management system, etc.

Researches on maintenance and management of road tunnels, such as measures against tunnel deterioration and water leakage, lighting methods in high-standard road tunnels, operation methods of emergency facilities in case of fire, etc.

Researches on maintenance and management of bridges, such as upgrading of existing bridges to jointless ones, evaluation of design live load, and estimation of the critical fatigue conditions for steel bridges, etc.

Researches on maintenance and management of road structures, such as seismic retrofication measures for reinforced concrete piers, technology for protection of concrete structures, technology of repairing substructures, etc.

Other common and fundamental research subjects such as rational designing methods of pavement and bridges, seismic design of road facilities, etc., which are not directly connected with administrative needs, are also important issues.

Besides experimental investigations using the expenses for the road projects, researches using the general budget are also conducted by the PWRI. For example, several road-related technologies have been developed through the Comprehensive Research Project for Construction Technology (joint researches by governmental and private sectors). There are the Development of the Dual-Mode Bus System, the Development of the Dual-Mode Truck System, the Development of the New Ground Improvement Technology, and the Development of the Durability Improvement Technology of Concrete, etc.

3. Research organizations and subjects of the PWRI

Figure 2 illustrates the organization of the PWRI. Among these,

researches on roads are mainly conducted by the Environment Department, the Erosion Control Department, the Road Department , the Material and Construction Method Department, the Structure and Bridge Department and the Earthquake Disaster Prevention Department.

Table 6 shows an outline of research subjects of each division. The PWRI also plays an important role in establishing various technical standards. Table 7 indicates standards on road technologies and the laboratories in charge. The PWRI utilizes directly or indirectly the results of its studies for the establishment of these technical standards.

4. Some examples of new technology

(1) Advanced Road Traffic Systems

The increasing sophistication and expansion of social and economic activities has resulted in a need for improved road services, making it necessary to implement a policy aimed at creating a more advanced highway system to handle these needs.

To address this issue, the Ministry of Construction has embarked on a search for a plan to improve the geometric layout, paving, and lighting of roads while studying methods to improve traffic safety and reduce traffic congestion.

To achieve this objective, the PWRI is working on ways to measure and automate the handling of traffic, as well as enhancing information systems for measuring distances between vehicles and developing a new traffic management systems using these systems.

In developing these traffic management systems, we must respond to social changes such as the increase of aged drivers, the increased performance offered by automotive technology, and advances in the tucking industry, and to do so we must develop technologies which improve both safety and shipping efficiency.

(2) New Urban Freight Transportation System

Freight transport in Japan is shared by roads, railways, shippings, and airplanes, and the share by roads has increased year by year. In particular, most goods in urban area are transported by trucks. However, there are serious problems regarding the urban freight transport.

The problems are as follows;

(1) traffic congestion;
(2) environmental problems like noise and air pollution;
(3) shortage of truck drivers and increase of their average age.

The new urban freight transport system is studied for reducing a large number of truck traffic in urban roads and substantially

solving the traffic problems. This system is supposed to have densely located depots, automated vehicles which carry freight and loading/unloading machines. Thus, this system can provide a higher level of services to trucking companies.

(3) Study on Long Span Bridges

The PWRI is carrying out studies concerning the survey, design and construction of long span bridges which are being planned such as in the bay areas (Tokyo Bay, Ise Bay and Osaka Bay). Since these bridges are very large and natural and social conditions at the construction sites are severe, the PWRI is engaged in leading studies and developments in the up-to-date bridge engineering, such as the design and construction of undersea foundations, estimation of safety in high winds, design and construction superstructures, etc., based on the limit state design method. As for the design of wind resistant structures, the PWRI has been conducting wind tunnel tests, field observations and theoretical analysis.

(4) Hybrid Control of Seismic Response of Bridge Structures

Along with the improvement of an usual seismic design method for making structures secure against earthquakes, passive and active control technologies are now being developed for reducing seismic response of civil engineering structures. Hybrid control, which is a new approach combining the advantages of passive and active control, can control seismic response of structures with a small amount of external energy supply. Hybrid control is expected to achieve the high safety of the structures even during serious earthquakes. Development of new devices and control algorithm for hybrid control systems is now conducted as an U.S.-Japan cooperative research.

Table 1 CIVIL ENGINEERING RESEARCH INSTITUTE

SECTION NAME	RESEARCH SUBJECTS
Traffic Engineering Section	Measures for winter traffic safety Measures against traffic accidents Measures against traffic congestion Evaluation of road improvement
Disaster Prevention and Snow Engineering Section	Poor visibility by blowing snow Hazardous conditions on highways Highway disaster prevention installations Highway disaster prevention systems
Maintenance and Management Section	Maintenance system of pavement and bridges Inspection robots for road facilities Transverse cracks in cold regions RCCP(Roller Compacted Concrete Pavement)
Structures Section	Base-isolated bridges in cold regions Shock absorbing system of the rock-shed The buried joint in cold regions Aerodynamic stability of bridges
Geotechnical Section	Soft ground improvements Ground survey methods Earth pressure reduction Expert systems for construction method
Materials Section	Evaluation of existing concrete structures Frost damage resistance of concrete Repair and rehabilitation of concrete structures High performance concrete
Geology and Rock Mechanics Section	Slope failures Tunnel engineering geology Rock engineering geology

Table 2 RESEARCH INSTITUTE OF JAPAN HIGHWAY PUBLIC CORPORATION

SECTION NAME	RESEARCH SUBJECTS
Geo-Technique Section	Earth work materiales Compaction control of earth work Stability of soft ground
Pavement Section	Pavement structural design Maintenance and repair of pavement Pavement Managemant Systems
Bridge Section	Evaluation of bridges and concrete structures Aseismic design for bridges and concrete structures Bridge deta base systems
Tunnel Section	Design of NATM-based tunnels Maintenance and rehabilitation methods for tunnnels Tunnel entrance reinforcement
Maintenance Section	Skid resisitance of road surface Maintenance and rehabilitation for road facilities Recycling of construction waste
Disaster Prevention and Snow Protection Section	Prevention of slope failure Disaster prevention systems Utilization of wether data and countermeasures against snow and ice on the road
Traffic and Environment Section	Traffic technology Environmental assessment Measures for saving environment
Landscape Section	Slope protection with planting Soil improvement for plants Artificial plantation

Table 3 NATIONAL RESEARCH INSTITUTE OF POLICE SCIENCE (TRAFFIC DEPARTMENT)

SECTION NAME	RESEARCH SUBJECTS
Traffic Regulation Section	Conditions and methods of regulation Traffic characteristics and simulations Hardware and software for traffic control systems Pollution by road traffic
Traffic Safety Section	Psychological and physical conditions required for drivers Traffic safety education Test for driver's license Traffic accident analysis
Automotive Engineering Section	Human-Vehicle movement analisys Vehicle structures for safety

Table 4 TRAFFIC SAFETY AND NUISANCE RESEARCH INSTITUTE TRAFFIC SAFETY DIVISION(EXCEPT RAILWAYS) AND TRAFFIC NUISANCE DIVISION

SECTION NAME	RESEARCH SUBJECTS
Traffic Safety Division	
Transportation Systems Section	Transportation systems
Motor Vehicle Dynamics Section	Drivability for safety driving
Motor Vehicle Structure Section	Vehicle structure for safety
Automotive Equipment Section	Methods and apparatus for automobile inspection and maintenance
Accident Analysis Section	Accidents due to vehicle defects
Traffic Nuisance Division	
Engine Section	Pollution control through engine improvement
Measurement Section	Measurement methods and apparatus for automobile exhaust gas
Fuel Economy Section	Energy saving of automobile engines
Traffic Noise Pollution Section	Noise control for automobiles

Table 5 JAPAN AUTOMOBILE RESEARCH INSTITUTE

DIVISION NAME	RESEARCH SUBJECTS
Research Division 1	Automotive power plants Automotive fuels and alternative fuels Atmospheric and health effects of automotive exhaust emissions Chemistry including analysis of fuels, exhaust emissions
Research Division 2	Performance of automobiles and relating control systems Automotive ergononics and preventative safety Influence of automobiles on roads and traffic systems
Research Division 3	Structure of automobiles and collision safety Traffic accident investigation and analysis

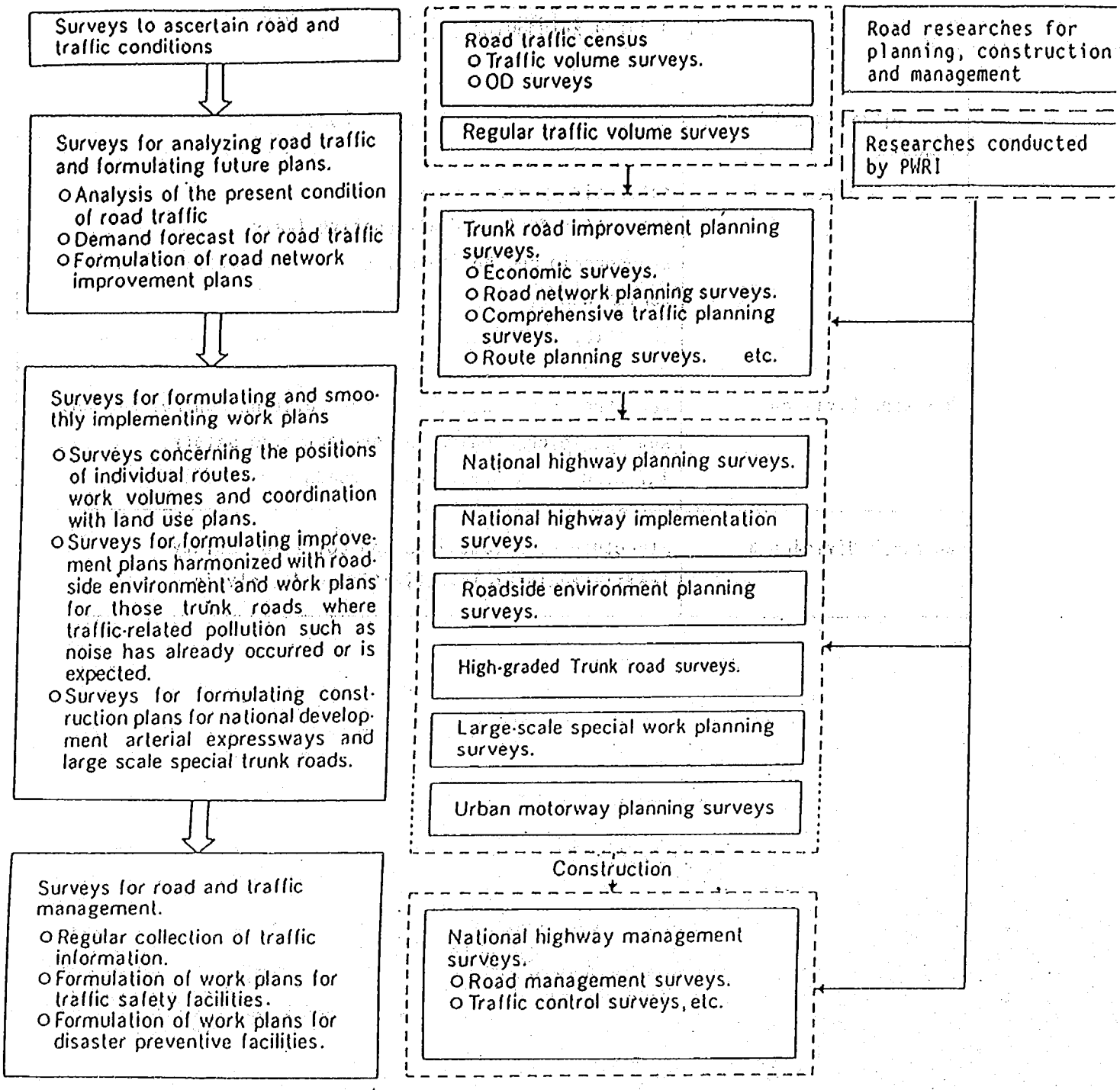


FIGURE 1 ROAD-RELATED SURVEY SCHEME IN MOC

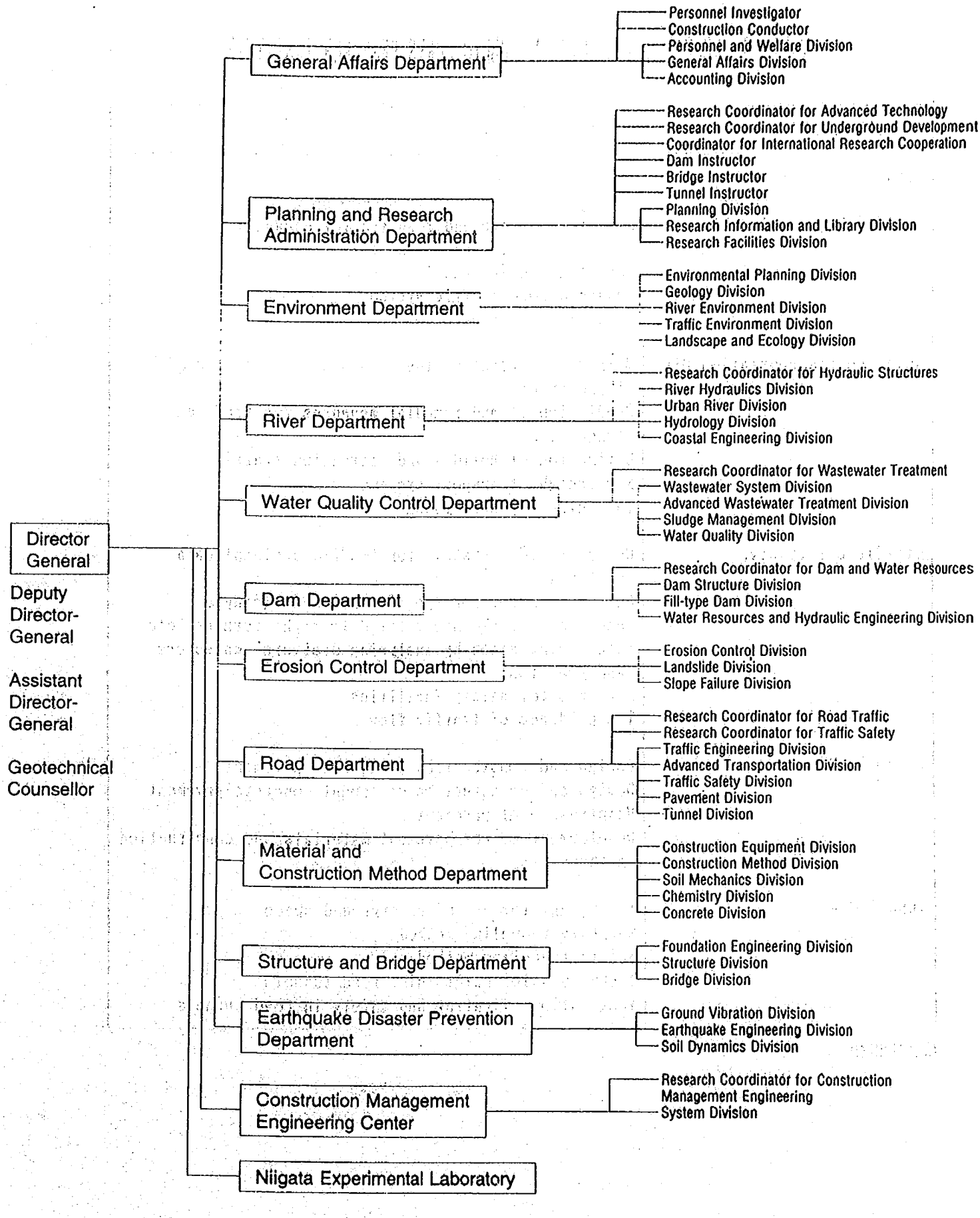


FIGURE 2 ORGANIZATION OF THE RWRI

Table 6 RESEARCH SUBJECTS IN PUBLIC WORKS RESEARCH INSTITUTE

DIVISION NAME	RESEARCH SUBJECTS
Road Department	
Traffic Engineering Div.	Geometric design and road traffci capacity Skid resistance and drivability Road traffic information system Advanced road traffic system Snow disaster prevention
Advanced Transportation Div.	Method of evaluating the economic effects of road improvements Prediction of and remedial measures for traffic congestion Estimation of holiday and recreation traffic New freight transport systems The Guide-way Bus system
Traffic Safety Div.	Computer-aided systems for traffic accident data analysis Safety measures for specific accidents(single accidents, accidents related to right turning, etc.) Safety evaluation by analysing dreivers' maneuvers and reaction Warrants for safety facilities The guidance of traffic flow
Pavement Div.	Design and construction of asphalt pavement Design and construction of cement concrete pavement Maintenance of pavement Development of new pavement materials and construction methods
Tunnel Div.	Technology for use of underground space Mountain tunneling method Shield tunneling method Techniques for maintaining road tunnels Ventilation, lighting and safety in road tunnels

CONTINUED

DIVISION NAME	RESEARCH SUBJECTS
Environment Department	
Environmental Planning Div.	Study on environment assessment technique Study on environmental information database Study on landscape simulation Study on impact of global climate change on infrastructure InterdisciplеYinary studies on environmental quality enhancement technifque
Geology Div.	Study on rationalization of slope stability evaluation methods Study on methods of evaluating Quaternary fault activity Development of field measurement techniques of rock properties for tunneling Research and development of efficient methods of submarine exploration in straits Development of new techniques for sub surface exploration
River Environment Div.	Research on water-front values Research on preservation of riverscapes Research on Naturally Diverse River Construction Methods Research methods of water purification
Traffic Environment Div.	Research on valuation of preserative measures of roadside environment Research on propagation of traffic noise Research on the natural environment around roads Research on the environmantal impacty of car exhaust Research on countermeasures to road noise, etc.
Landscape and Ecology Div.	Research on landscaping Research on ecosystem Research on park planning and open spaces Research on prediciton and improvement of landscapes
Structure and Bridge Department	
Foundation Engineering Div.	The limit state design method of bridge substructures Bearing capacity of shallow foundation Foundation in deep water Design methods for earth retaining structures for deep excavation The labor-saving construction bridge substructures

Continued

DIVISION NAME	RESEARCH SUBJECTS
Structure Div.	The aerodynamic stability of long span bridges The dynamic response of highway bridges due to moving vehicles Development of the Expert System concerning bridge type selection The reliability of the design strength of superstructures
Bridge Div.	Rationalization of bridge design Durability design of highway bridges Rationalized construction methods to cope with labor-saving Maintenance and improvement technology of existing bridges Application of advanced materials to highway bridges
Earthquake Disaster Prevention Department	
Ground Vibration Div.	Earthquake response characteristics of soft ground Earthquake resistance of civil engineering structures against soil liquefaction Earthquake response characteristics of slopes Design seismic loads for civil engineering structures Visual information systems on ground damage of during earthquake
Earthquake Engineering Div.	Seismic design methods for highway bridges including long-span bridges Seismic design methods for underground structures (shield tunnels, underground parking structures, submerged tunnels, common utility ducts) Base isolation, active structural control and hybrid control systems Prediction methods for assessing direct and indirect damage and the socioeconomic effect of earthquakes Information processing systems for earthquakes disaster mitigation
Soil Dynamics Div.	Mechanical property of soils subjected to dyanamic loading Design methods based on seismic behaviors and earthquake resistance of embankments, semi-buried and underground structures Reinforcement of earth structures and improvement of ground to withstand earthquakes Bejavior of falling rocks and design method for falling rock protection works In-situ ground investigation methods

DIVISION NAME	RESEARCH SUBJECTS
Material and Construction Method Department	
Construction Equipment Div.	Improvement method for construction with mechanics Pipe transportation technique for snow by air pressure
Construction Method Div.	Sophistication of construction controls of earthworks Designing and construction methods for earth retaining structures for the roads on mountainous terrain Stability of reinforced retaining walls constructed on inclined surfaces
Soil Mechanics Div.	Design method of reinforced earth with geotextiles Embankment constructed on soft ground Sethod for rational evaluation of slope stability
Chemistry Div.	Application of new materials to construction Permeable pavement materials and recycling of asphalt pavement
Concrete Div.	Advanced concreting technologies Comprehensive maintenance technologies of concrete structures
Erosion Control Department	
Erosion Control Div.	Preventing methods against debris flows in upper watersheds
Landslide Div.	Anti-slide retaining walls
Slope Failure Div.	Evaluation of slope stability under rainfall and earthquake conditions Investigation rockfall
Niigata Experimental Lab.	Landslide stability in Spring Design and construction of direct-protection structures for avalanche Strategical use of weather forecasting information Prediction of frozen and compacted snow on the road

Table 7 TECHNICAL STANDARDS AND DIVISIONS OF PWRI ON DUTY

TECHNICAL STANDARDS ,etc.	DIVISIONS OF PWRI ON DUTY
(1) IN GENERAL	
Road Structure Ordinance	Traffic Engineering Div.
Vehicle Restriction Ordinance	Traffic Engineering Div.
Traffic Capacity of Highway	Traffic Engineering Div.
Standard for Design of Bicycle Paths, etc.	Traffic Engineering Div.
Manual for Road Snow Disaster Prevention	Traffic Engineering Div. & Niigata Experimental Lob.
Manual for Road Maintenance and Rehabilitation	Pavement Div. & Tunnel Div.
(2) TRAFFIC SAFETY	
Technical Standard for Road Lighting	Traffic Safety Div. & Tunnel Div.
Guidelines for Guide Blocks for Visually Handicapped People	Traffic Safety Div.
Technical Standard for Traffic Signs	Traffic Safety Div.
(3) TRAFFIC ENVIRONMENT	
Technical Standard for Planting around Roads	Planting Div.
Manual for Assessing the Environment alongside the Roads	Traffic Environment Div.
Manual for Improving Landscape around Roads(Draft)	Planting Div.
(4) PAVEMENT	
Manual for Design and Construction of Asphalt Pavement	Pavement Div.
Manual for Design and Construction of Cement Concrete Pavement	Pavement Div.
Technical Guidelines for Roller Compacted Concrete Pavement(Draft)	Pavement Div.& Concrete Div.
Technical Guidelines for Recycling Pavement Waste (Draft)	Pavement Div.& Concrete Div.
Technical Guidelines for the In-Place Base Course Recycling Method(Draft)	Pavement Div.
Technical Guidelines for the In-Place Surface Recycling Method(Draft)	Pavement Div.
Manual for Pavement Testing Method	Pavement Div.
Technical Guidelines for Design and Construction of Slag Base	Pavement Div.
Technical Guidelines for Design and Construction of Asphalt Pavement Using Steel Slag	Pavement Div.
Technical Guidelines for Design and Construction of Steel Slag Base	Pavement Div.
Technical Guidelines for Design and Construction of Full Depth Pavement	Pavement Div.

Continued

TECHNICAL STANDARDS ,etc.	DIVISIONS OF PWRI ON DUTY
(5) SOIL STRUCTURES	
Manual for Highway Earthwork	Soil Mechanics Div.
Technical Guidelines for Highway Earthwork - Soil Investigation	Soil Mechanics Div.
Technical Guidelines for Highway Earthwork - Construction Method in General	Construction Method Div.
Technical Guidelines for Highway Earthwork-Retaining Walls, Culverts and Temporary Structures	Construction Method Div.
Technical Guidelines for Highway Earthwork - Soft Ground Improvement	Soil Mechanics Div.
Technical Guidelines for Highway Earthwork - Slope Protection	Soil Dynamics Div.
Technical Guidelines for Highway Earthwork - Drainage Works	Soil Dynamics Div.
Guidelines for Design of Common Ducts	Foundation Engineering Div.
(6) TUNNELS	
Technical Standard for Road Tunnel Structure	Tunnel Div.
Technical Standard for Road Tunnel Ventilation	Tunnel Div.
Technical Standard for Road Tunnel Emergency Facilities	Tunnel Div.
Technical Standard for Road Lighting (Tunnel)	Tunnel Div.
(7) HIGHWAY BRIDGES	
Specifications for Highway Bridges	
Part I Common Specifications	Bridge Div.
Part II Steel Bridges	Bridge Div.
Part III Concrete Bridges	Bridge Div.
Part VI Substructures	Foundation engineering Div.
Part V Earthquake Resistant Design	Earthquake Engineering Div.
Guidelines for Preventing Deterioration due to Chloride Ions for Highway Bridges (Draft)	Bridge Div. Chemistry Div.&Concrete Div.
Guidelines for Design of Steel Pipe Sheet Pile Foundations	Foundation Engineering Div.
Guidelines for Design and Construction of Continuous Diaphram Wall Foundations	Foundation Engineering Div.
Manual for Design of Steel Bridges	Bridge Div.
Manual for Construction of Steel Bridges	Bridge Div.
Manual for Painting of Steel Bridges	Bridge Div.
Manual for Design of Concrete Bridges	Bridge Div. & Concrete Div.
Manual for Construction of Concrete Bridges	Bridge Div. & Concrete Div.
Manual for Design of Pile Foundations	Foundation Engineering Div.
Manual for Wind Resistant Design of Highway Bridges	Structure Div.
Manual for Bearings of Highway Bridges	Bridge Div.
Manual and Standards for High Strength Bolts	Bridge Div.
Manual for Retrofit and Post Earthquake Methods of Road Facilities (Pre-Earthquake Countermeasures) (Post-Earthquake Countermeasures)	Earthquake Engineering Div. Ground Vibration Div. Earthquake Engineering Div.

Transport Canada
Policy and Coordination

Research and Development

Transports Canada
Politiques et coordination

Recherche et développement

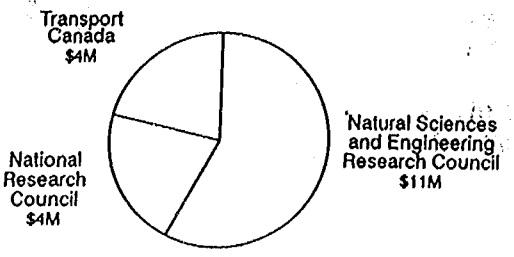
Canada

HIGHWAY RESEARCH IN CANADA

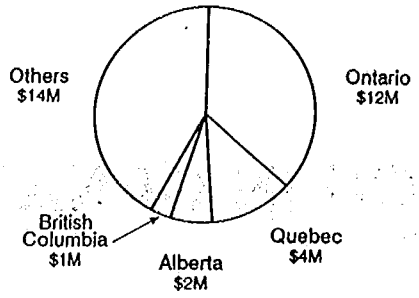
Presentation
to the
Canada-Japan Joint Panel

Tsukuba, Japan
December 8, 1993

FUNDING BY SOURCE



Federal Funding Sources
$19 million

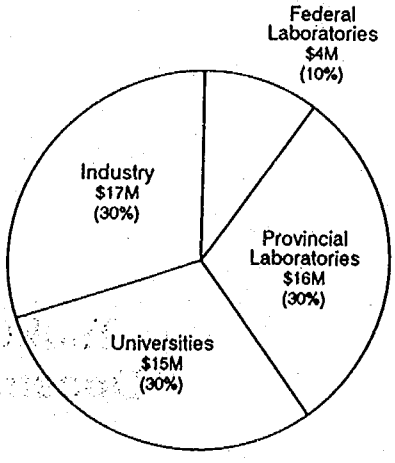


Provincial Funding Sources
$33 million

Total funding (1991): $52 million

(No.1)

EXPENDITURE BY PERFORMER



Total funding (1991): $52 million

(No.2)

RESEARCH LABORATORY FACILITIES (150)

Provincial

Ontario
- Pavements and Roadway Research
- Materials Research
- Structures Research
- Energy/Emissions Laboratory
- Vehicle Safety/Dynamics Test Centre

Quebec
- Central Laboratory

Alberta
- Transportation Laboratory

British Columbia
- Geotechnical/Materials Laboratory

(No.3)

RESEARCH LABORATORY FACILITIES (150)

Federal

National Research Council
- Centre for Surface Transportation Research
- Institute for Research in Construction
- Applied Aerodynamics Laboratory

University-Based

- 13; at all major Universities

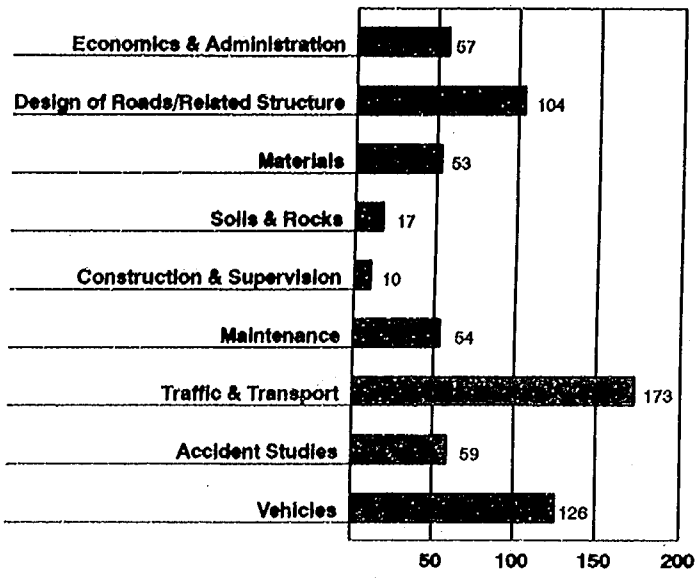
Private Industry

- Over 80 Facilities

(No.4)

HIGHWAY RESEARCH BY TOPICS

International Road Federation Research Topics



Total of number of Canadian projects: 653

(No.5)

HIGHWAY RESEARCH BY WORKSHOP TOPICS

PICA

- Provinces, universities, NRC, industry
- Relatively mature field

IVHS

- New and growing field
- Ontario, Quebec; possible federal initiative
- Need for industry involvement

WIND/SEISMIC

- NRC, universities

Road environment

- Provinces; scope for expansion

Advanced composite materials

- Provinces, universities
- Network of centres of excellence for high-performance concrete

(No.6)

SELECTED MAJOR RESEARCH PROGRAMS

Canadian Heavy Vehicles Weights and Dimensions

- Agreement on weights and dimensions
- Implementation of regulations
- Information dissemination
- Ongoing research

Canadian Strategic Highway Research Program (C-SHRP)

- Cooperation with U.S. SHRP
- Information dissemination from SHRP
- Specific Canadian research

Intelligent Vehicle-Highway Systems (IVHS)

- Development, demonstration and standardization
- Information dissemination
- International liaison

(No.7)

NATIONAL RESEARCH AGENDA:1992-94

Safety

- New methods, technologies, regulations; behavioral changes

Mobility

- Reduced congestion through new technologies, innovative traffic management; control of trucking in urban areas

Infrastructure

- Rehabilitation, maintenance strategies; efficient construction

Economic efficiency and performance

- Opportunities in emerging technologies: IVHS, GIS, expert systems

Government regulatory role

- Continued standardization and harmonization

Environmental issues

- Minimize detrimental environmental impacts

Energy efficiency

- Maximize energy efficiency

(No.8)

INTERNATIONAL COOPERATION

Multilateral

- OECD Road Transport Research Program
- International Road Federation
- U.S. Transportation Research Board
- IVHS America

Bilateral

- U.S. Department of Transportation
  (MOU; Addendum on Highway Research)
- Japan Ministry of Construction
  (Public Works Research Institute)

Upcoming conferences in Canada

- IRF Regional Conferences: Calgary, Sept. 94
- PIARC World Meeting: Montreal, Sept. 95
- IRF World Congress: Toronto, Sept. 97

(No.9)

HIGHWAY RESEARCH PRIORITIES: 1995-97

Infrastructure

- Innovative financing methods
- Performance of prestressed concrete highway bridges
- Economics of infrastructure maintenance
- Extending service life of pavements and structures
- Seismic bridge evaluation analysis
- Roadway slope and embankment seismic response analysis
- Alkali-silica reactive aggregate analysis
- Feasibility of overcoating v/s re-coating for bridge maintenance
- Ground penetrating radar to provide subsurface information
- Pavement fatigue analysis

(No.10)

HIGHWAY RESEARCH PRIORITIES: 1995-97

Roads and the Environment

- Erodible soil stabilization
- Biodegradable waste disposal systems for highways rest areas

Traffic and Transport Systems

- Muliti-modal benefit/cost analysis
- IVHS applications: AVI, CVO, ATMS, ATIS, APTS
- Dynamic traffic pattern recognition for corridor and network signal optimization
- Expert systems for avalanche forecasting
- Congestion cost-benefit impact analysis

(No.11)

HIGHWAY RESEARCH PRIORITIES: 1995-97

Road Safety Strategies

- Assessment of economic models of traffic demand and exposure to risk
- Ergonomic issues associated with IVHS technology proposals
- Cost effectiveness of human factors measures v/s road engineering for safety
- Incident management strategy for two-lane roadways and major arterials

Research Policy

- Technology transfer and information dissemination

(No.12)

HIGHWAY RESEARCH PRIORITIES IN JAPAN: 1995-97

Infrastructure

Recycling system in road improvment:

- Construction methods to control by-products
- Advanced methods for testing by-products
- Economic evaluation systen
- Institution of recycling system

Traffic and Transportation Systems

Advanced road transport technologies:

- Traffic Control Systems
- Information Providing Systems
- Vehicle Control Systems
- Freight Transportation Management Systems
- Public Transportation Priority Systems
- Advanced Road Systems
- Advanced Vehicle Systems

Traffic demand management

Advanced logistics and road transport policy

Road Safety Strategies

Safety of vulnerable road users

(No.13)

4. Paving in Cold Area (PICA)

General Situation of Pavement in Japan

Speaker: Toshiyuki Nakamura,
Head of Pavement Division,
Public Works Research Institute,
the Ministry of Construction, Jaspan

Contents

1. Introduction
1-1 A Brief Description of Japan
1-2 History of Road Development
2. Present Status of Road and Road Transport
2-1 Various Types of Roads in Japan
2-2 Present Conditions of Road Transport
3. Engineering standards and Specifications
3-1 Standars for Geometric Design of Highways
3-2 Standards for Highway Pavement

1. Introduction

1-1. A Brief Description of Japan

(1) Land

Japan is an island country stretching along the north-eastern coast of Asia. It is made up of four main islands — Hokkaido, Honshu, Shikoku and Kyushu from north to south — and more than 3,900 smaller islands. The largest island is Honshu, which has Japan's major cities including Tokyo, the nation's capital, Nagoya, and Osaka. With the total land area of 377,815 square kilometers, Japan accounts for less than 0.3% of world's total land area. Of the total area, forest lands occupy 65.1% ; cultivated lands 14.3% ; grass-lands 1.6% ; and densely inhabited districts 2.7%.

Japan is characterized by complex geographical features, with basins and mountains of various heights and shapes. About 71% of the land area is mountainous, mostly forested.

Japan has numerous hot springs and volcanoes as well as rivers and lakes, which enhance the scenic beauty of the country.

(2) Climate

Japan is located at the northeastern end of the monsoon area which also includes Korea, China, Southeast Asia, and India. Japan's climate varies from north to south, mainly due to the continental air current from the northwest and oceanic air current from the southeast. The seasons are clearly divided into spring, summer, autumn, and winter. In Tokyo, the seasons have the following characteristic features : temperature and humidity are high in summer, moderate in spring and autumn, and low in winter. According to records of the thirty years from 1961 to 1990, the annual average temperature in Tokyo was 15.6°C, with a low of 5.2°C in January and a high of 27.1°C in August. The annual average precipitation in Tokyo was 1,405 mm.

(3) Population

The current population of Japan is approximately 124 million, and this means that Japan ranks seventh in the world in terms of population, after China, India, the USSR, the United States, Indonesia, and Brazil.

The future population of Japan is projected to increase moderately, to total 129 million by the year 2010, after which it will gradually decrease.

The population density of Japan in 1989 was 331 persons per square kilometer, making it among the most densely populated nations in the world, along with Belgium, the Netherlands, and the Republic of Korea.

As a result of the vast increases in urban population especially in the 1960's, about 43% of the total population in 1988 was concentrated in three major metropolitan areas of Tokyo, Osaka and Nagoya, which correspond to only 10% of the total land area. In these metropolitan areas, the rate of increase in population of the suburbs is far higher than that of the central parts. In some rural areas, there arose a problem of sparse population caused by young people's outward migration, correlating with the population concentration into cities.

1-2. History of Road Development

As we can find the word "road" in records of about 2,000 years ago, it may be said that the history of roads in Japan is pretty old.

During the Tokugawa Era (1603—1868 A.D.), the so-called "Five-Roads", namely, Tokaido, Nakasendo, Nikko-kaido, Koshu-kaido and Oshu-kaido radiated from Edo (old name of Tokyo), the center of Japan, and, gradually, towns grew up along these old roads. But the Tokugawa Government permitted few bridges to be built across the rivers surrounding Edo, from the standpoint of defense.

In the Tokugawa Era horses were used for transport, but carriages had not yet been developed. It was in the Meiji Era (1868—1912 A.D.) that the carriage became a normal traffic mode. Since the Meiji Era, railway networks have been rapidly constructed all over Japan, but the construction of highways was neglected in the early stages.

Since the first road network plan was made in this country in 1920, several long-term road improvement programs were made until the outbreak of World War Ⅱ. These plans, however, were not completely executed because of the occurrence of the Kanto Earthquake in 1923 and the rushing into the wartime economic system.

In November of 1948, immediately after World War Ⅱ, the five-year plan for maintaining and repairing roads and streets, with a sum of 217,200 million yen, was made by the Supreme Commander of the Allied Powers, General MacArthur, and executed by 1951. This plan was not completely executed in consideration of the whole national finance, but it had a very important meaning because it functioned as a significant step toward the subsequent leap in road construction projects.

Substantial development of post-World War Ⅱ road policies actually began after 1952 in this country. This was

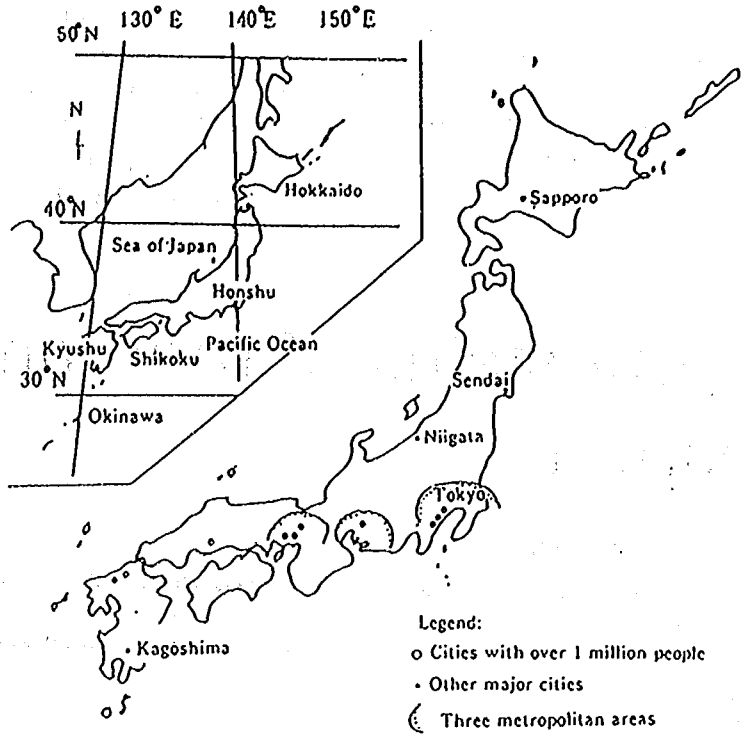


Fig.-1.1 Topography of Japan

Table 1-1 Progress of the Five-Year Road Improvement Programs

(Unit: 100 mil yen, %)

Items	Construction works		Footroad works		Locally funded road works		Total
	Investment	Composition	Investment	Composition	Investment	Composition	
1st program (A)	3,600	100.	–	–	–	–	3,600
1954–1957 Fiscal year (a)	1,021	59.0	146	4.7	1,119	36.3	3,086
a/A (%)	28.0	–	–	–	–	–	–
2nd program (B)	6,100	61.0	2,000	20.0	1,900	19.0	10,000
1958–1960 Fiscal year (b)	3,222	61.3	510	9.7	1,521	29.0	5,252
b/B (%)	52.8	–	25.5	–	80.1	–	52.5
3rd program (C)	13,000	61.9	4,500	21.4	3,500	16.7	21,000
1961–1963 Fiscal year (c)	7,222	57.9	2,256	18.0	3,045	24.3	12,522
c/C (%)	55.6	–	50.1	–	87.0	–	59.6
4th program (D)	22,000	53.7	11,000	26.8	8,000	19.5	41,000
1964–1966 Fiscal year (d)	12,441	56.8	4,432	20.2	5,023	23.0	21,896
d/D (%)	56.6	–	40.3	–	62.8	–	53.4
5th program (E)	35,500	53.8	10,000	23.3	11,000	16.9	11 66,000
1967–1969 Fiscal year (e)	17,956	51.9	2,535	21.0	9,127	26.4	34,618
e/E (%)	50.6	–	41.9	–	83.0	–	52.5
6th program (F)	52,000	50.3	25,000	24.4	25,500	24.9	21 102,500
1970–1972 Fiscal year (f)	31,000	50.0	13,179	21.2	17,063	28.8	62,235
f/F (%)	59.8	–	52.7	–	70.1	–	60.1
7th program (G)	93,400	49.2	49,600	26.1	47,000	24.7	31 190,000
1973–1977 Fiscal year (g)	77,578	47.3	33,608	24.1	46,939	28.6	164,125
g/G (%)	83.1	–	33.8	–	99.9	–	84.2
8th program (H)	135,000	48.0	60,000	24.5	75,000	27.0	41 205,000
1978–1982 Fiscal year (h)	129,430	45.0	66,145	23.0	92,353	32.0	287,930
h/H (%)	95.8	–	97.9	–	123.1	–	101.0
9th program (I)	180,000	41.0	92,000	24.1	117,000	30.6	51 382,000
1983–1987 Fiscal year (i)	159,764	43.1	87,403	26.4	112,527	30.5	369,194
i/I (%)	99.5	–	105.5	–	96.2	–	96.6
10th program (J)	230,000	44.9	140,000	26.4	139,000	26.2	61 530,000
1988–1992 Fiscal year (j)	226,355	41.7	142,350	26.3	173,703	32.0	542,458
j/J (%)	85.1	–	101.7	–	125.0	–	102.4
11th program (K)	248,000	37.8	206,000	27.1	252,000	33.2	71 760,000
1993(K) K/(%)	40,020	33.8	36,332	28.4	43,400	34.0	127,360
	16.1	–	17.6	–	17.2	–	16.8

Note 1) Including 150 billion yen of contingency
2) Including 100 billion yen of contingency
3) Including 500 billion yen of contingency
4) Including 700 billion yen of contingency
5) Including adjustment expenses of 1,300 billion yen
6) Including adjustment expenses of 1,300 billion yen
7) Including adjustment expenses of 1,400 billion yen
8) A portion implemented in 6th Program includes provisional costs of 11.2 billion yen (Okinawa).
9) Investment of general and toll roads is on an initial and supplementary basis for fiscal 1992, and on an actual basis for fiscal 1993.
10) Investment of locally funded works is as estimated for fiscal 1991~1993.

the year when revolutionary changes in road laws were made, which were very significant in the history of roads in Japan since these changes included a complete revision of the road laws, new founding of toll road system, five-year road improvement programs, and utilization of gasoline tax as a source of road funds.

In 1954, the 1st Five-Year Road Improvement Program was proved to be effective because it brought a considerable increase of road funds. Thus, the real development of roads in this country was started.

Trends of the five-year road improvement programs are shown in Table 1-1.

2. Present status of road and road transport

2-1. Various Types of Roads in Japan

Roads in Japan are classified into four categories in accordance with the Road Law.

a. National expressway
b. National highway
c. Prefectural road
d. Municipal road

This classification is done by administrative body of roads. To be more practical, roads are classified by their functions. The classification is as shown in Fig. 2-1.

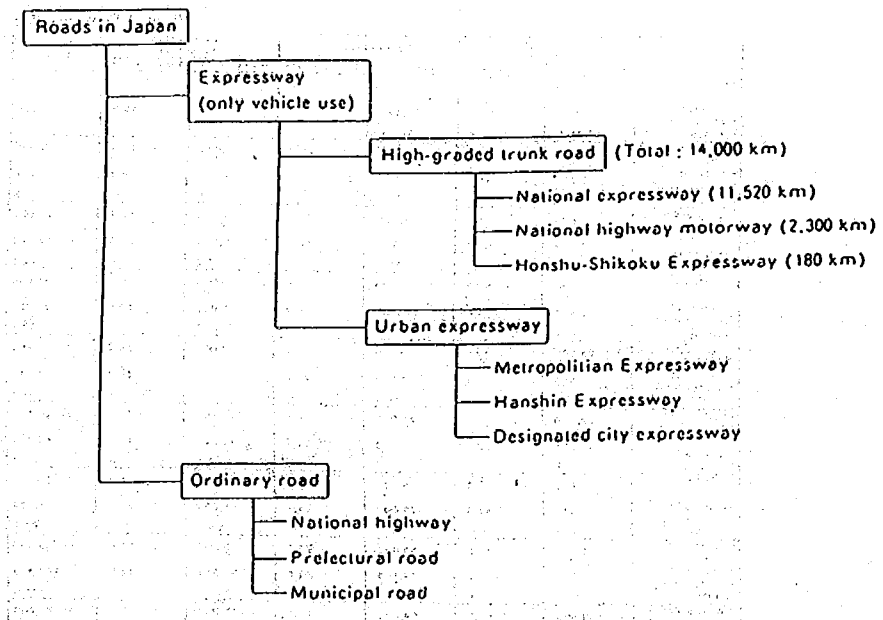


Fig. 2-1 The Classification of Roads

2-2. Present Condition of Road Transport

(1) Shares of traffic modes for domestic freight transport

The traffic for domestic cargo and passenger transportion in Japan have greatly changed with the rapid progress of motorization. With the economic growth and road improvement in the background, the role of the automotive transport has strikingly increased. For determining the shares of the traffic modes, it is important to realize a system in which the characteristics of the respective traffic modes are effectively utilized through adequate competition and free choice of the users, and the foregoing change in the shares of traffic modes indicates that the automotive transport adapts itself flexibly to the needs of the people and offers the transport services suitable in quality and cost for the characteristics of the commodities to be transported.

For freight transport, the share of the automotive transport has increased from 68% to 91% in tonnage or 12% to 51% in ton-kilometerage for 34 years during the period from 1955 to 1989 (Table 2-1.)

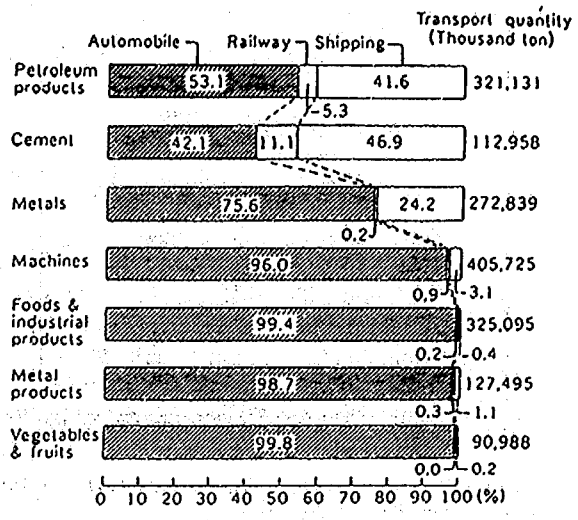
Table 2-1 Trend of Freight Transport

(Unit : One million ton-kilometers)

Year	Gross Total		Automobile	
		Growth Rate to Previous Year(%)		Share (%)
1955	81,787	5.2	9,510	11.6
1960	138,901	16.0	20,801	15.0
1965	186,346	1.1	48,392	26.0
1970	350,656	11.3	135,916	38.8
1975	360,779	-4.0	129,701	36.0
1980	439,065	-0.7	178,901	40.7
1985	434,375	-0.1	205,941	47.4
1986	435,230	0.2	216,115	49.7
1987	448,918	-	226,425	50.4
1988	482,877	7.6	246,088	51.0
1989	513,439	6.3	262,857	51.2

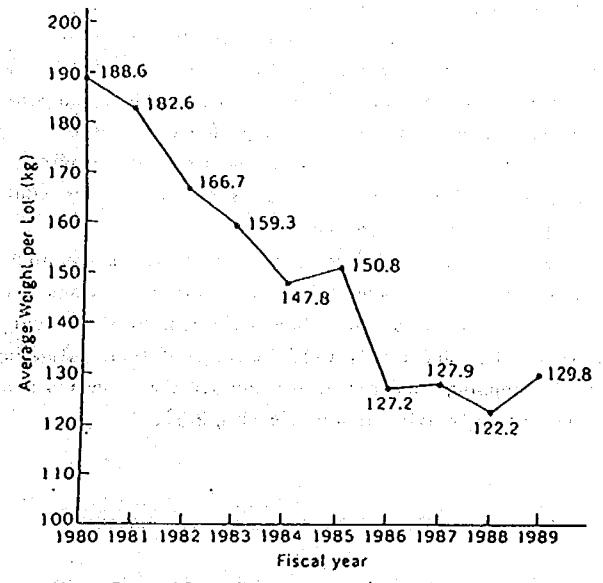
Note : 1. Source : "Land Transport Statistics Manual".
2. Light motor vehicles not included until fiscal 1986.

In the qualitative aspect, transportation of highly valuable products and materials such as machines, metal products and fresh foods are increasing, also small-lot, high frequency and "just-in-time" transportation demands are increasing, furthering the specialization and mutual dependency of the industries (Fig. 2-2 and 2-3). Also, dispersal of the industries to local regions through, for example, construction of technopolis has intensified the interdependent relationship of the regional areas and induced longer distance movement of the commodities (Fig. 2-3).



Note : Source : "Land Transport Statistics Manual" (Ministry of Transport)

Fig. 2-2 Share of Transportation of Products

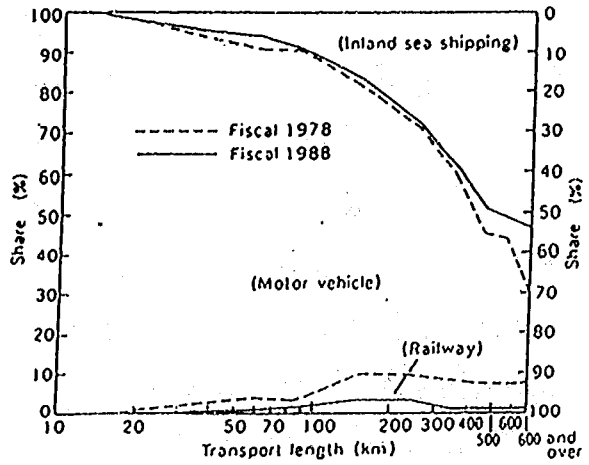


Note : Source "Route Truck Survay" (Ministry of Transport)

Fig. 2-3 Trend of Share of The Automotive Transportation

(2) Shares of traffic modes for domestic passenger transport

For passenger transport, the share of the automotive transport increased from 30% to 72% in the number of pas-



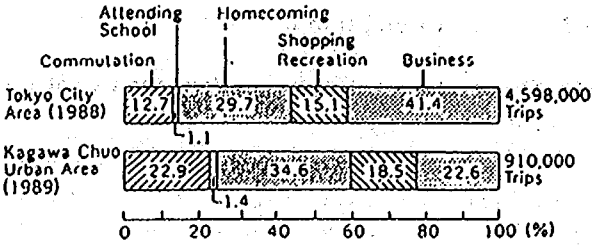
Note : Source "Land Transport Statistics Manual (1979 and 1989 Editions)" (Ministry of Transport)

Fig. 2-4 Share of Freight Transportation

sengers or 17% to 67% in the man-kilometers during the same 34-year period (Table 2-2).

Elevation of the income level called for higher level of education, medical services, culture, shopping, etc., resulting in an increase of mobility. Thus, intercity and other wide area movements are increasing. Moreover, sports and leisure activities which accompanies stays at resorts are increasing, and this situation relies on automobiles which are highly flexible and convenient.

Now, looking at different uses ; automobiles are highly used for business in large cities and serve as a means supporting the foundation of urban activities, while in rural districts, they are highly used for commutation, attending school, shopping, and recreation and serve as a means supporting the daily living as a whole (Fig.2-5).



Source 1. Homecoming refers to trips coming back to home from the places of work, schools and places of shopping and business.

Source 2. "Tokyo Urban Area Person-Trip Survey (1988)" and "Kagawa Chuo Urban Area Person-Trip Survey (1989)".

Fig. 2-5 Share of Automobile Users' Purposes

The automobile traffic has functions which can not be substituted by any other traffic means, such as mobility, availability at any time and door-to-door transport. Also, it assumes the terminal transport of all other traffic means to maintain the continuity of traffic and thus serves as a basic traffic means indispensable for the people.

Table 2-3 shows the number of motor vehicles in use at the end of March each year.

The number of motor vehicles in use with not less than three wheels, at the end of March 1991, was 57,668,683. It means the ratio of persons to vehicles is approximately 2.1 to 1.0.

The number of motor vehicles in use was increasing at a rate of approximately 20% each year until 1970, but the increasing rate has recently decreased and in 1991 it was 4.5%.

Table 2-2 Trend of Passenger Transport

(Unit : One million man-kilometers)

Mode / Year	Automobile								Railway		Passenger boat		Airline		Total		
	Passenger car	Share (%)	Bus	Share (%)	Privately owned truck	Share (%)	Total	Share (%)									
1950	730	0.6	8,300	7.0	–	–	9,030	7.7	105,468	90.0	2,628	2.2	–	–	117,126	100.0	12.2
'55	4,180	2.5	23,320	14.1	–	–	27,500	16.6	136,112	82.1	1,996	1.2	218	0.1	165,826	100.0	6.4
'60	11,532	4.7	43,999	18.1	–	–	55,531	22.8	184,340	75.8	2,670	1.1	734	0.3	243,275	100.0	9.9
'65	40,622	10.6	80,133	21.0	–	–	120,759	31.6	255,384	66.8	3,402	0.9	2,939	0.8	382,481	100.0	7.6
'70	181,335	30.9	102,894	17.5	–	–	284,229	48.4	288,816	49.2	4,814	0.8	9,319	1.6	587,178	100.0	11.0
'75	250,804	35.3	110,063	15.5	–	–	360,868	50.8	323,800	45.6	6,895	1.0	19,148	2.7	710,711	100.0	2.5
'76	264,499	37.3	98,714	13.9	–	–	363,213	51.2	319,566	45.1	6,651	0.9	20,119	2.8	709,549	100.0	0.2
'77	263,961	37.1	104,639	14.7	–	–	368,600	51.9	312,297	43.9	6,500	0.9	23,636	3.3	711,033	100.0	0.2
'78	296,043	39.6	107,009	14.3	–	–	403,063	53.9	311,129	41.6	6,384	0.9	26,923	3.6	747,489	100.0	5.1
'79	319,869	41.1	108,317	13.9	–	–	428,187	55.1	312,460	40.2	6,443	0.8	30,246	3.9	777,336	100.0	4.0
'80	321,272	41.1	110,396	14.1	–	–	431,669	55.2	314,542	40.2	6,132	0.8	29,688	3.8	782,031	100.0	0.6
'81	328,251	41.5	108,828	13.8	–	–	437,079	55.3	316,204	40.0	6,132	0.8	31,032	3.9	790,338	100.0	1.1
'82	347,219	43.2	104,836	13.0	–	–	452,055	56.2	316,375	39.3	5,859	0.7	30,106	3.8	804,395	100.0	1.8
'83	360,747	43.9	103,415	12.6	–	–	464,162	56.5	321,452	39.1	5,722	0.7	30,627	3.7	821,963	100.0	2.2
'84	365,631	43.9	103,064	12.4	–	–	468,695	56.3	324,334	39.0	5,780	0.7	33,498	4.0	832,110	100.0	1.2
'85	384,362	44.8	104,898	12.2	–	–	489,260	57.0	330,083	38.5	5,733	0.7	33,118	3.9	858,194	100.0	3.1
'86	398,216	45.5	101,629	11.6	–	–	499,843	57.1	334,745	38.2	5,684	0.7	35,324	4.0	875,596	100.0	2.0
'87	456,030	41.1	102,895	9.3	159,553	14.4	718,478	64.9	344,728	31.1	5,850	0.5	38,535	3.5	1,107,591	100.0	–
'88	500,945	42.1	107,221	9.0	173,680	14.6	782,033	65.7	361,796	30.4	5,672	0.5	41,102	3.5	1,190,603	100.0	7.5
'89	556,031	43.9	109,130	8.6	179,962	14.2	845,123	66.7	368,817	29.1	5,955	0.5	47,141	3.7	1,267,036	100.0	6.4
'90	575,507	44.3	110,372	8.5	167,182	12.9	853,060	65.7	387,478	29.8	6,275	0.5	51,624	4.0	1,298,437	100.0	2.5
'91	595,481	44.7	108,212	8.1	165,644	12.4	869,337	65.3	400,083	30.1	6,195	0.5	55,348	4.2	1,330,964	100.0	2.5

Note Source: "Statistical Abstract of Land Transport" by Ministry of Transport (1991). Transport Economy Monthly Report (Nov. 1992)

Light automobiles included in 1987 and on

Airline shows total of regular and irregular flight. Passenger boat includes irregular runs from 1973 on

Table 2-3 Number of Motor Vehicles in Use
(at the end of March every year)

(Unit : 1,000 vehicles)

Year	Passenger cars	Buses	Trucks	Special cars	total	Rate of average annual increase (%)	References			
							Smallsized special · motor · vehicles	Traliers	Motor cycles	Mopeds
1950	37	17	221	17	292	19.7	–	–	32	–
1955	139	32	613	29	813	15.0	–	2	523	505
1960	331	52	1,406	65	1,854	25.3	–	6	1,039	1,999
1965	1,779	95	4,007	145	6,026	23.2	1,153	9	950	6,722
1970	7,271	176	8,064	306	15,816	18.7	1,641	19	693	8,159
1975	16,044	219	10,242	557	27,063	7.5	1,675	39	769	7,984
1076	17,378	220	10,173	596	28,366	4.8	1,788	40	737	8,195
1977	18,618	222	10,787	631	30,258	6.7	1,980	42	747	8,579
1978	19,942	224	11,326	671	32,163	6.3	2,088	44	758	9,288
1979	21,400	227	11,972	720	34,328	6.7	2,165	48	803	10,098
1980	22,751	228	12,645	766	36,390	6.0	2,236	53	890	11,075
1981	23,646	229	13,246	794	37,915	4.2	2,299	57	1,019	12,072
1982	24,579	230	13,966	823	39,598	4.4	2,337	59	1,177	13,381
1983	25,435	230	14,725	852	41,242	4.2	2,358	59	1,386	14,826
1984	26,320	230	15,460	880	42,890	4.0	2,377	61	1,608	15,745
1985	27,038	230	16,296	912	44,476	3.7	2,410	64	1,823	16,357
1986	27,790	231	17,186	944	46,151	3.8	2,424	66	2,204	16,644
1987	28,538	232	18,184	988	47,942	3.9	2,425	68	2,213	16,423
1988	29,601	235	19,274	1,037	50,147	4.6	2,438	71	2,427	16,023
1989	30,713	239	20,412	1,097	52,461	4.6	2,414	76	2,599	15,609
1990	32,938	242	20,862	1,155	55,196	5.2	2,406	82	2,715	15,056
1991	35,152	246	21,057	1,214	57,669	4.5	–	89	2,741	–

Note : Refers to the Brief Statistics for Land Transportation, Ministry of Transport.

3. Engineering standards and specifications

3-1. Standards for Geometric Design of Highways

Stuctural Standards for public roads are provided in the Road Structure Ordinance (enacted in 1970 according to the Road Law, and revised in 1982). The outline of this ordinance is as follows :

(1) Classification and application of structural standards

Roads are classified into four types according to whether they are expressways or not, and to the area where they are located.

Type 1 and 2 roads are respectively located in rural and urban areas, and classified into four and two classes respectively. Both types are expressways. On the other hand, Type 3 and 4 roads are also respectively located in rural and urban areas, and classified into five and four respective classes. These roads are not expressways.

Each type and class of structural standards is applied to the road according to the designed daily traffic volume and the terrain where it is located (Table 3-1).

Structural standards of cross-section, design speed, etc. are provided according to the type and class of the road.

(2) Design vehicles

The size of vehicles is so important for the design of width of lanes, widening of a lane at curve, sight distance, clearance on road, etc. that it is determined according to the standards as shown in Table 3-2.

Type 1, 2, 3-1, 4-1 roads are designed for semitrailers and ordinary motor vehicles, whereas other roads are designed for ordinary motor vehicles and small-sized motor vehicles.

(3) Cross section elements

Cross section elements are as follows.

1) Carriageway (traffic lane, stopping lane, bus bay, emergency parking bay, etc.)
2) Center strip
3) Shoulder
4) Bicycle track or bicycle-pedestrian track
5) Sidewalk
6) Green belt

These are as shown in Fig. 3-1, and their standard widths are shown in Table 3-3.

Table 3-1 Structural Standard (1)

<table>
<tr><th rowspan="2">Express-way or not</th><th rowspan="2">Type (Area)</th><th rowspan="2">Class</th><th rowspan="2">Design speed (km/h)</th><th rowspan="2">Access control</th><th colspan="4">Designed daily volume : (vehicle/day)</th><th rowspan="2">Remarks</th></tr>
<tr><th>Over 30,000</th><th>30,000~ 20,000</th><th>20,000~ 10,000</th><th>Less than 10,000</th></tr>
<tr><td rowspan="10">Express-way</td><td rowspan="8">1 (Rural)</td><td>1</td><td>120</td><td>F</td><td>N.E. in level terrain</td><td colspan="3"></td><td></td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">100</td><td rowspan="2">F. P</td><td>N.E. in mountainous terrain</td><td colspan="2">N.E. in level terrain</td><td></td><td rowspan="2"></td></tr>
<tr><td colspan="2">E. in level terrain</td><td colspan="2"></td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">80</td><td rowspan="2">F. P</td><td></td><td>N.E. in mountainous terrain</td><td>N.E in level terrain</td><td rowspan="2"></td></tr>
<tr><td colspan="2">E. in mountainous terrain</td><td colspan="2">E. in level terrain</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">60</td><td rowspan="2">F. P</td><td colspan="2"></td><td colspan="2">N.E. in mountainous terrain</td><td rowspan="2"></td></tr>
<tr><td colspan="2"></td><td></td><td>E. in mountainous terrain</td></tr>
<tr><td rowspan="2">2 (Urban)</td><td>1</td><td>80</td><td>F</td><td colspan="4">N.E. & E. except in the center of Metropolis</td><td></td></tr>
<tr><td>2</td><td>60</td><td>F</td><td colspan="4">E. in the center of Metropolis</td><td></td></tr>
</table>

Note : N.E : National Expressway
E. : Expressway other than National Expressway
F : Full control of access
P : Partial control of access
N : Non control of access

Table 3-1 Structural Standard (2)

Express. way or not	Type (Area)	Class	Design speed (km/h)	Access control	Designed daily Volume : (vehicle/day) Over 20,000 vehicles	20,000~10,000	10,000~4,000	4,000~1,500	1,500~500	Less than 500	Remarks
Roads other than Express-way	3 (Rural)	1	80	P.N	N/H in level terrain						
		2	60	N	N.H. in mountainous terrain	N.H. in level terrain					
					P.M. in level terrain						
		3	60 50 40	N		N.H. in mountainous terrain		N.H. in level terrain P. in level terrain			
					P.M. in mountainous terrain			M. in level terrain			
		4	50 40 30	N				N.H. & P. in mountainous terrain			
									M. in level terrain		
								M. in mountainous terrain			
		5	40 30 20	N						M. in level terrain or mountain-ous terrain	1-lane road
	4 (Urban)	1	60	P.N	N.H.						
					P.M.						
		2	60 50 40	N			P.M.	N.H.			
		3	50 40 30	N				P.			
								M.			
		4	40 30 20	N						M.	1-lane road

Note : N.H. . National Highway P. : Prefectural Road
M. : Municipal Road

Table 3-2 Design Vehicles

(Unit : meter)

Type of vehicles	Length	Width	Height	Front over-hang	Wheel base	Rear over-hang	Minimum turning radius
Small-sized motor vehicle	4.7	1.7	2.0	0.8	2.7	1.2	6
Ordinary motor vehicle	12	2.5	3.8	1.5	6.5	4	12
Semi-trailer	16.5	2.5	3.8	1.3	front 4 rear 9	2.2	12

Table 3-3 Cross-Section Elements

(Unit : meter)

Type	Class	Lane	Center strip Total	Center strip Marginal strip	Shoulder Total	Shoulder Marginal strip	Sidewalk	Bicycle-pedestrian track	Bicycle track	Green belt	Stopping lane
1	1	3.50((3.75))	Over 4.50(3.00)	0.75	Over 2.50(1.75)	0.75(0.50)					
	2	3.50((3.75))	4.50(3.00)	0.75	2.50(1.75)	0.75(0.50)					
	3	3.50	3.00(2.25)	0.50	1.75(1.25)	0.50(0.25)					
	4	3.25	3.00(1.75)	0.50	1.75(1.25)	0.50(0.25)					
2	1	3.50[3.25]	Over 2.25	0.50	Over 1.25	0.50					
	2	3.25	1.75	0.50	1.25	0.50					
3	1	3.50	Over 1.75(1.00)	0.25	Over 1.25(0.75)		Over [1.50(1.00)]	Over [2.00(1.50)]	Over [2.00(1.50)]	about [1.50]	
	2	3.25((3.50))	1.75(1.00)	0.25	0.75(0.50)		[1.50(1.00)]	[2.00(1.50)]	[2.00(1.50)]	[1.50]	
	3	3.00	1.75(1.00)	0.25	0.75(0.50)		[1.50(1.00)]	[2.00(1.50)]	[2.00(1.50)]	[1.50]	
	4	2.75	1.75(1.00)	0.25	0.75(0.50)		[1.50(1.00)]	[2.00(1.50)]	[2.00(1.50)]	[1.50]	
	5	4.00 or 3.00 (carriageway)			0.50		[1.50(1.00)]	[2.00(1.50)]			
4	1	3.25((3.50))	Over 1.00	0.25	Over 0.50		Over [3.00(2.25)]	Over [3.50(2.75)]	Over [2.00(1.50)]	about 1.50	[2.50(1.50)]
	2	3.00	1.00	0.25	0.50		[3.00(1.50)]	[3.50(2.00)]	[2.00(1.50)]	[1.50]	[2.50(1.50)]
	3	3.00	1.00	0.25	0.50		[1.50(1.00)]	[2.00(1.50)]	[2.00(1.50)]	[1.50]	[2.50(1.50)]
	4	4.00 or 3.00 (carriageway)			0.50		[1.50(1.00)]	[2.00(1.50)]	[2.00(1.50)]		

Note : (( )) : When high percentage of large-sized vehicles is expected.
[ ] : Only when necessary
( ) : Exception as in the case of bridge, etc.

(4) Elements of alignment

Alignment of the road is an important factor to ensure safety, smoothness and comfort of traffic, and it directly influences the driving speed of vehicles. Therefore, values of design elements are all provided according to the design speed. They are shown in Table 3-5.

Table 3-4 Standard design Volume

Type	Class	Each lane of 4-or over 4-lane highway		2 lanes of 2-lane highway	
		Level terrain	Moun-tainous terrain	Level terrain	Moun-tainous terrain
1	1	12,000			
	2	12,000	9,000	14,000	
	3	11,000	8,000	14,000	10,000
	4	11,000	8,000	13,000	9,000
2	1	18,000			
	2	17,000			
3	1	11,000			
	2	9,000	7,000	9,000	
	3	8,000	6,000	8,000	6,000
	4		5,000	8,000	6,000
4	1	12,000		12,000	
	2	10,000		10,000	
	3	10,000		9,000	

Note :

1. With regard to a Type 4 road where there are many intersections the above values should be multiplied by 0.6 if it is a 4 or over 4-lane road or by 0.8 if it is a 2-lane road.

Table 3-5 Elements of Alignment

Design speed (km/h)	Radius of curve (m)		Length of transition section	Maximum grade	Minimum stopping sight distance	Radius of vertical curve (m)		Compound Grade
	Maximum superelevation rate							
	6%	10%	(m)	(%)	(m)	Crest	Sag	(%)
120	710	570	100	2	210	11,000	4,000	10.0
100	460	380	85	3	160	6,500	3,000	10.0
80	280	230	70	4	110	3,000	2,000	10.5
60	150	120	50	5	75	1,400	1,000	10.5
50	100	80	40	6	55	800	700	11.5
40	60	50	35	7	40	450	450	11.5
30	30		25	8	30	250	250	11.5
20	15		20	9	20	100	100	11.5

Notes :

1. the maximun values of the superelevation are shown in the following table.

	Snowy or freezing area		Other areas
	Severely snowy or freezing area	Other areas	
Type 1, Type 2 and Type 3 road with bicycle track, etc.	6	8	10
Other road	6	6	6

2. With reference to grade, in case it is necessary because of the topographical condition or for any other reason, the value may be increased by 3% for Type 1, Type 2 and Type 3 roads, and by 2% for Type 4 roads.
3. For Type 4 Class 1 roads whose design speed is 60 km/h, radius of vertical curve may be down to 1,000 m.
4. With regard to compound grade, in case it is necessary because of topographical or for any other conditions, the value may be raised up to 12.5 for roads whose design speed is 30 km/h or 20 km/h. The maximum compound grade of a road in severely snowy or freezing areas must be 8%

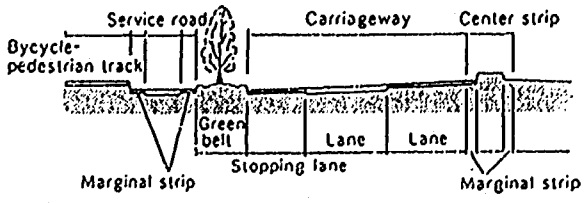
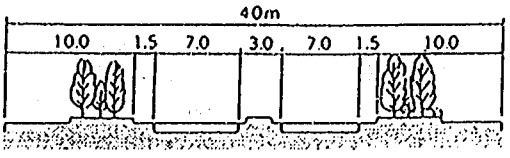
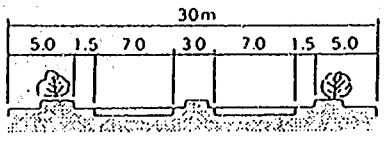


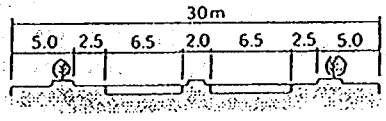
Fig. 3-1 Example of Cross-Section (Type 4 Roads)



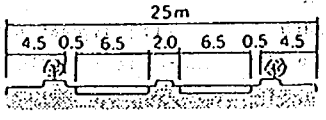
1. 4-Lane major arterial road
(Urban area with good residential environment)



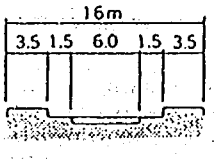
2. 4-Lane major arterial road
(Urban area other than described above)



3. 4-Lane arterial road
(Urban area with good residential environment)



4. 4-Lane arterial road
(Urban area other than described above)



5. 2-Lane collector road (Urban area)

Fig. 3-2 Configuration of Road Sections

3-2. Standards for Highway Pavement

(1) Structural Design Method of Asphalt Concrete Pavement (Japan Road Association, 1992)

Structural design method which has been used for bituminous pavements is based on the CBR method. The principal points of this design method are summarized as follows :

1) Bearing capacity of subgrade is obtained by the CBR method.

2) Layer equivalency obtained by the AASHO road tests is used.

3) The volume of traffic is classified according to the actually measured distribution of vehicle weights.

Table 3-13 Road Classification by Traffic

Traffic classification	Traffic volume of heavy vehicles after 5 years (/day-one direction)
L	Less than 100
A	100 to 250
B	250 to 1,000
C	1,000 to 3,000
D	More than 3,000

4) In frost-prone districts, the depth of freezing is taken as the design thickness.

5) For soft subgrade soils, some particular methods, such as replacement, are used.

In many cases, it is impossible to compact soil to the optimum water content because the natural moisture content of subgrade is high in this country. Therefore, the CBR method is based upon the natural moisture content. The total thickness and structure are determined by the design CBR and the volume of traffic, using Table 3-13 and Table 3-14.

Table 3-14 Target Values for T_A, cm

Design CBR	Road classification				
	L	A	B	C	D
(2)	(17)	(21)	(29)	(39)	(51)
3	15	19	26	35	45
4	14	18	24	32	41
6	12	16	21	28	37
8	11	14	19	26	34
12	11	13	17	23	30
20	11	13	17	20	26

T_A shown in Table 3-14 designates the converted thickness of hot bituminous mixture for surface course from the strength and thickness of pavements, which is based upon the concept of the layer equivalency by the AASHO road test. T_A is determined by the following equation :

$$T_A = \Sigma a_n T_n$$

where a_n : coefficient of relative strength of the n th layer (Table 3-15)

T_n : thickness of the n th layer (cm)

T_A : thickness of hot bituminous mixture for surface course converted from the total pavement.

The road classification by traffic (shown in Table 3-13) was determined using the results of both the AASHO road test and the actual measurement in Japan.

When the structural design is conducted by using Table 3-14, with reference to design example shown in Fig. 3-14, the structure of pavements is determined and T_A and H are calculated. The T_A value should be greater than that shown in Table 3-14.

Besides the above-mentioned regular pavements, low cost pavements are adequately constructed.

The typical cross sections of bituminous pavements which are presently used in Japan are as shown in Fig. 3-1.

Table 3-15 Coefficients of Relative Strength for Calculating T_A

Pavement course	Method and material of construction used	Conditions	Coefficient
Binder and surface courses	Hot asphalt mix for binder and surface courses		1.00
Base	Bituminous stabilization	-Hot-mixed, Marshall stability : 350 kg or more	0.80
		-Cold-Mixed, Marshall stability : 250 kg or more	0.55
	Cement stabilization	-Unconfined compressive strength (7 days) : 30 kg/cm²	0.55
	Lime stabilization	-Unconfined compressive strength(10 days) : 10 kg/cm²	0.45
		-Modified CBR : 80 or more	0.35
	Mechanically stabilized gravel and slag		
	Hydraulic mechanically stabilized slag	-Unconfined compressive strength(14 days) : 12 kg/cm²	0.55
Subbase	Crusher-run, slag, sand, etc.	-Modified CBR : 30 or more	0.25
		-Modified CBR : less than 30	0.20
	Cement stabilization	-Unconfined compressive strength (7 days) : 10 kg/cm²	0.25
	Lime stabilization	-Unconfined compressive strength (10 days) : 7 kg/cm²	0.25

Note : Layer coefficient for any construction method or material other than those listed in table 3-15 should be adopted only when based on established engineering experience.

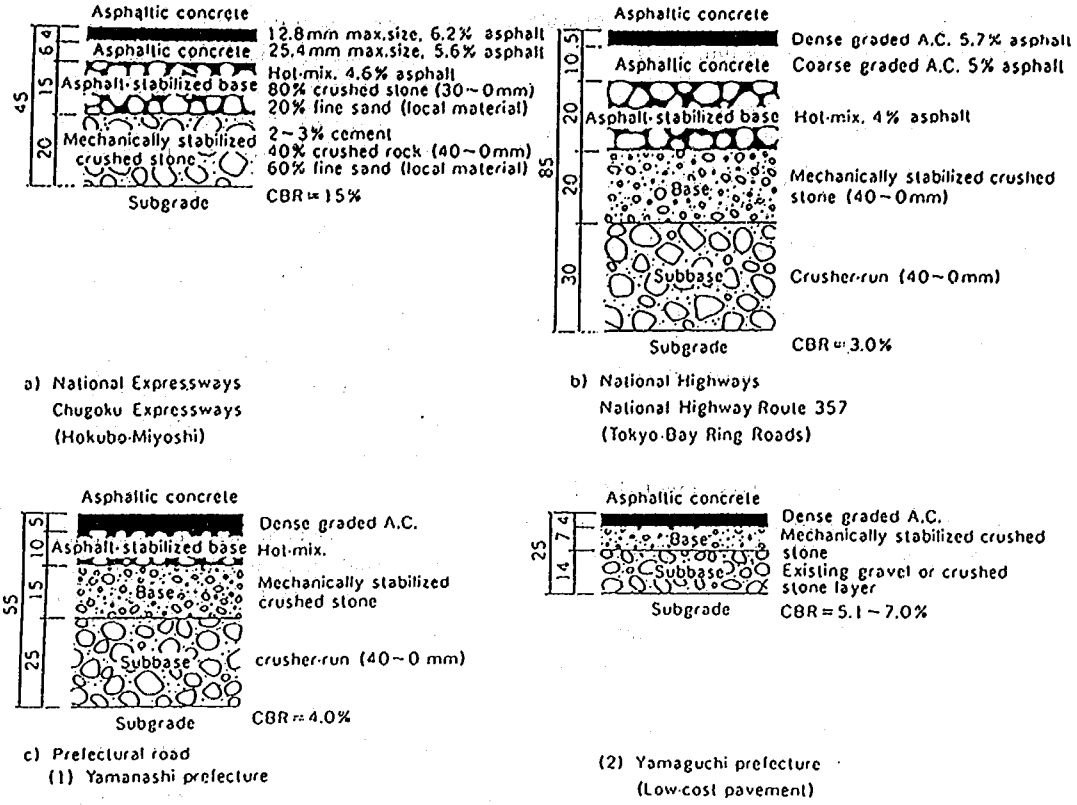


Fig. 3-14 Typical Bituminous Pavement Structures (unit : cm)

(2) Structural Design Method of Cement Concrete Pavement (Japan Road Association, 1983)

Base course thickness is designed based on design coefficient of bearing capacity of subgrade, or design CBR.

To obtain base course thickness from coefficient of bearing capacity, it shall be so designed that ; coefficient of bearing capacity of base course thickness in B, C, and D traffic shall be $K_1 = 20$ kg/cm³ and over ; and in L, A traffic, $K_1 = 15$ kg/cm³ and over, respectively. Design method includes : design curve as illustrated in Fig. 3-15 ; and test base course. For measurement of coefficient of bearing capacity, a loading plate 30 cm in diameter shall be used.

For design of base course thickness from CBR of subgrade, the value in Table 3-16 shall be the base course thickness in accordance with traffic classification and design CBR.

The value in Table 3-17 shall be the standard thickness of concrete pavement in accordance with traffic classification. Design bending strength of concrete for design of concrete pavement shall be 45 kg/cm³ (age ; 28 days).

For concrete pavement, in principle, wire mesh and edge reinforcing bar shall be used. The standard quantity of reinforcing bar in wire mesh shall be approximately 3 kg, normally a deformed steel bar 6 mm in diameter shall be used. (for example, see Fig. 3-16)

To reduce stress by a certain amount of expansion, shrinkage and camber, a joint is provided.

Longitudinal joints shall normally be installed where traffic lanes are divided. (Fig. 3-17)

While transverse expansion joints shall be installed based upon the location of bridge and crossing structure, distance between contraction joints, and daily length of pavement, with reference to the value in Table 3-18. (Fig. 3-18)

The standard distance between transverse contraction joints shall be 8 meters when the pavement thickness is less than 25 cm, and 10 meters when 25 cm and over. (Fig. 3-19)

Table 3-16 Relationship between Design CBR and Base Course Thickness (Unit : cm)

Traffic classification \ Design CBR of subgrade	2	3	4	6	8	12 and over
L and A traffic	50	35	25	20	15	15
B, C, and D traffic	60	45	35	25	20	15

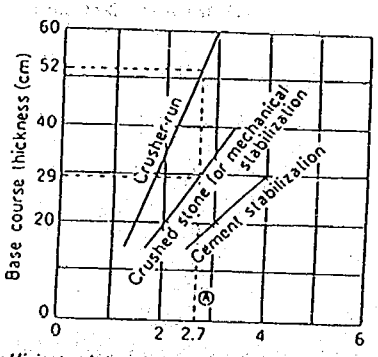
Table 3-17 Thickness of Concrete Pavement

Traffic classification	Thickness of concrete pavement(cm)
L traffic	15(20)
A traffic	20(25)
B traffic	25
C traffic	28
D traffic	30

Note : Figures in parentheses are under bending strength of 40 kg/cm² in L and A traffic.

Table 3-18 Standard Value of Distance between Transverse Expansion Joints

Pavement thickness (cm) \ Time of execution of work	From December to March	From April to November
15, 20	60~120 m	120~240 m
25 and over	120~240 m	240~480 m



$$\frac{\text{Coefficient of bearing capacity of base course}}{\text{Design coefficient of bearing capacity of subgrade}} = \frac{K_1}{K_2}$$

Example:

Traffic classification : C ; and coefficient of bearing capacity of subgrade: 7.4.

$$\frac{K_1}{K_2} = \frac{20}{7.4} = 2.7$$

(In the Fig. marked (A))

Therefore, in the case of crusher-run, 52cm, while in the case of crushed stone for mechanical stabilization, 29cm.

Fig. 3-15 Design Curve of Base Course (Using 30cm Diameter Loading Plate)

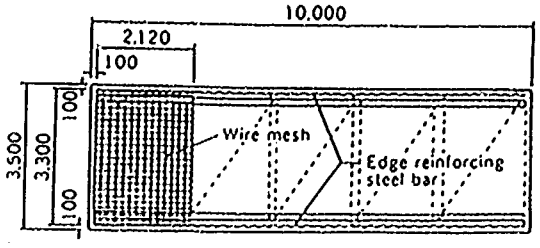


Fig. 3-16 Example of Wiremesh and Edge Reinforcing Steel Bar (Unit : mm)

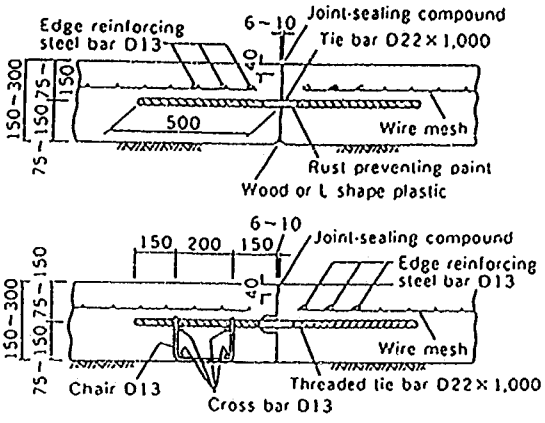


Fig. 3-17 Example of Configuration of Longitudinal Joint

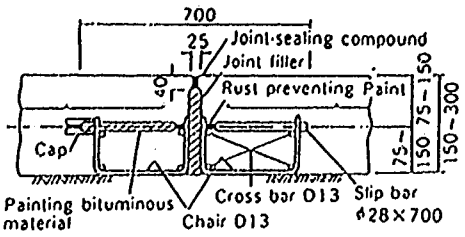


Fig. 3-18 Example of Configuration of Transverse Expansion Joint

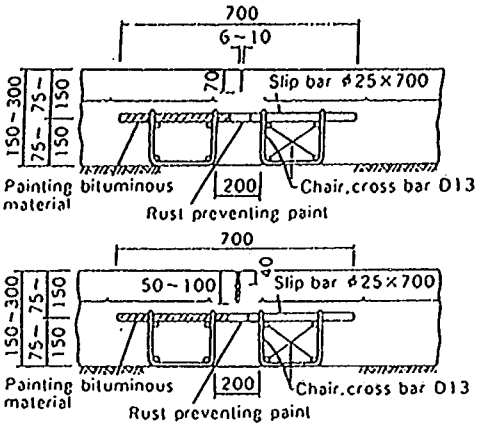


Fig. 3-19 Example of Configuration of Transverse Contraction Joint

PAVEMENTS IN CANADA

Overview of Development, Implementation, and Management of Pavement Technology

BY

Dr. Gerhard J.A. Kennepohl, Head
Pavements and Roadway Office
Ministry of Transportation, Ontario

Presentation for the AHSCA (Advanced Highway Systems in Cold Area) Joint Task Committee
Tsukuba, Japan, December 6, 1993

(No.1)

OUTLINE OF PRESENTATION

1. Background
2. Definition and Scope of Technologies
3. Manadate, Organizations and Responsibilities
4. Major Pavement Technology Areas
   - Materials
   - Maintenance/Rehabilitation
   - Design/Construction
   - Vehicle Impacts
   - Vehicle - Environment Interaction
   - Pavement Management
5. New Challenges, Trends and Future Direction
6. Conclusions

(No.2)

1. BACKGROUND

- o ROAD TRANSPORTATION A VITAL ELEMENT TO CANADIAN ECONOMY
- o PAVEMENTS A SIZEABLE INVESTMENT IN ROADWAY INFRASTRUCTURE ($200 BILLION)
- o INCREASED REQUIREMENTS AND ENHANCED TECHNOLOGY NEEDS
- o MORE VULNERABLE TO ENVIRONMENT
- o SHRP AND C-SHRP TO ADDRESS ISSUES
- o INTERNATIONAL COOPERATION

(No.3)

2. DEFINITION AND SCOPE OF TECHNOLOGY

(A) PAVEMENT SURFACE AND INFRASTRUCTURE

(B) ROADWAY APPURTENANCES

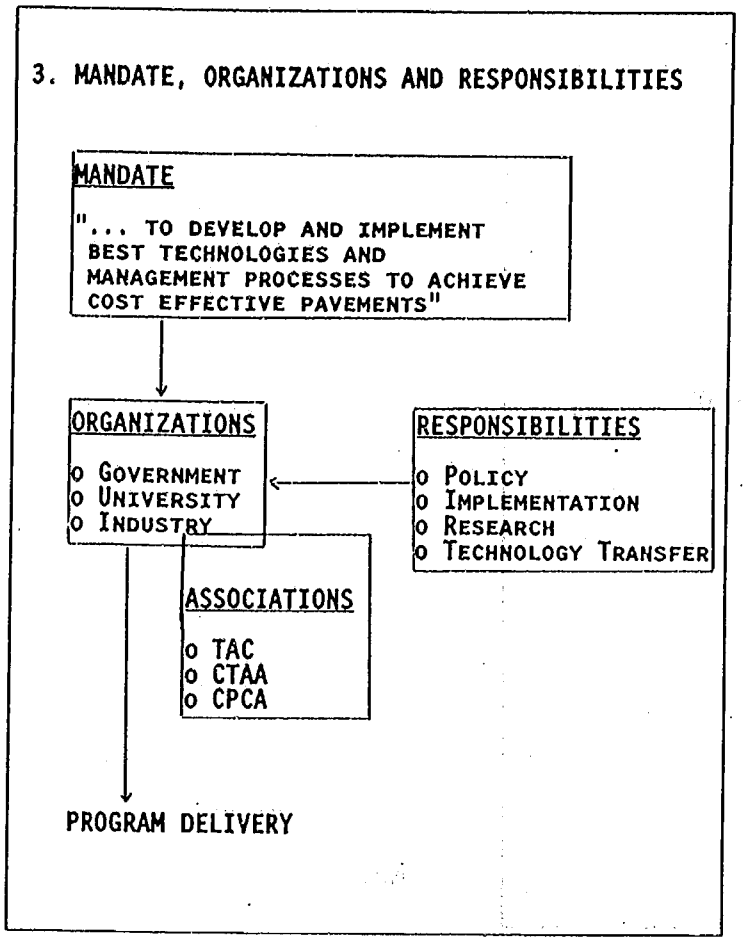
- GUIDE RAILS
- SIGNS
- MARKINGS
- LIGHTS

ETC.

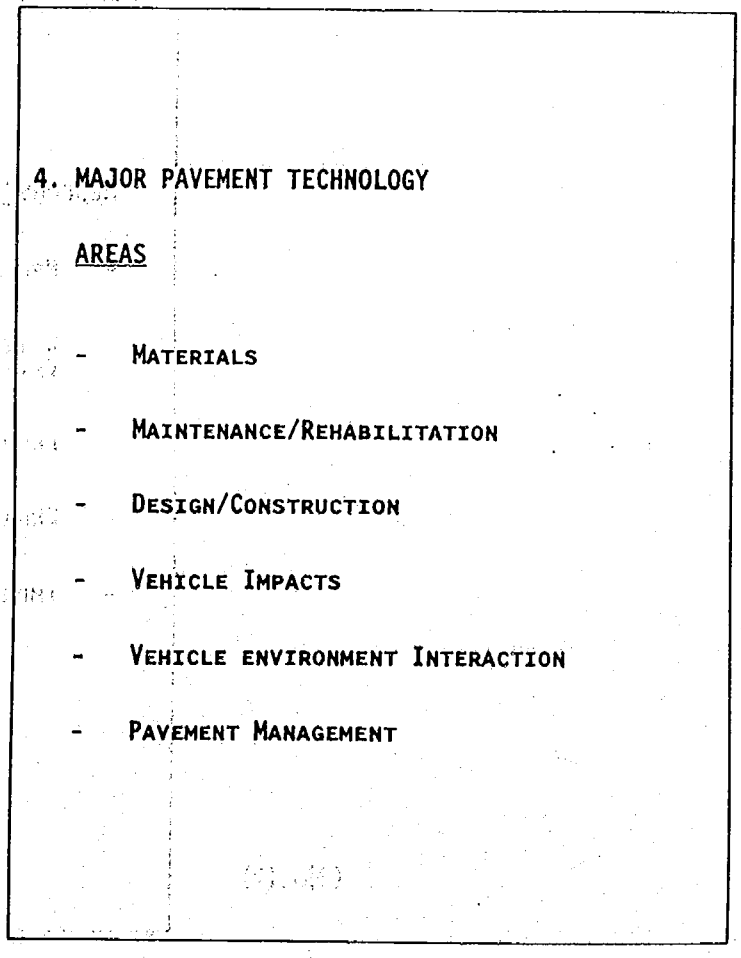
(C) INTERACTING TECHNOLOGIES

- ROADWAY SAFETY (E.G. FRICTION)
- NOISE
- ILLUMINATION

(No.4)


3. MANDATE, ORGANIZATIONS AND RESPONSIBILITIES
MANDATE
"... TO DEVELOP AND IMPLEMENT BEST TECHNOLOGIES AND MANAGEMENT PROCESSES TO ACHIEVE COST EFFECTIVE PAVEMENTS"
ORGANIZATIONS
o GOVERNMENT
o UNIVERSITY
o INDUSTRY
RESPONSIBILITIES
o POLICY
o IMPLEMENTATION
o RESEARCH
o TECHNOLOGY TRANSFER
ASSOCIATIONS
o TAC
o CTAA
o CPCA
PROGRAM DELIVERY

(No.5)


4. MAJOR PAVEMENT TECHNOLOGY
AREAS
- MATERIALS
- MAINTENANCE/REHABILITATION
- DESIGN/CONSTRUCTION
- VEHICLE IMPACTS
- VEHICLE ENVIRONMENT INTERACTION
- PAVEMENT MANAGEMENT

(No.6)

ISSUES

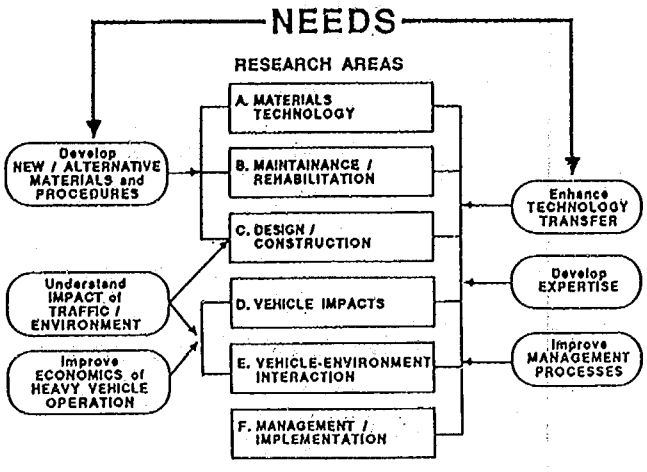
- PAVEMENT AGEING
- INCREASING LOADS/VOLUMES
- HIGHER VEHICLE OPERATING COSTS
- ACCELERATED DETERIORATION
- INCREASED REHABILITATION
- DEPLETING RESOURCES
- LIMITED FUNDING

(No.7)

RESPONSE

- NEW ALTERNATIVE MATERIALS
- BETTER UNDERSTANDING OF TRAFFIC/ ENVIRONMENT IMPACT
- ECONOMIC OF HEAVY VEHICLES
- ENHANCE TECHNOLOGY TRANSFER/EXCHANGE
- IMPROVE MANAGEMENT PROCESSES

(No.8)



Research Needs and Major Research Areas

(No.9)

EXAMPLES OF RESEARCH TOPICS

MATERIALS

- ROLLER COMPACTED PCC
- RUTTING RESISTANT MIXES
- MODIFIED ASPHALTS
- MIX DESIGN FOR EMULSIFIED ASPHALTS

MAINTENANCE/REHABILITATION

- DESIGN FOR REHABILITATION
- PAVEMENT RECYCLING
- MICRO SURFACING

(No.10)

EXAMPLES OF RESEARCH TOPICS (CONT'D)

DESIGN/CONSTRUCTION

- PAVEMENT PERFORMANCE MODELLING
- GEOSYNTHETIC APPLICATIONS
- LONG-TERM PAVEMENT PERFORMANCE
- AMI COMPACTION

VEHICLE IMPACTS

- WEIGH-IN-MOTION STUDIES
- DYNAMIC LOAD EFFECTS
- TIRE PAVEMENT INTERFACE

(No.11)

EXAMPLES OF RESEARCH TOPICS CONT'D)

VEHICLE-ENVIRONMENT INTERACTION

- EFFECTS OF THAW AND FROST ACTION
- PORE PRESSURE STUDIES
- LONG-TERM SEASONAL EFFECTS
- LOW TEMPERATURE MOISTURE INDUCED DAMAGE

PAVEMENT MANAGEMENT

- CANADIAN HIGHWAY TRAFFIC MONITORING GUIDE
- NON-DESTRUCTIVE PAVEMENT TESTING
- PAVEMENT INSTRUMENTATION TECHNOLOGY
- UPDATE OF PAVEMENT DESIGN AND MANAGEMENT GUIDE
- UPDATE OF PAVEMENT COST ANALYSIS

(No.12)

5. NEW CHALLENGES, TRENDS, AND FUTURE DIRECTION

- o Key Issues
- o Future Nature of Paving Industry
- o SHRP Products
- o Future Prospects

(No.13)

KEY ISSUES

Environmental

- o Use of Waste Products
- o Recycling

Health

- o Fumes/Leachates
- o Recycling

Social

- o Communication with Public
- o Opportunities

(No.14)

KEY ISSUES (CONT'D)

POLICY

- o INSTITUTIONAL CHANGES
- o ACCOUNTABILITY
- o COOPERATION BETWEEN PUBLIC AND PRIVATE

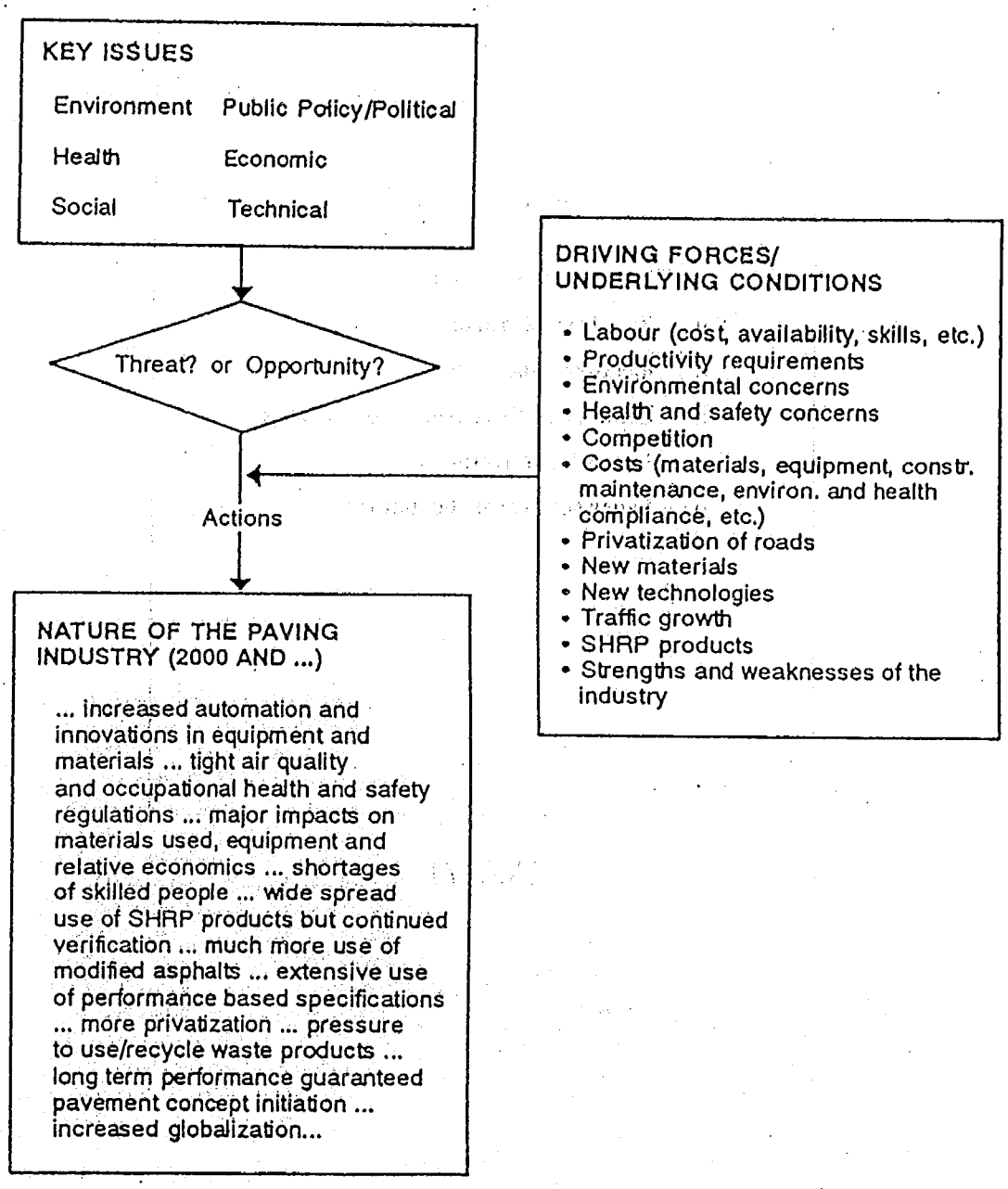
TECHNICAL

- o RIGID REGULATIONS
- o INCREASED LOADS
- o INNOVATION

ECONOMIC

- o INCREASED COST
- o PRIVATIZATION
- o PERFORMANCE SPECIFICATION

(No.15)


KEY ISSUES
Environment
Public Policy/Political
Health
Economic
Social
Technical
Threat? or Opportunity?
Actions
DRIVING FORCES/
UNDERLYING CONDITIONS
• Labour (cost, availability, skills, etc.)
• Productivity requirements
• Environmental concerns
• Health and safety concerns
• Competition
• Costs (materials, equipment, constr. maintenance, environ. and health compliance, etc.)
• Privatization of roads
• New materials
• New technologies
• Traffic growth
• SHRP products
• Strengths and weaknesses of the industry
NATURE OF THE PAVING
INDUSTRY (2000 AND ...)
... increased automation and innovations in equipment and materials ... tight air quality and occupational health and safety regulations ... major impacts on materials used, equipment and relative economics ... shortages of skilled people ... wide spread use of SHRP products but continued verification ... much more use of modified asphalts ... extensive use of performance based specifications ... more privatization ... pressure to use/recycle waste products ... long term performance guaranteed pavement concept initiation ... increased globalization...

(No.16)

SHRP PRODUCTS

- o Performance Specs
- o New Test Methods
- o National Data Base
- o Long Term Deterioration Models
- o Field Test Methods
- o Rehabilitation Guidelines

(No.17)

SOME FUTURE EXPECTATIONS FROM SHRP PRODUCTS - Asphalt Pavements

Summarized from [Hawks 92]

Area	Expectations
Pavement Structural Design	• Stabilized or drainable bases will be common (Standard for Interstate type highways) and cost effective • Distress prediction rather than serviceability loss prediction will be the primary design parameter • Designs will have to be very sensitive to climate influences, in terms of distress types, subgrade strength assessment, base type and design, surface type and design and materials selection
Materials	• Trend toward coarser aggregates • More stringent durability specifications • Specifications for fractured faces on aggregates • More manufactured and less natural sands • Mix design related to structural requirements
Construction	• More stringent quality control on: • thickness • segregation • paving temperatures • smoothness specifications
Rehabilitation	• Thicker overlays • Milling will be advised as a part of rehabilitation • Recycled asphalt used for all layers (limited by environmental regulations and aggregate quality) • Rehabilitation will be managed (i.e., within long term planning) rather than reactive to problems

(No.18)

FUTURE PROSPECTS

1. Increased Automation
2. Environmental Controls
3. Shortage of Skilled People
4. Use of SHRP Products
5. Modified Asphalts
6. Performance Specification
7. Privatization
8. LTPP Specs
9. Use of Waste Products
10. Increased Globalization

(No.19)

6. CONCLUSIONS

- Pavements in Canada are considered vital to the economy
- Increased requirements and economic constraints present new challenges but also new opportunities
- By realizing the benefits of technology and cost-effective improvements Canada is preparing to achieve a strong, competitive paving industry
- International cooperation plays a vital role in technology development and acquisition

(No.20)

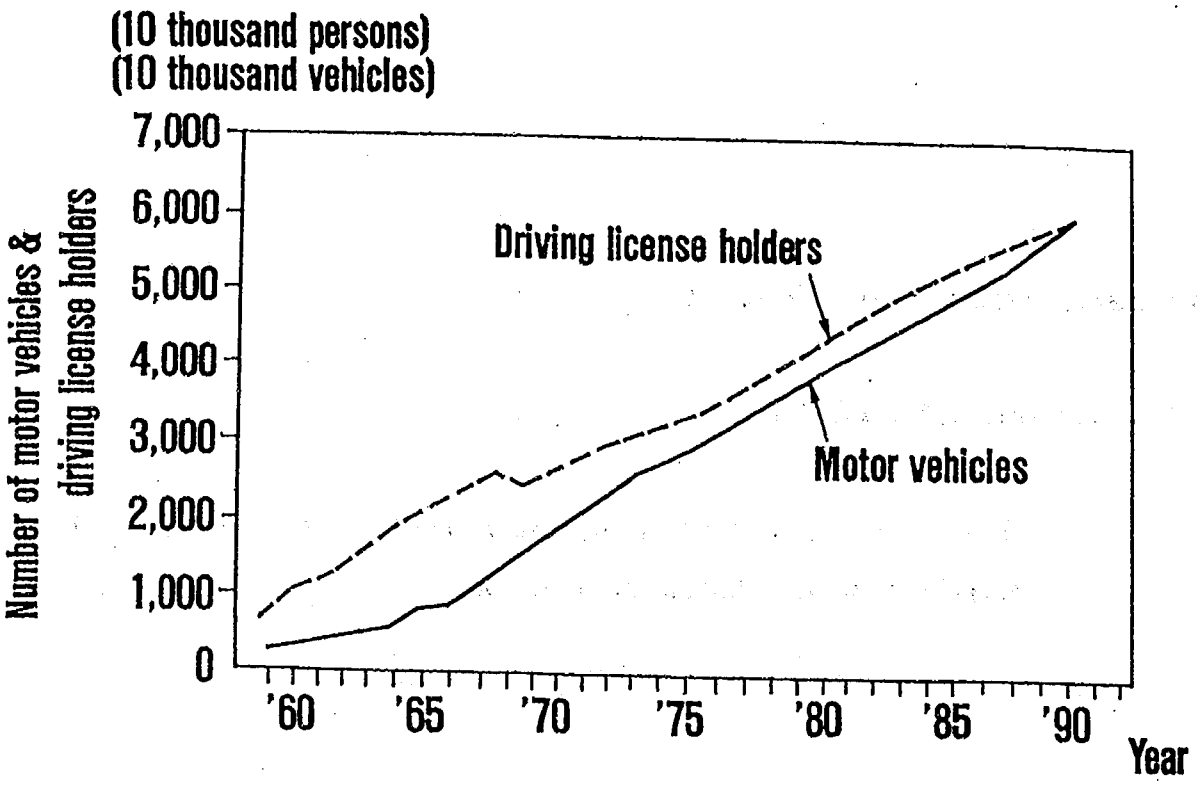
5. Intelligent Vehicle Highway Systems (IVHS)

Present State of IVHS in Japan

Makoto NAKAMURA

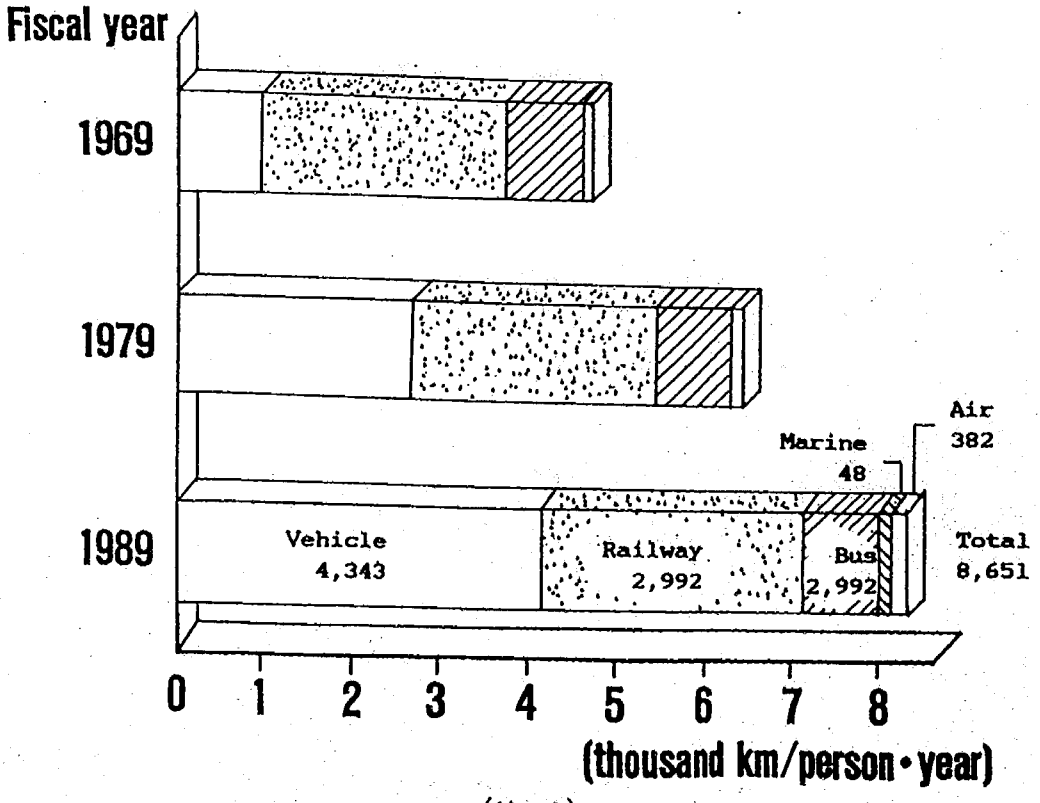
Head of Traffic Engineering Division,PWRI
Ministry of Construction

Trend of the Number of Vehicles & Licenses



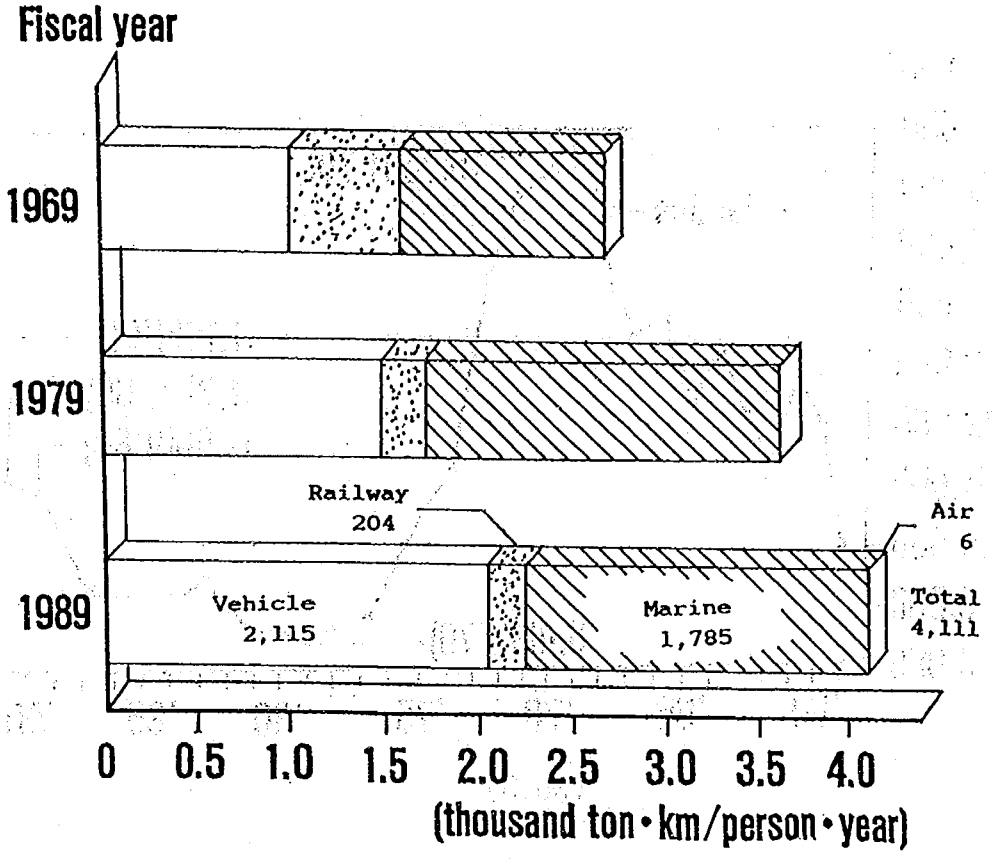
(No.1)

Modal Share in Domestic Passenger Transport per Person



(No.2)

Modal Share in Domestic Freight Transport per Person



(No.3)

Traffic Congestion in the Tokyo Metropolitan Area

Average Travel Speed at Peak Hour

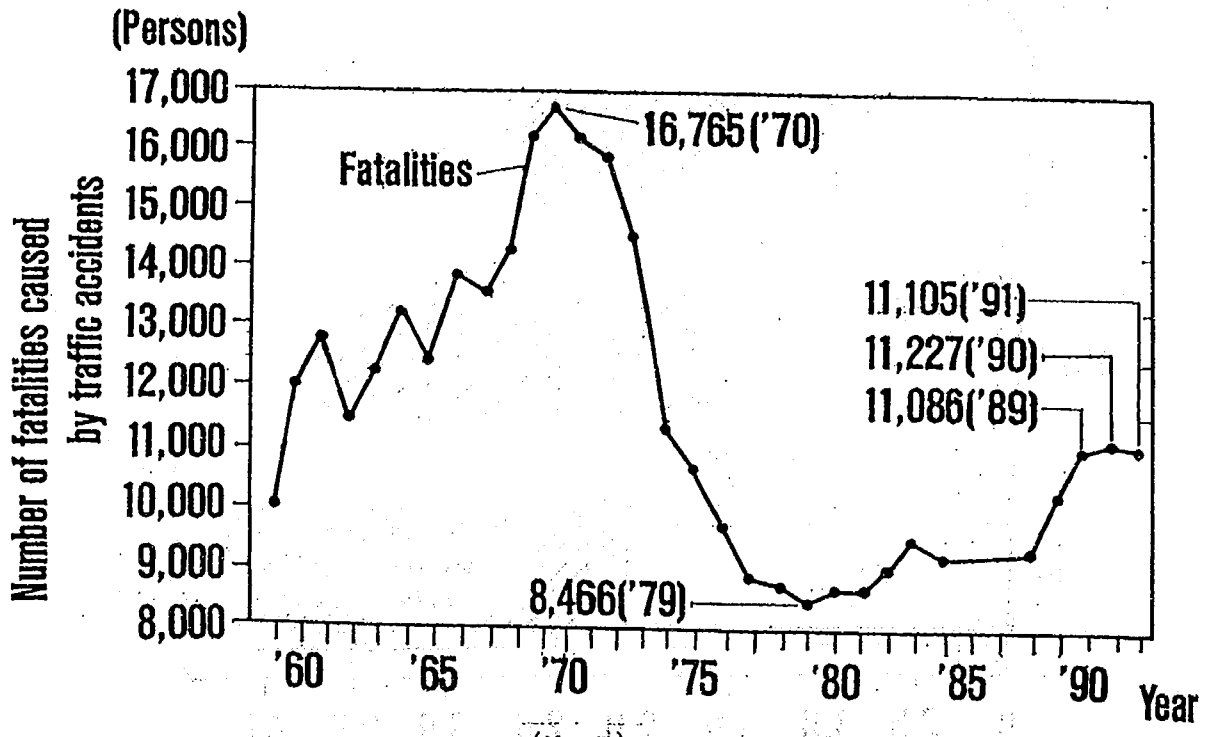
(National Highway & Principal Local-Road)

fiscal Year 1990

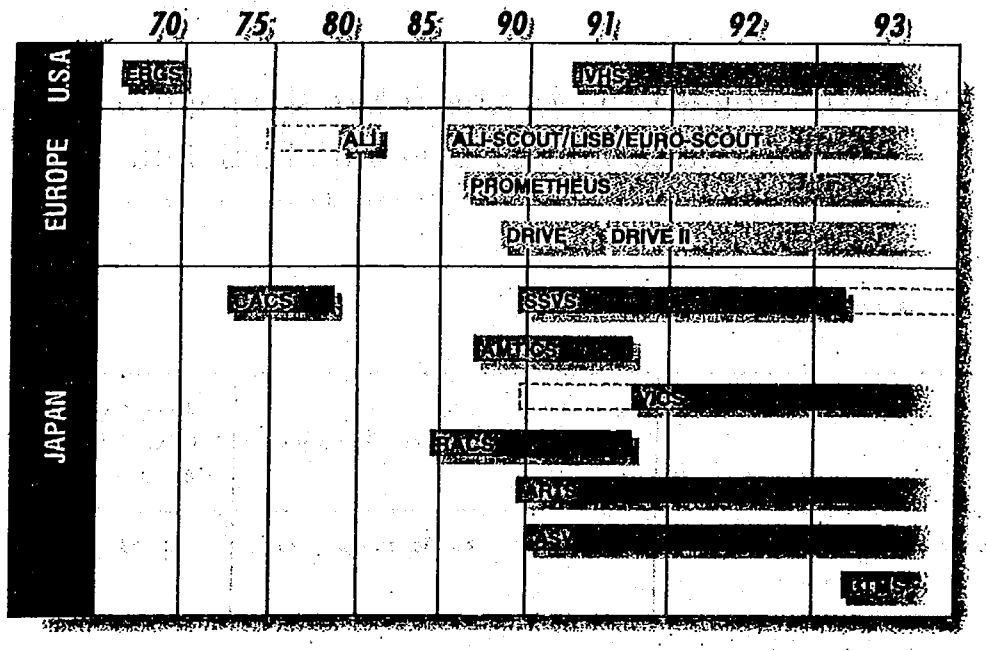
	23 Ward in Tokyo	Tokyo, Saitama, Chiba, Kanagawa, & Ibaraki Pref.
Average Travel Speed	16.8 km/h	28.5 km/h

(No.4)

Trend of the Number of Fatalities

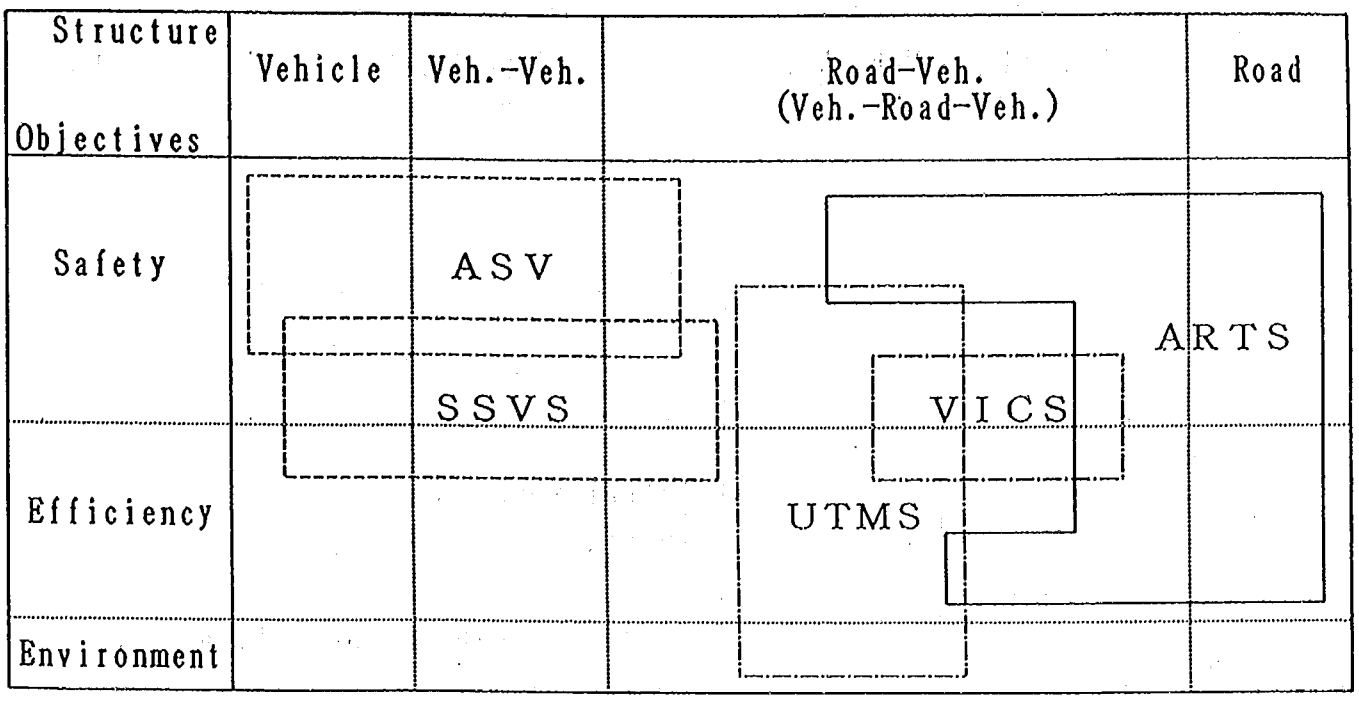


(No.5)



(No.6)

Classification of IVHS in Japan by system objectives and structure



(No.7)

System Objectives and structure of VICS

Structure / Objectives	Vehicle	Veh.-Veh.	Road-Veh. (Veh.-Road-Veh.)	Road
Safety			Road Traffic Information	
Efficiency			- Beacon - Teleterminal - FM Multiplex	
Environment				

(No.8)

System Objectives and structure of UTMS

Structure / Objectives	Vehicle	Veh.-Veh.	Road-Veh. (Veh.-Road-Veh.)	Road
Safety			Advanced Traffic Management	
Efficiency			Dynamic Route Guidance Traffic Information Fleet Management Public Transport Priority	
Environment			Traffic Polution Reduction	

(No.9)

System Objectives and structure of ASV

Structure / Objectives	Vehicle	Veh.-Veh.	Road-Veh. (Veh.-Road-Veh.)	Road
Safety	Automatic Hazard Lamp Lighting Rear & Lateral Warning Lane Out Warning Headway Warning Optimum Headway Control Automatic Accident Avoidance Automatic Intersection Stoppage Pedestrian Protection		Navigation using Traffic Information Emergency Call Curving Speed Control	
Efficiency				
Environment				

(No.10)

System Objectives and structure of SSVS

Structure / Objectives	Vehicle	Veh.-Veh.	Road-Veh. (Veh.-Road-Veh.)	Road
Safety		Active Driving	Smart Surrounding Recognition Smart Intersection Support	
Efficiency	Super Mini-size Car	Cooperative Driving	Intelligent Logistics	
Environment				

(No.11)

Approaches of ARTS
(Advanced Road Transportation Systems)

(1)Utilization of advanced telecommunications & Information Technologies

(2)Unification & Systematization of Roads & Vehicles

(3)Infrasturucture Oriented Approach

(No.12)

Major Subsystems of ARTS

① Guidelight systems

② Headway & lateral control system

(No.13)

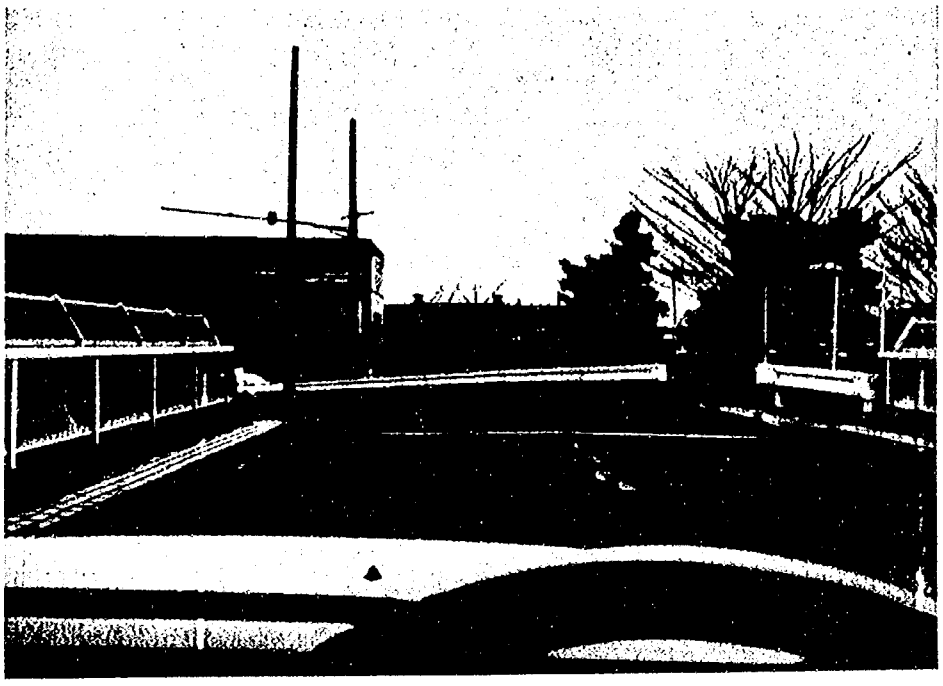
Examples of Guidelight Systems

① Opposite lane traffic warning & road alignment indication

② Intersection warning

③ Guidelight for foggy conditions

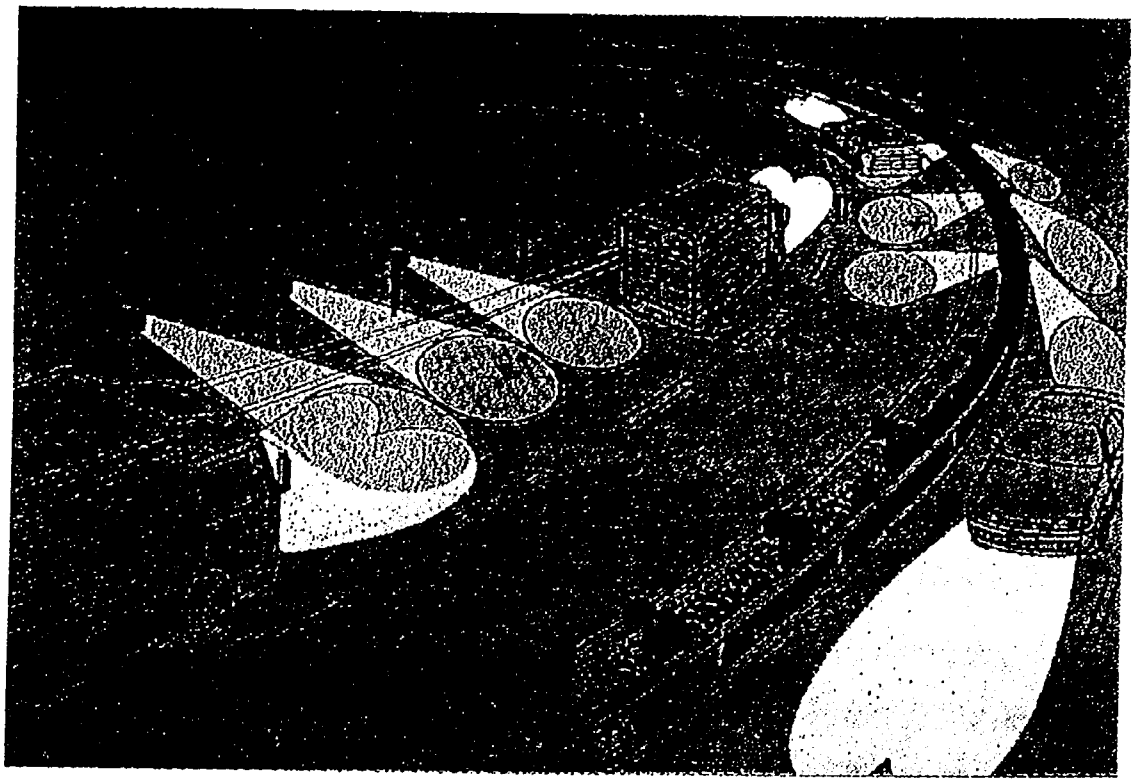
(No.14)



(No.15)

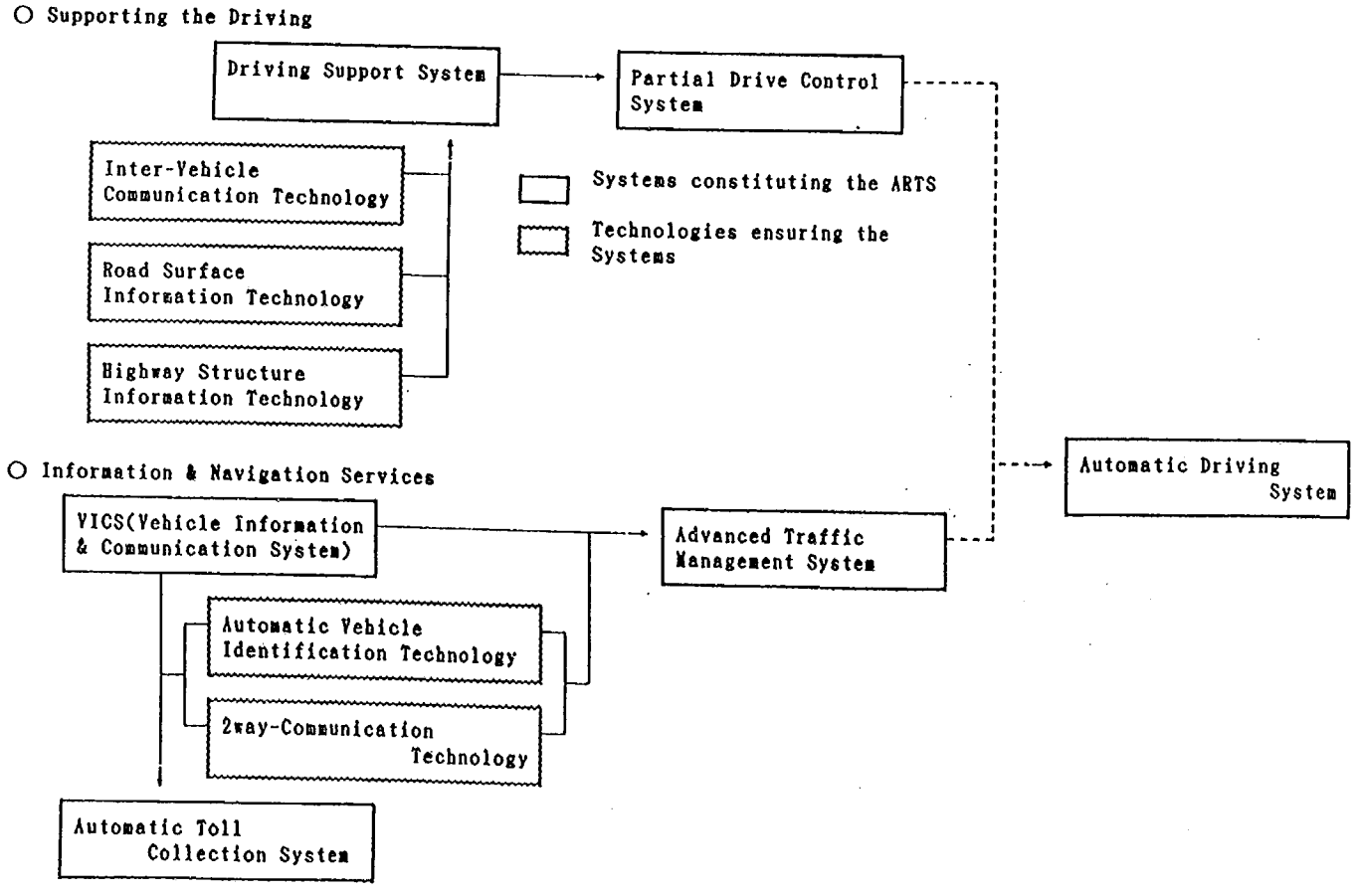


(No.16)



(No.17)

System Configuration of ARTS



(No.18)

Examples of the Systems constituting the ARTS (1)

Driving Support System

◇ Surrounding Vehicles Monitoring

◇ Highway Incident Detection

◇ Emergency Call

◇ Merging Vehicle Detection

(No.19)

Examples of the Systems constituting the ARTS (2)

Partial Drive Control System

◇ Headway Control

◇ Speed Limitation

◇ Rear-end Collision Prevention

(No.20)

Example of the Systems constituting the ARTS (3)

VICS(Vehicle Information & Communication System)

◇ Traffic Information

◇ Route Guidance

◇ Parking Information

(No.21)

Example of the Systems constituting the ARTS (4)

Advanced Traffic Management System

◇ Optimal Usage of Highway Network

(No.22)

Example of the Technology constituting the ARTS

AVI(Automatic Vehicle Identification)

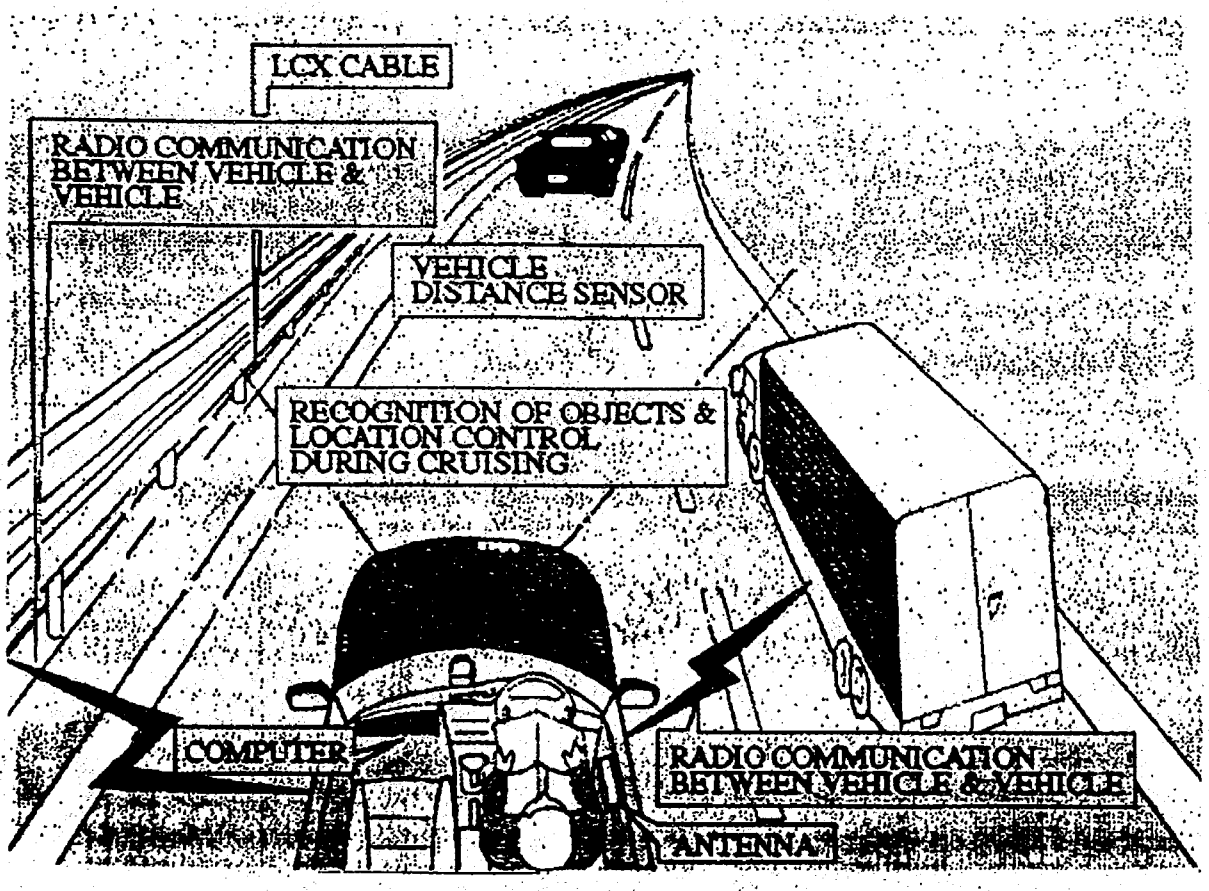
Identification of

◇ Speed

◇ Vehicle Location

(No.23)

Vehicle Headway Lateral Control System



(No.24)



Vehicle Information & Communication System

— V I C S —

IVHS Meeting

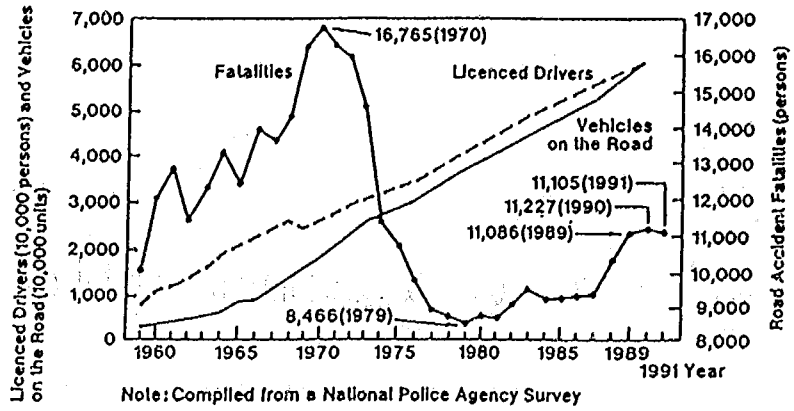
December 6~8, 1993, Tsukuba, Japan.

Highway Industry Development Organization.

Yoshitaro Masuda.

1

Changes in the Number of Road Accident Fatalities Etc.



Note: Compiled from a National Police Agency Survey

Changes in the Traffic Congestion Situation in Tokyo and its Surroundings

Average Driving Speed During Peak Hours (Km/hours on national and principal regional roadways)

	1983	1988	1990
Twenty-three wards of Tokyo	17.3	16.0	16.8
1 metropolitan prefecture 4 rural prefectures	30.7	28.3	28.5

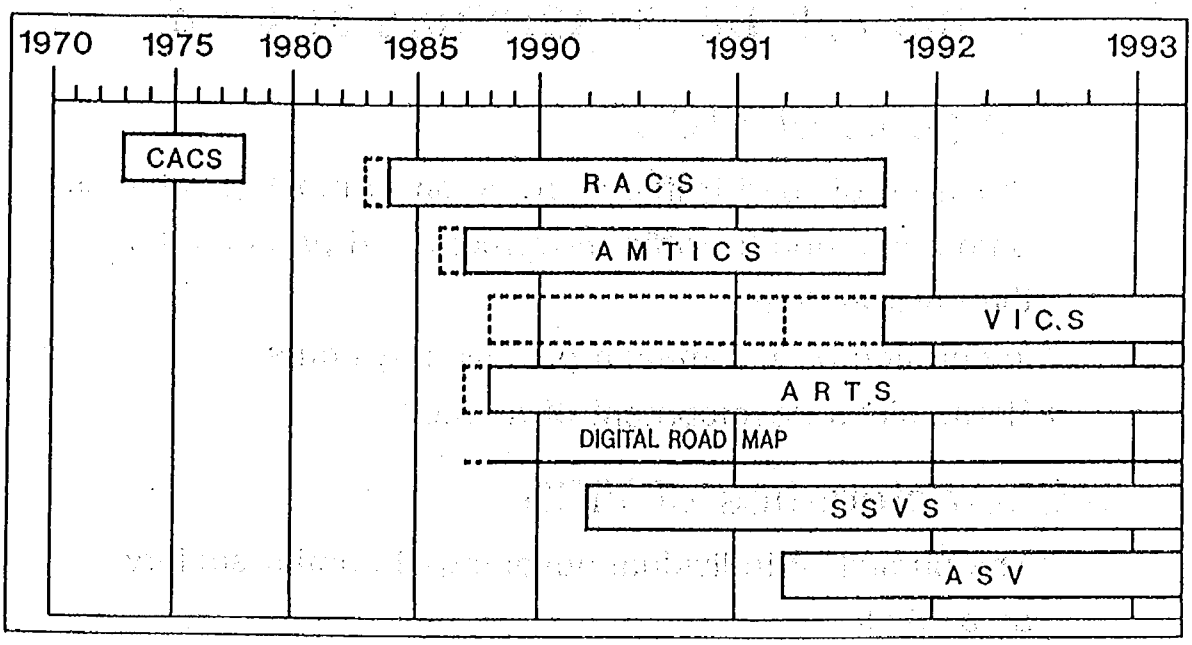
Note: 1. Based on a Ministry of Construction road traffic census
2. 1 metropolitan prefecture 4 rural prefectures: Metropolitan Tokyo and the prefectures of Saitama, Chiba, Kanagawa, and Ibaraki.

HIDO

- The table and graph above describe road traffic conditions in Japan.
- The graph on the upper right indicates how the annual number of road accident fatalities has changed.
- There are 60 million vehicles on the road, which is about 3 times as many as there were 20 years ago. About the same number of people hold drivers licenses.
- The annual number of road accident fatalities peaked in 1970 at 16,765, fell to half that figure by 1979, but has begun rising recently, surpassing 11,000.
- The table on the lower left indicates changes in traffic congestion conditions in Tokyo and its surroundings.
- The average driving speed during peak hours in the 23 wards of Tokyo has been declining, and now stands between 16 and 17 kilometers per hour.
- Traffic congestion at this level causes substantial losses for both individuals and for society as a whole.
- In an effort to contribute to the resolution of these problems, new road traffic systems such as the Vehicle Information and Communication System (VICS) described below are being introduced, and research and development work is continuing on the next generation of road traffic systems.

2

Next Generation Road Traffic System Related Projects Underway in Japan



HIDO

- These are the next generation road traffic system related projects now underway in Japan.
- Research and development of road vehicle communication technology commenced with the Comprehensive Automobile traffic Control System (CACS) project conducted by the Ministry of International Trade and Industry 20 years ago.
- This was followed by the Road/Automobile Communication System (RACS), a Ministry of Construction project, and the Advanced Mobile Traffic Information and Communication System(AMTICS) conducted in the same period by the ~~Metropolitan Police Office~~ National Police Agency.
- The functions characteristic of these two systems were similar in many respects, and it became necessary to integrate and improve their information and communication functions.
- Vehicle Information and Communication System(VICS), which was born as a product of this series of projects, introduced the first practical use of roadway information communication between the road and cars travelling on it.
- The Ministry of Construction's Advanced Road Transportation System(ARTS) project, the Ministry of International Trade and Industry's Super Smart Vehicle System(SSVS) project, and the Ministry of Transportation's Advanced Safety Vehicle(ASV) project, which are now in progress, are intended to develop next generation systems.
- All three projects are managed by organizations composed of industrial, academic, and administrative bodies, and each has been planned and implemented to achieve specific development goals.

3

Goals and Characteristics of VICS

★The goals of VICS

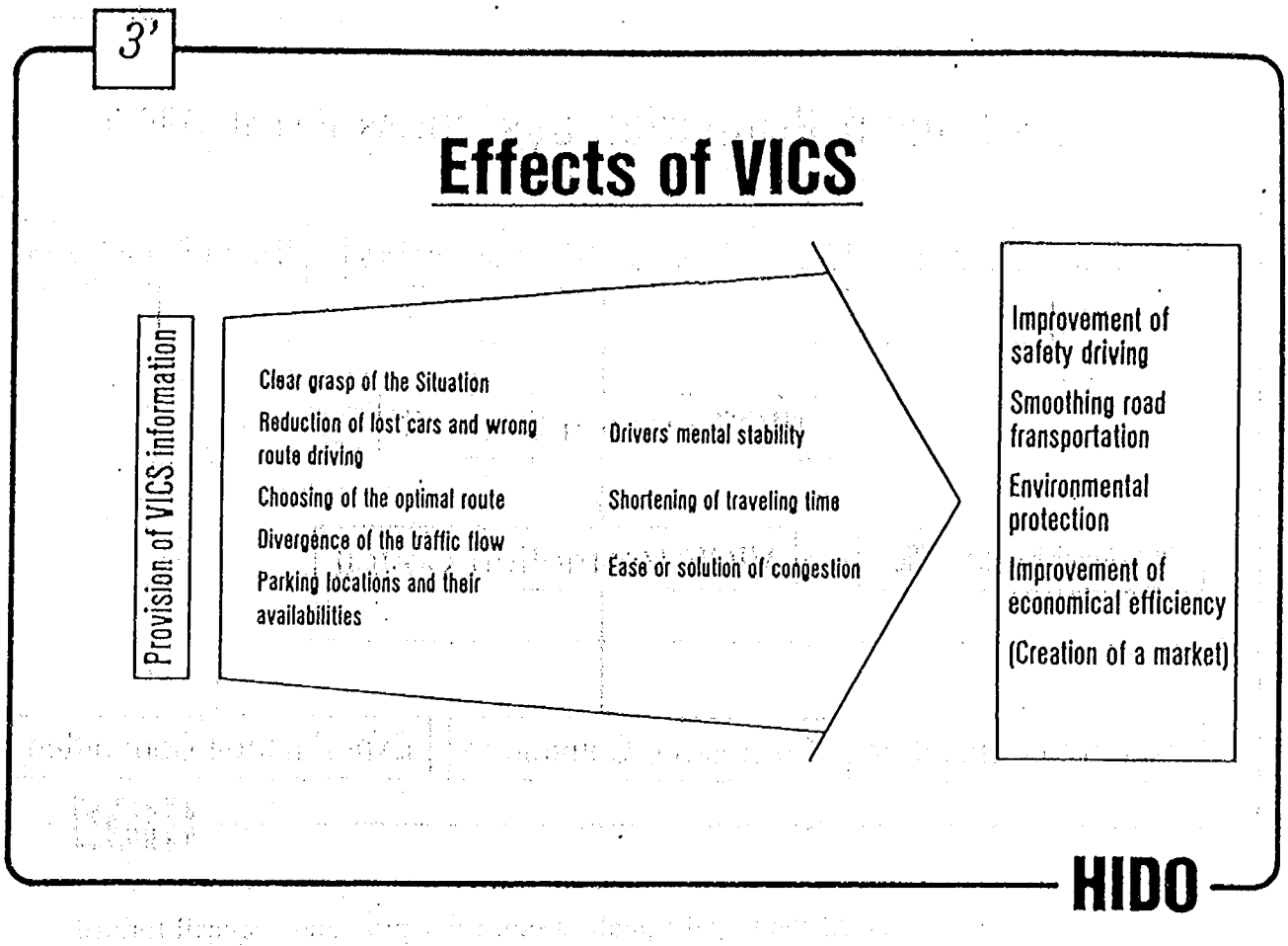
- Provision of road traffic information to moving vehicles
- Safe and smooth traffic movement and preservation of the environment
- Integration of information provision systems
- Harmonious development of all media

★Characteristics of VICS

- The pursuit of individual advantage benefits society as a whole

HIDO

- The purpose of VICS is to obtain information about congestion, parking availability, etc. from information sources, and provide it to drivers.
- Drivers will be able to use this information to choose which route to travel.
- The result will be safe, smooth, efficient traffic and a reduction in damage to the environment.
- With its implementation, it will be possible to integrate independently developed systems, effectively exploit radio frequency resources, and develop various classes of media in mutual harmony.
- The advantages obtained through the use of VICS will not only benefit drivers, but everyone who travels.

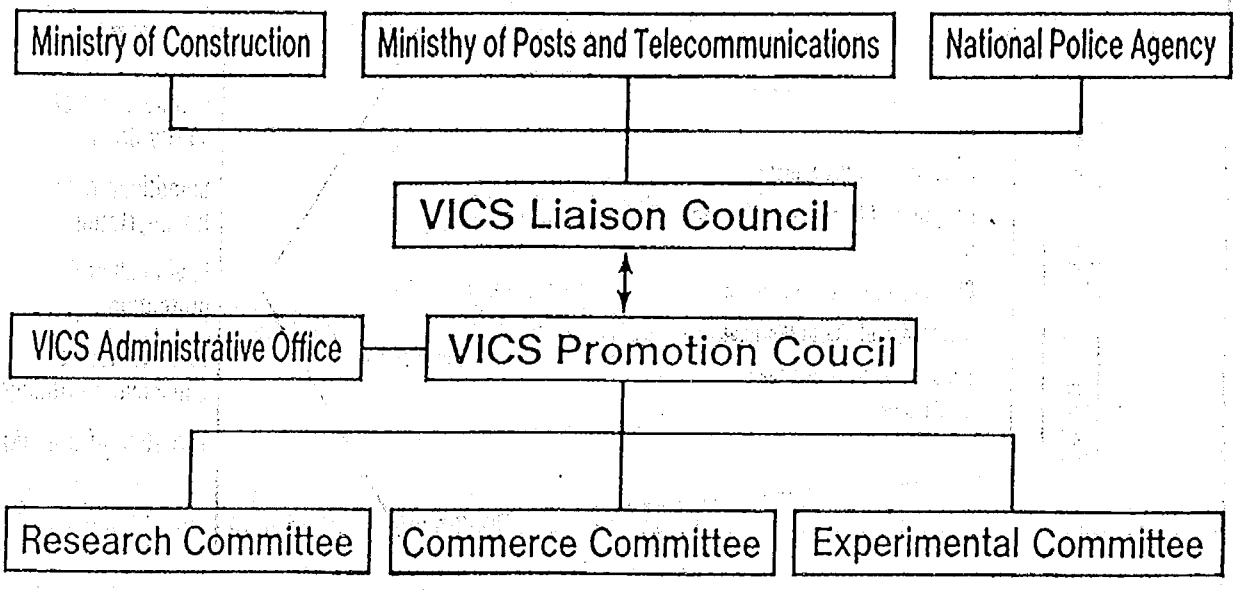


Effects of VICS

- This shows several effects of VICS.
- Thanks to information through VICS, drivers can easily choose their next step by themselves by learning the section and level of congestion, the temporary regulation by construction or accident, the optimal route to the destination, and the traveling time.
- As a result traffic flow diverges, leading to reduction of traveling time, ease or solution of congestion.
- Ultimately VICS can realize 'an unbelievable story' that the pursuit of individual advantage benefits society as a whole.

4

VICS Project Promotion System (As of April 1.1993)

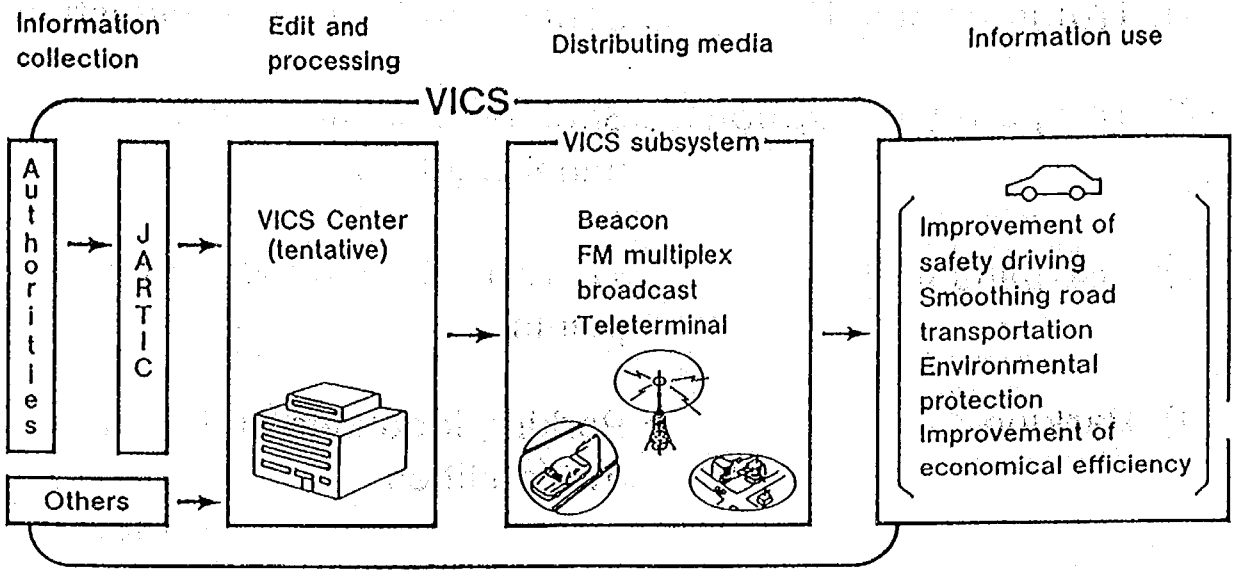


HIDO

- A liaison council established by the public sector and a promotion council formed by private sector companies are undertaking positive and broad-reaching activities while aiming at a mutual interrelationship in order to promote VICS.
- Actual VICS promotion work is the responsibility of three committees and eight subordinate subcommittees.
- The commerce committee is studying the basic form of VICS and the commercial operation of the system.
- The research committee is studying the systems to be used to handle the various kinds of media that will be part of VICS.
- The experimental committee is making all studies and preparations in order to achieve the success of VICS demonstration experiments.
- The key members of each committee and subcommittee are technicians from the information, communication, and automobile manufacturing industries.

5

General Concept of VICS



HIDO

- The above flow-chart presents the total VICS concept, with the flow of VICS information as its principal element.
- Roadway management bodies and traffic police, which have gathered road traffic information they need to carry out their administrative functions, will provide this information to VICS.
- To prepare this information for use, the VICS center (tentative name) will edit and process it, then distribute it to VICS subsystems.
- The VICS subsystems--information provision media--now being considered include beacons, FM multiplex, and teleterminals.
- At the final stage, benefits will appear as drivers use the information. These effects will only be realized when large numbers of drivers use the information, and VICS begins to make an ever greater contribution to society as a whole.

6

Information Service Items (Tentative)

(1) Traffic congestion : Section and level of congestion

(2) Temporary regulation : Section, time, and causes under controll

(3) Traveling time : Traveling time between two points

(4) Parking : Parking locations and their availabilities

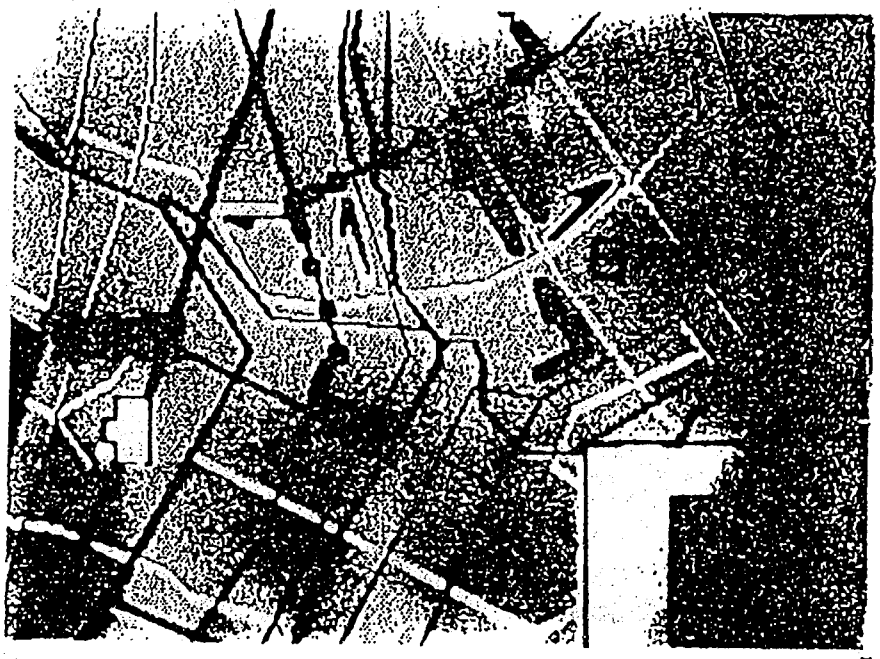
…etc.

HIDO

- The above are examples of the information which VICS is now expected to provide to drivers.
- The first class of road traffic information will be indications of sections of the road where traffic is congested and the level of this congestion.
- Secondly, it will provide information about temporary regulations: where and during what time periods they are in force, and their causes.
- The third class of information will be traveling time information, which will indicate the time needed for travelling through a particular section.
- Another type of road traffic related information VICS will provide will be parking lot information: locations of parking facilities, and information indicating whether or not each is full or can accommodate more cars.
- Accident information is also expected to be available.

7

Service Images (1) Map Display Format

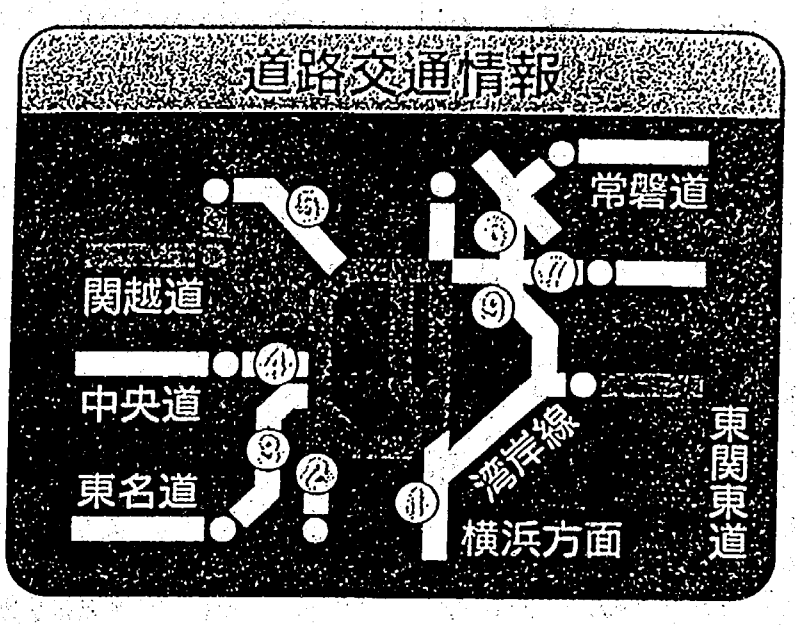


HIDO

- The next issue is the form in which drivers will be able to receive and utilize the information provided by VICS. Three representative forms of information presentation now at the concept stage are introduced below through demonstrations of how each will be used to present traffic congestion information.
- The first is the map display format.
  This method, one which will probably be used in high function in-car equipment, will display information from VICS by superimposing it on digitalized map data stored in the vehicle.
- As shown in the above example, roads, railway lines, and railway stations are displayed on the map, and various types of roads are indicated by different color lines.
- The VICS information is displayed along the sides of roadways indicating the location and level of congestion on each roadway.
- This in-car equipment provides a self-locating function, and the point of the ▲ indicates where the car is at any moment.
- One of the advanced functions of the in-car equipment uses VICS data to determine and indicate the optimal route. A line of black dots is used to indicate the optimal route around the congested area to the driver's destination, which in this case, is above the top of the map segment displayed on the screen.
- An advanced-function in-car equipment will also be able to provide left and right turn indications at intersections. In this example, the driver is being instructed to turn right at the next intersection by the arrow in the lower right corner of the screen.

8

(2) Map Display (Deformation Format)



HIDO

- The second example is a Deformation Format.
- With this type, deformation maps, diagrams, and letters are created at the VICS system media center, transmitted to cars as congestion information, and are displayed exactly as received.
- The in-car equipment is simplified, but its applications are limited.
- This example of congestion on an expressway near the center of Tokyo includes indications of the location (and level) of the congestion.

9

(3) Character Display Format

渋 滞　　12:50現在

東名高速 上り　　川崎-東京

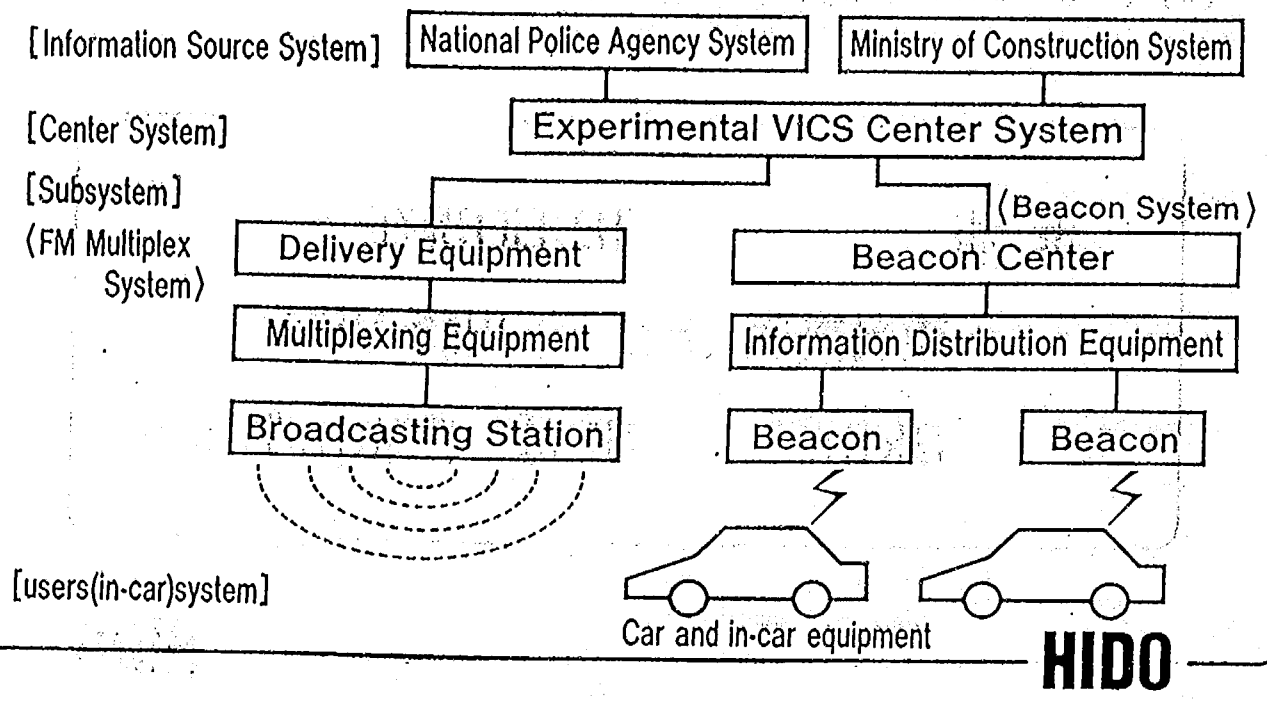
3km　　事 故　20km/h以下

HIDO

- This third example shows a display consisting only of letters and numbers.
- This letter and number information is provided for display on a relatively small screen on the in-car equipment.
- In this case, the display indicates the name of the road and the section of that road where the congestion has occurred, its length, cause, and level.
- The above are typical examples of ways in which drivers can make use of VICS information, but it is likely that various new approaches will be developed as a result of the popularization of the system and future studies of its application.

10

Conceptual Diagram of the VICS Demonstration and Testing System

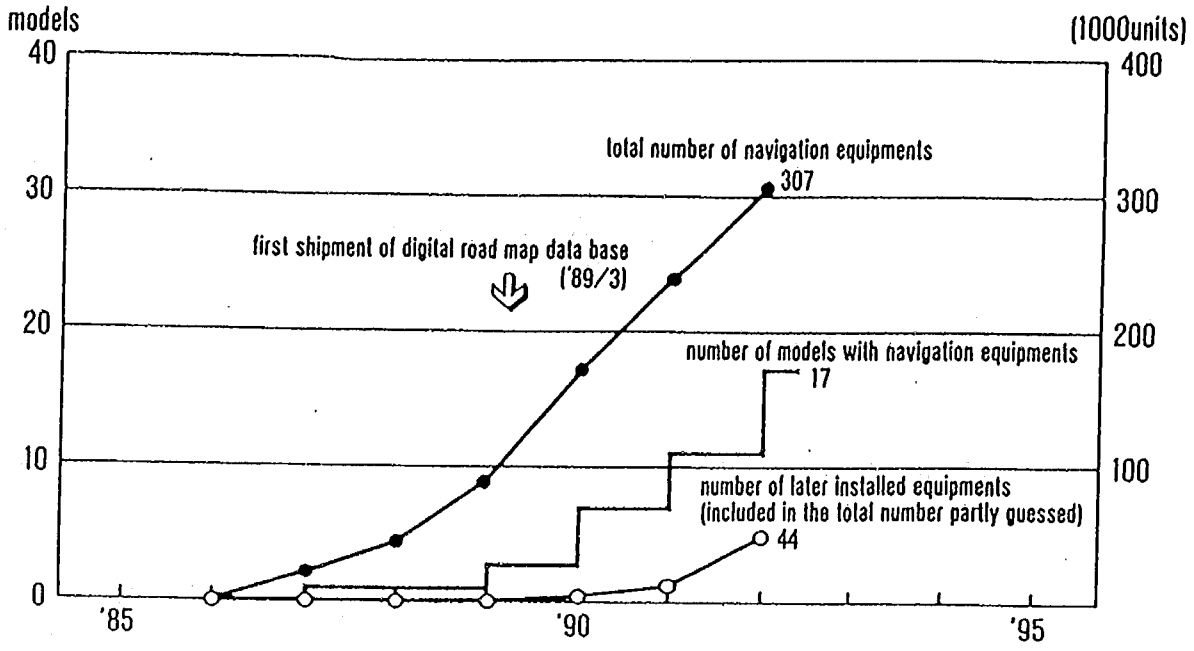


HIDO

- This is a conceptual diagram of the demonstration and testing system.
- Demonstrating and testing the system is an extremely important step if working systems are to be introduced and their use is to spread.
- This system will be used to increase public awareness of the social utility of VICS and to confirm and assess the technology used in the system.
- Testing will begin in June 1993 with a trial operation of the FM multiplex subsystem, and when all testing is completed, an open demonstration and trial will be performed on the ninth and tenth of November.
- The testing will be conducted within an area 20 kilometers by 20 kilometers in the center of Tokyo, and along an 84 kilometer stretch of the Tomei Expressway from Tokyo to Gotemba.
- The media used for the trials will be FM multiplex and beacons, and it will operate almost exactly like future working systems.
- The Testing ended successfully with the participation of about 2,000 people including three ministers, top officials of related agencies, academics, the media and so on.

11

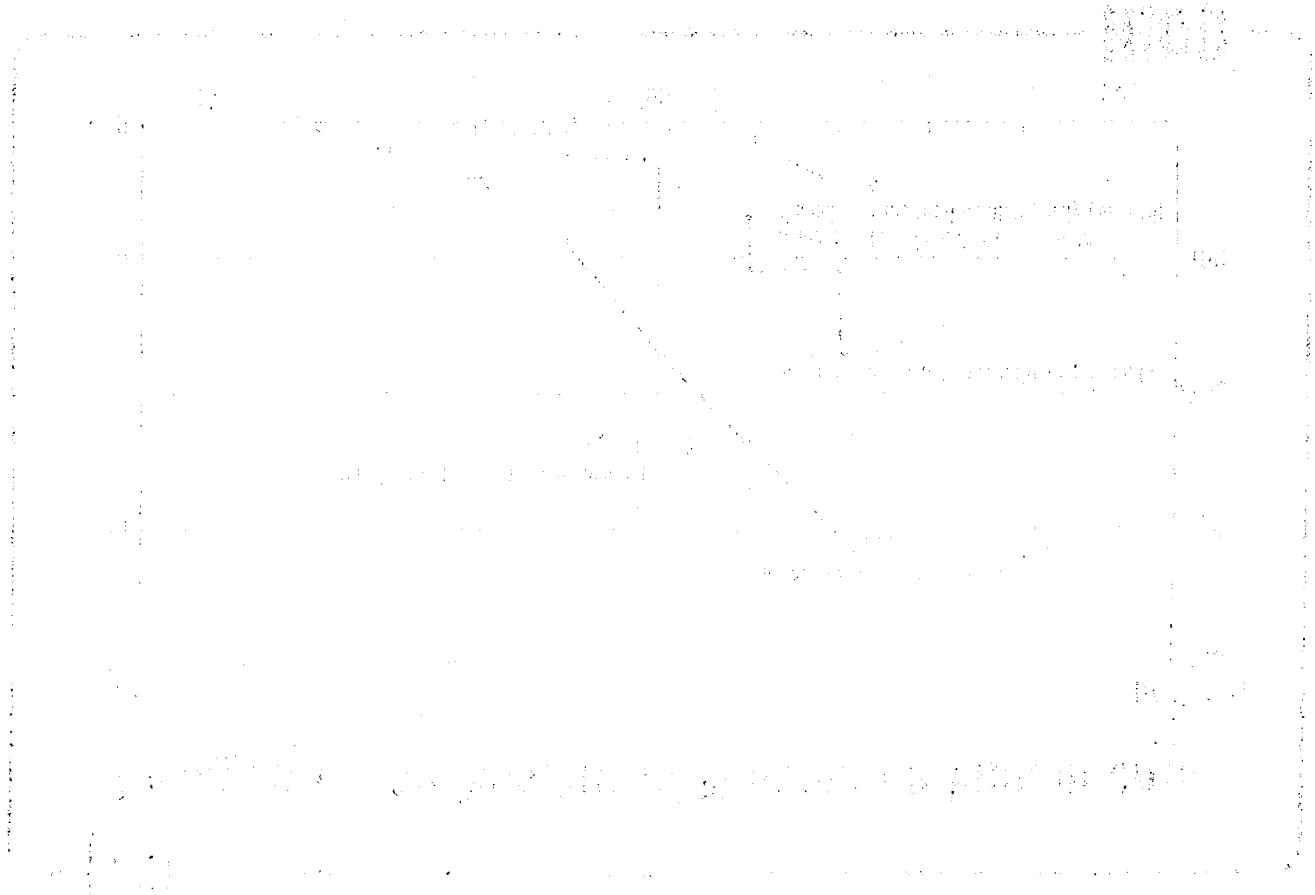
Changes in the Number of Navigation Equipments



HIDO

Foundations to realize VICS

- There is much social need for VICS due to road traffic conditions in Japan.
- Information which is necessary for implementation of VICS has been already collected through administrative need. So the next step is how to use it more effectively.
- In-car equipments have been upgraded. Especially the digital road map database for navigation completed the foundations to realize VICS.
- Navigation equipments have been already installed on more than 300,000 units, and recently sales have improved very much.



Current Status and Future Plans for Digital Map Database in Japan

September 12, 1993

Masao Shibata , Yasuomi Fujita

Japan Digital Road Map Association

(No.1)

Current Status and Future Plans for Digital Map Database in Japan

1 Japan Digital Road Map Association (JDRMA)

2 Digital Road Map Standards

3 Current Status of JDRMA Database Production

4 JDRMA Database Applications

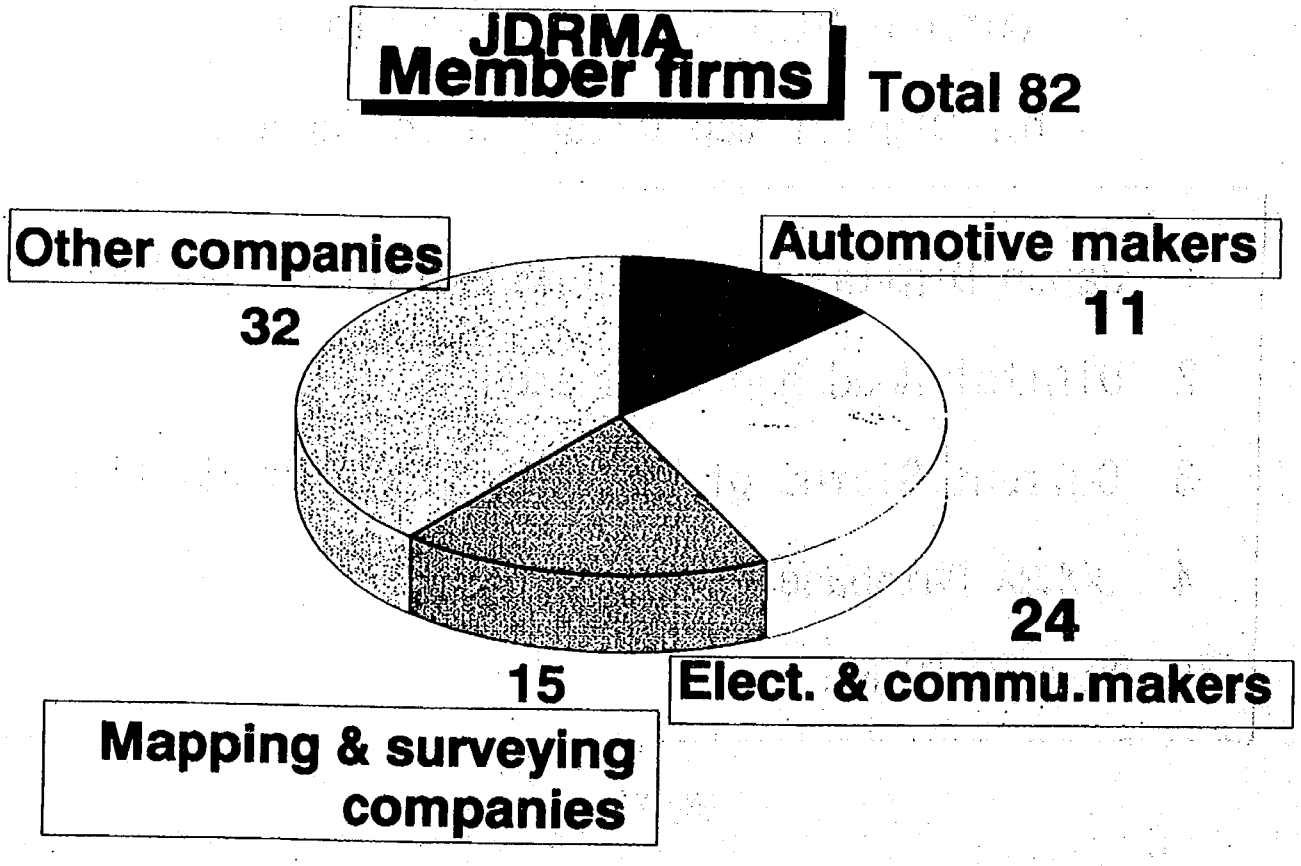
5 Future Plans

(No.2)

DRM Database and JDRMA

- Digital Road Map (DRM) Database is indispensable to the development of car navigation systems and other systems in the field of IVHS /ATT.
- RACS Research Group proposed in 1987 DRM Database using standardized specifications must be constructed as early as possible.
- Japan Digital Road Map Association (JDRMA) was established in August of 1988 supported by MOC.

(No.3)



(No.4)

Objectives of JDRMA

- Establishment of the standards for DRM Database
- Production, Maintenance, and update of DRM Database
- Making DRM Database available to the interested users
- Survey and study of DRM

(No.5)

Standardization of Digital Road Map

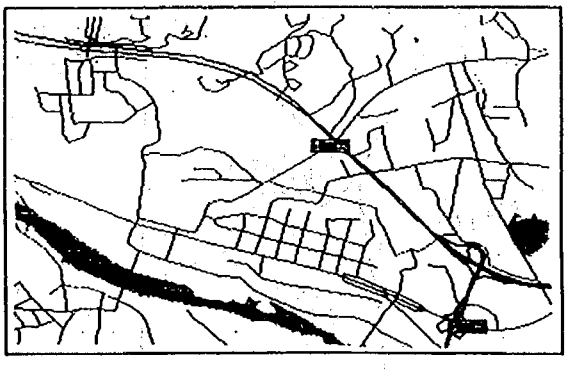
- Classification of road network

  ■ Basic road network

  National & prefectural roads and other roads wider than 5.5 m

  ■ All road network

  Basic road network and other roads wider than 3 m

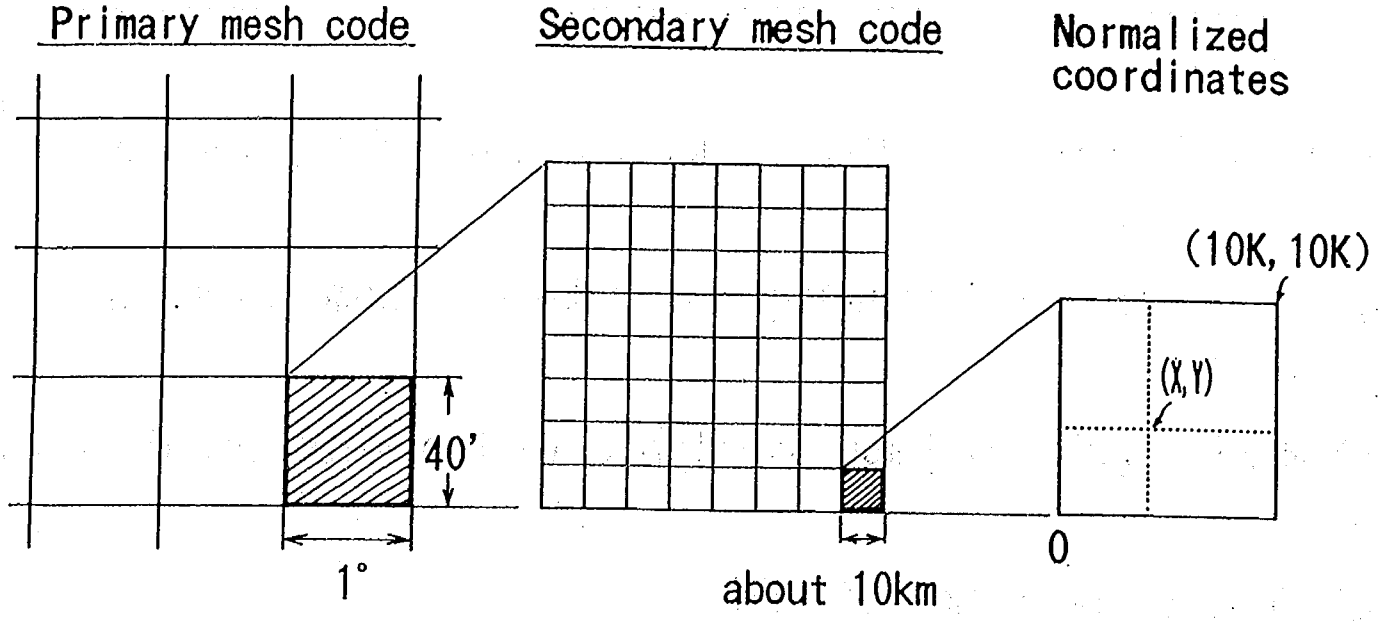




example 0 500 1000(m)

(No.6)

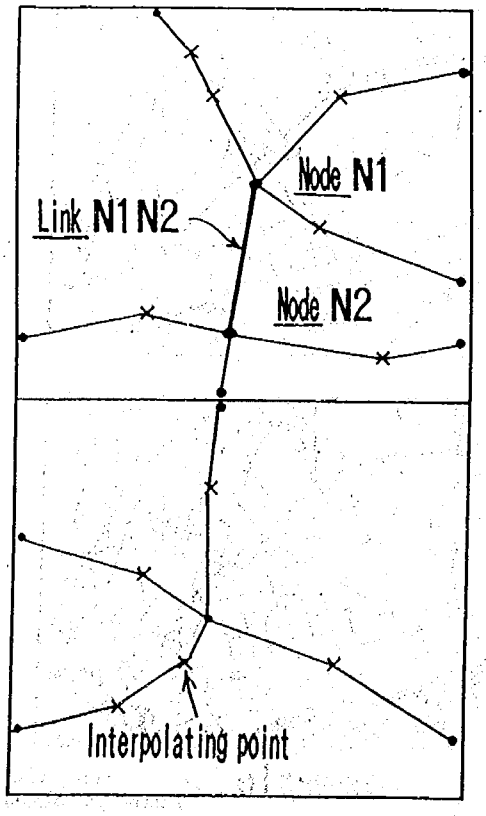
Expression of location



Standard Regional Grid and
Mesh Code System in 1973
by Administrative Management Agency

(No.7)

Expression of Road Line



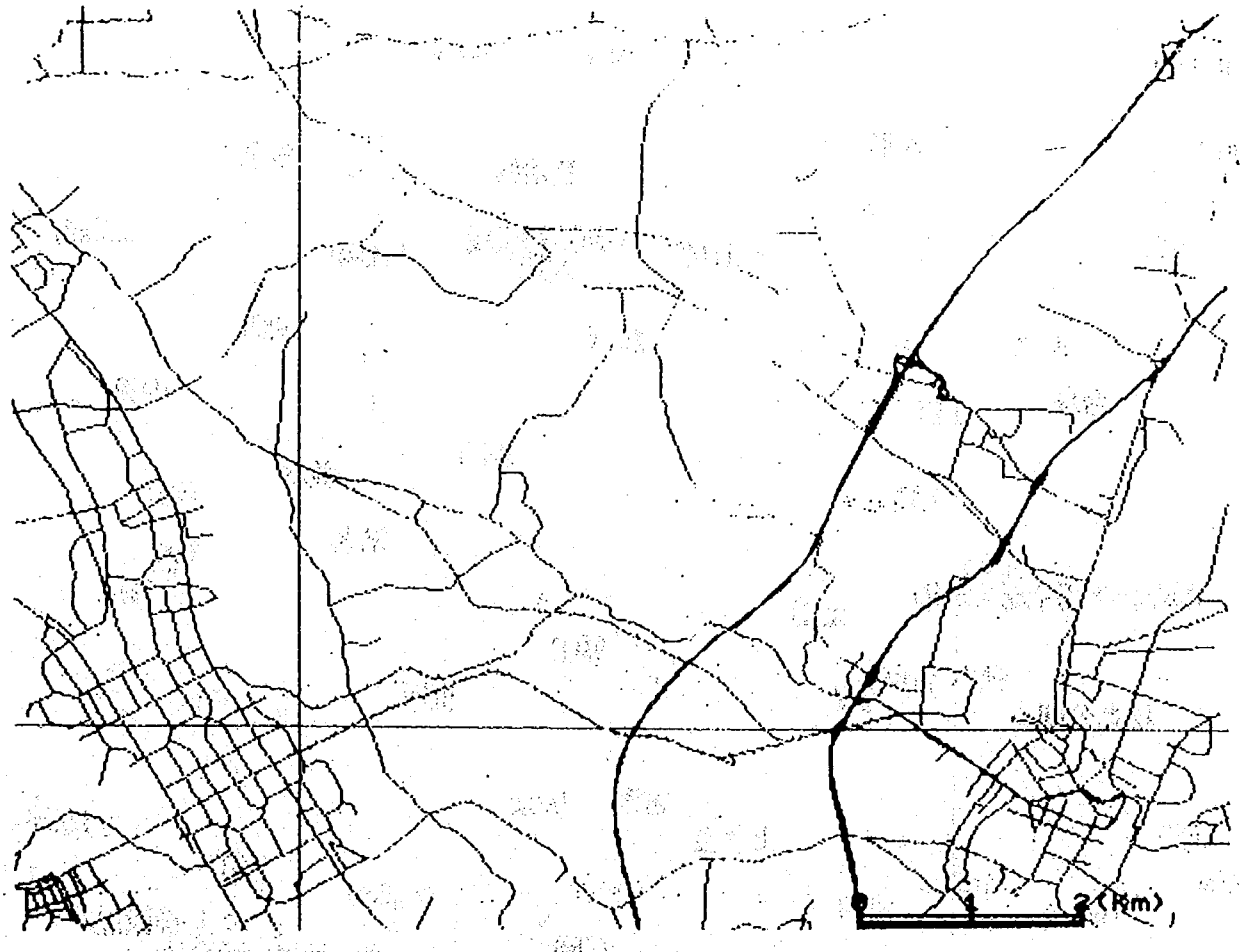
- **Node** ;
  - Intersections
  - Dead-ends
  - Road attributes changing points
  - Unique number in secondary mesh
- **Link** ;
  - Combination of node numbers
- **Road** ;
  - Combination of nodes and links

(No.8)

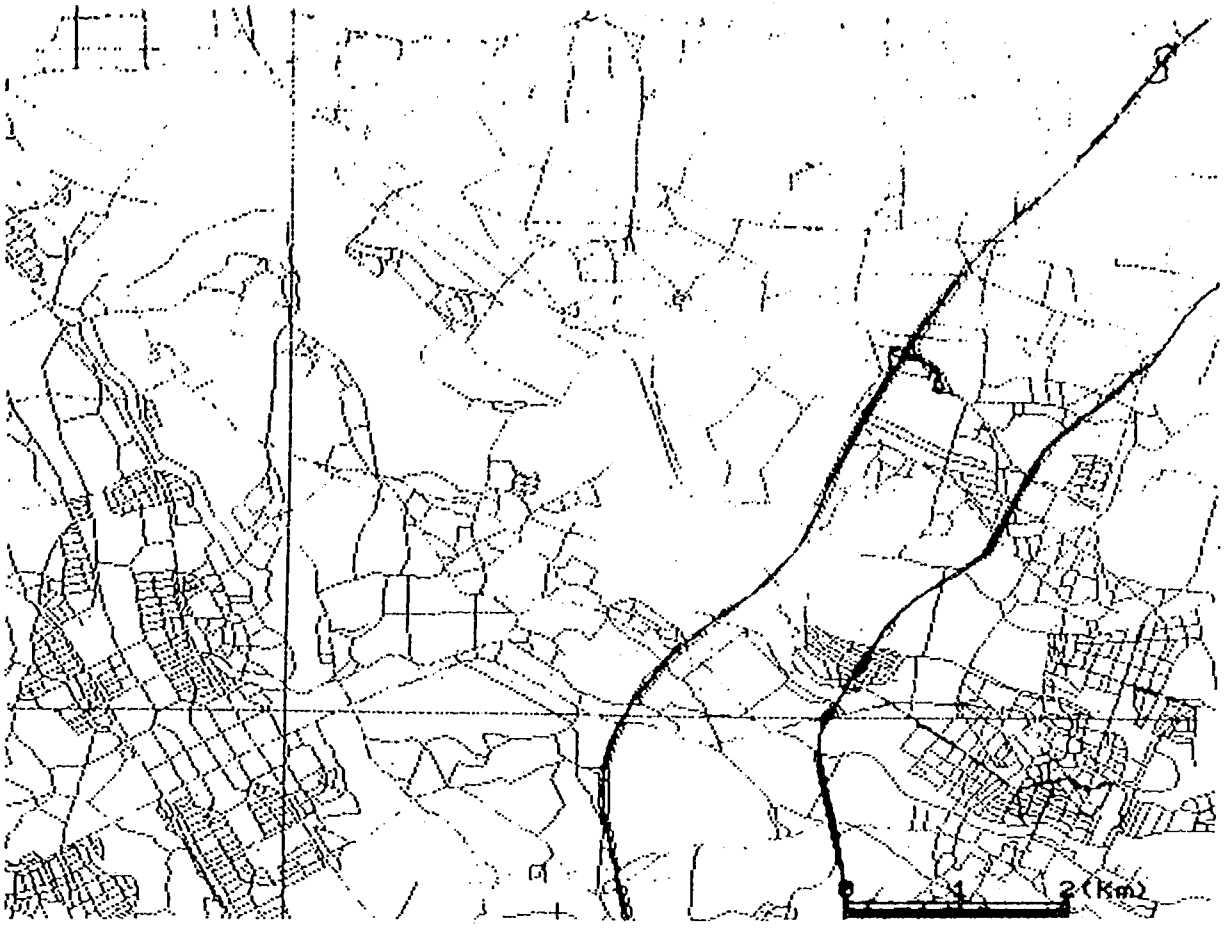
Structure of JDRMA's DRM Database

Control data	・data necessary to control the data for secondary mesh
Basic road data	・node and link data ・link attribute data ・reference between basic and all road data
All road data	・node and link data
Background data	・water system data ・location data of administrative boundary, railroad, and facility ・facility shape data ・location data for place name display

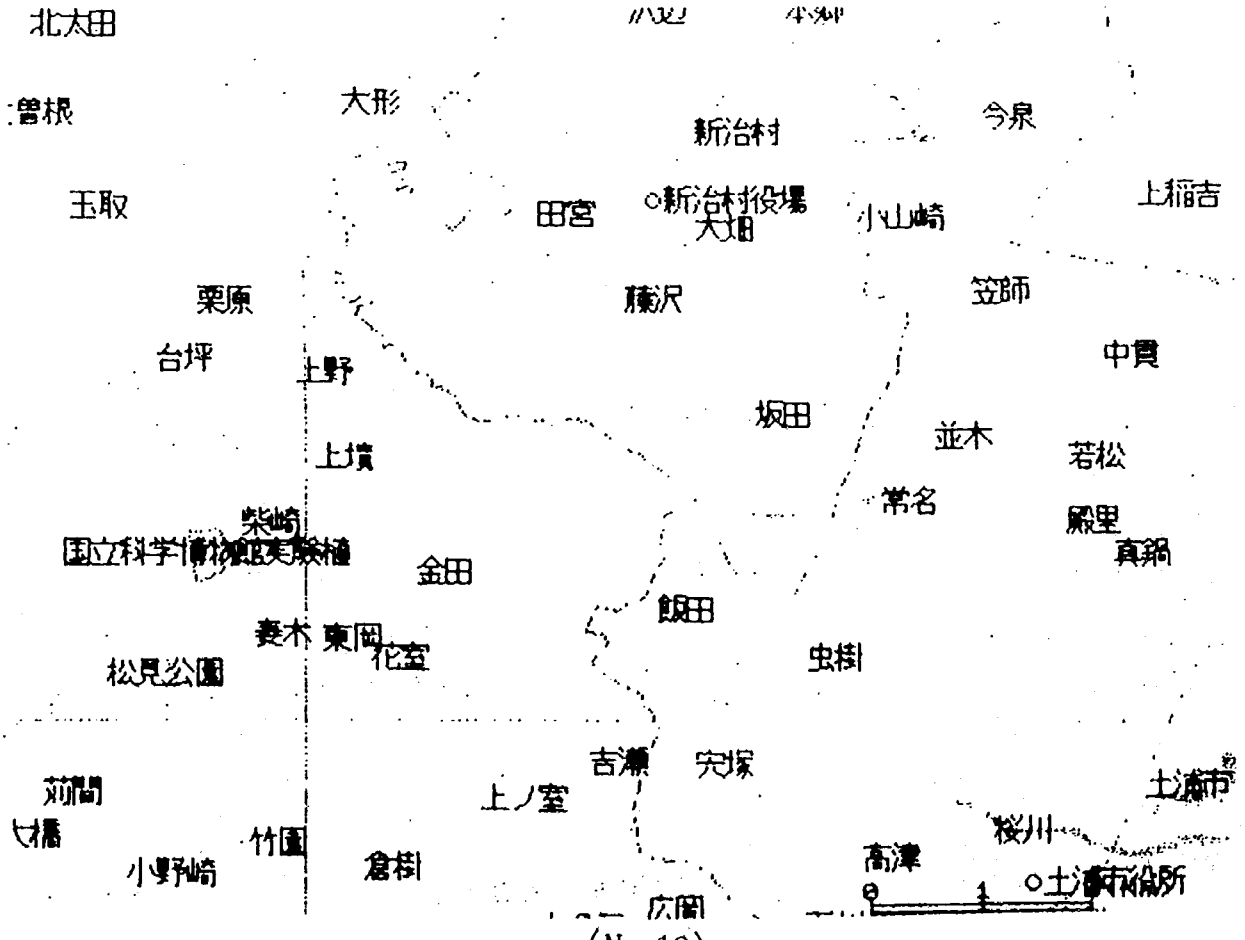
(No.9)



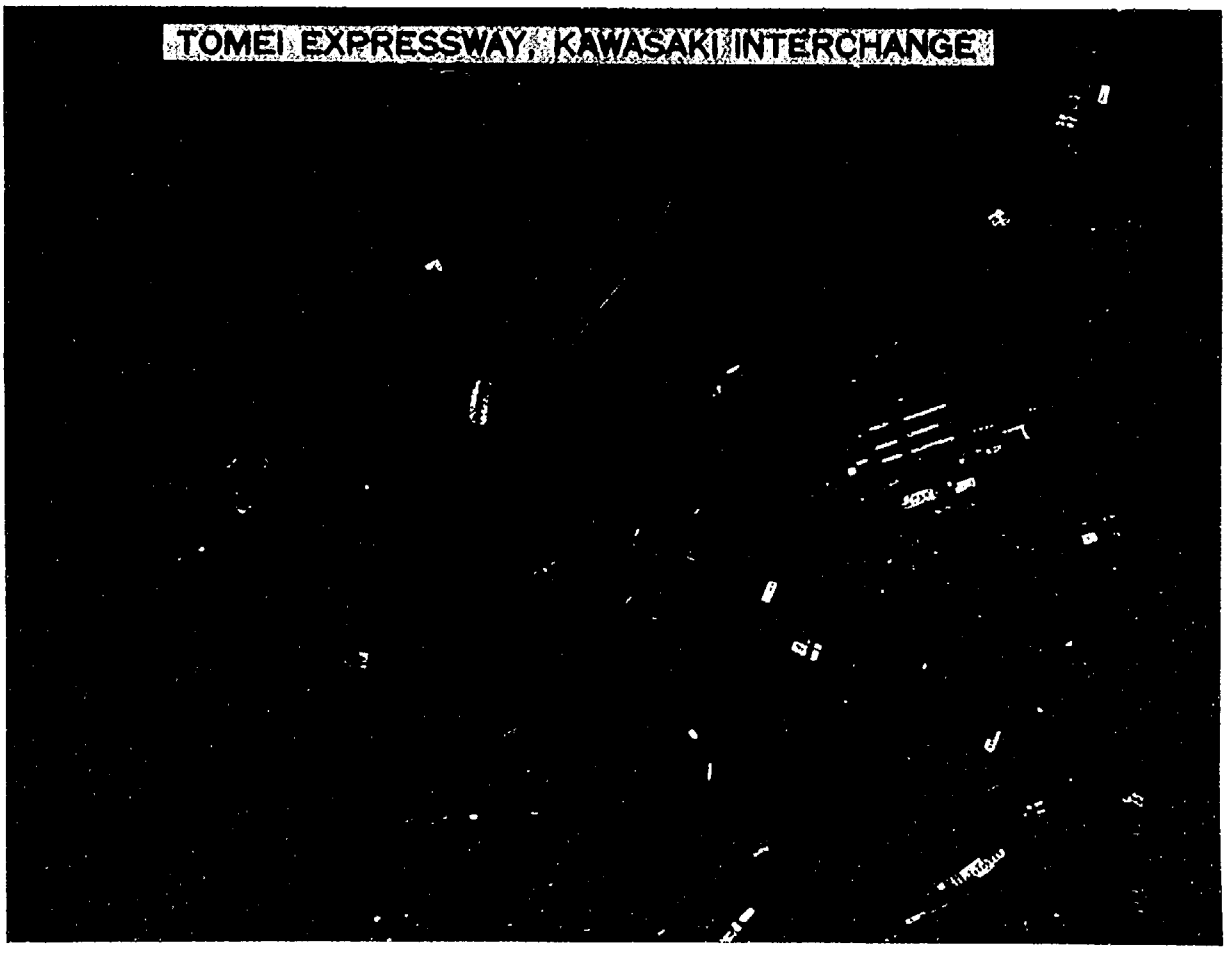
(No.10)


0
1
2(Km)

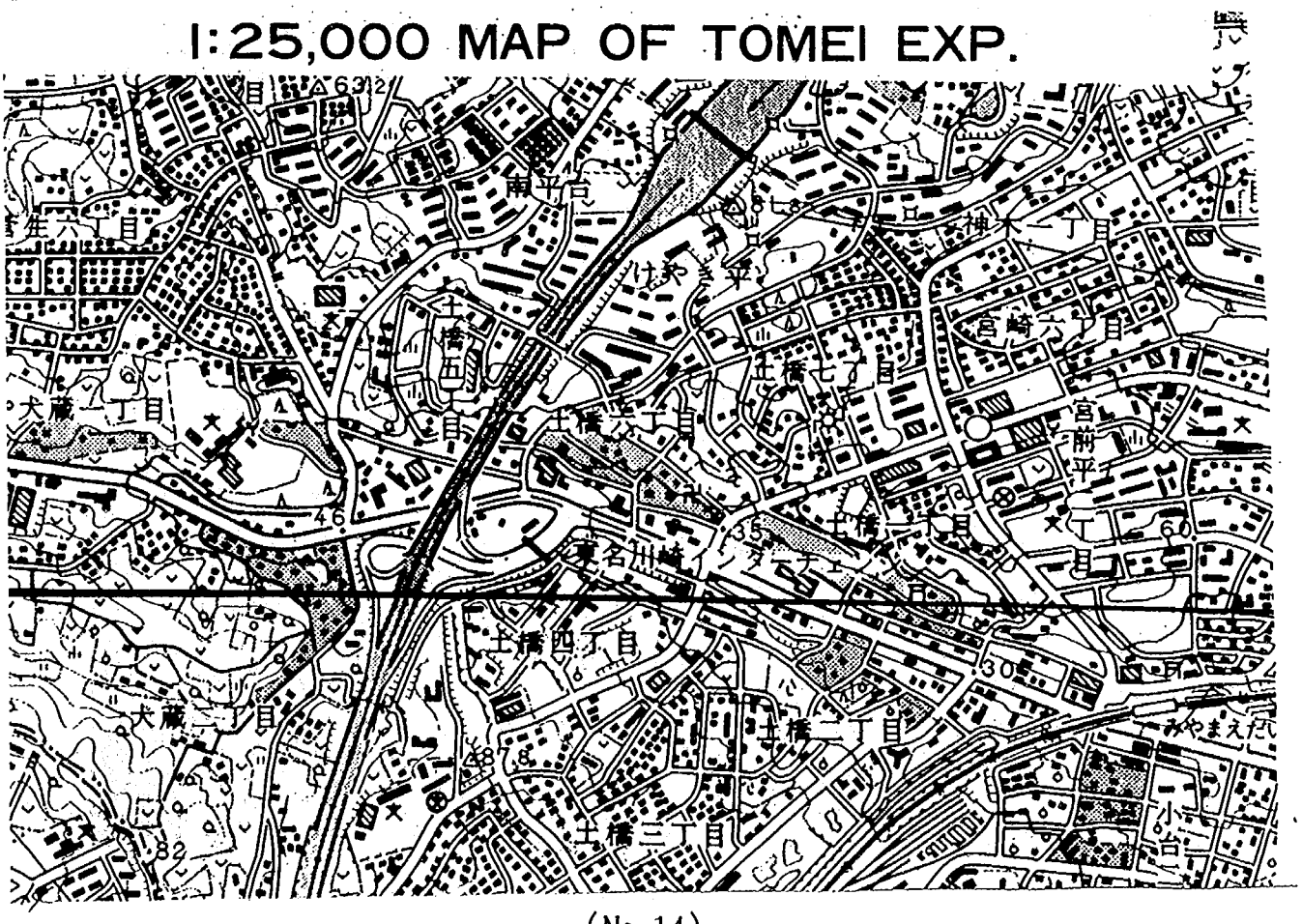
(No.11)


北太田
大形
新治村
今泉
玉取
田宮
新治村役場
大畑
小山崎
上稲吉
栗原
藤沢
笠師
台坪
上野
中貫
坂田
並木
上境
若松
常名
柴崎
殿里
金田
真鍋
飯田
妻木
東岡
花室
虫掛
松見公園
吉瀬
宍塚
上ノ室
竹園
倉掛
小野崎
高津
桜川
広岡
0
1

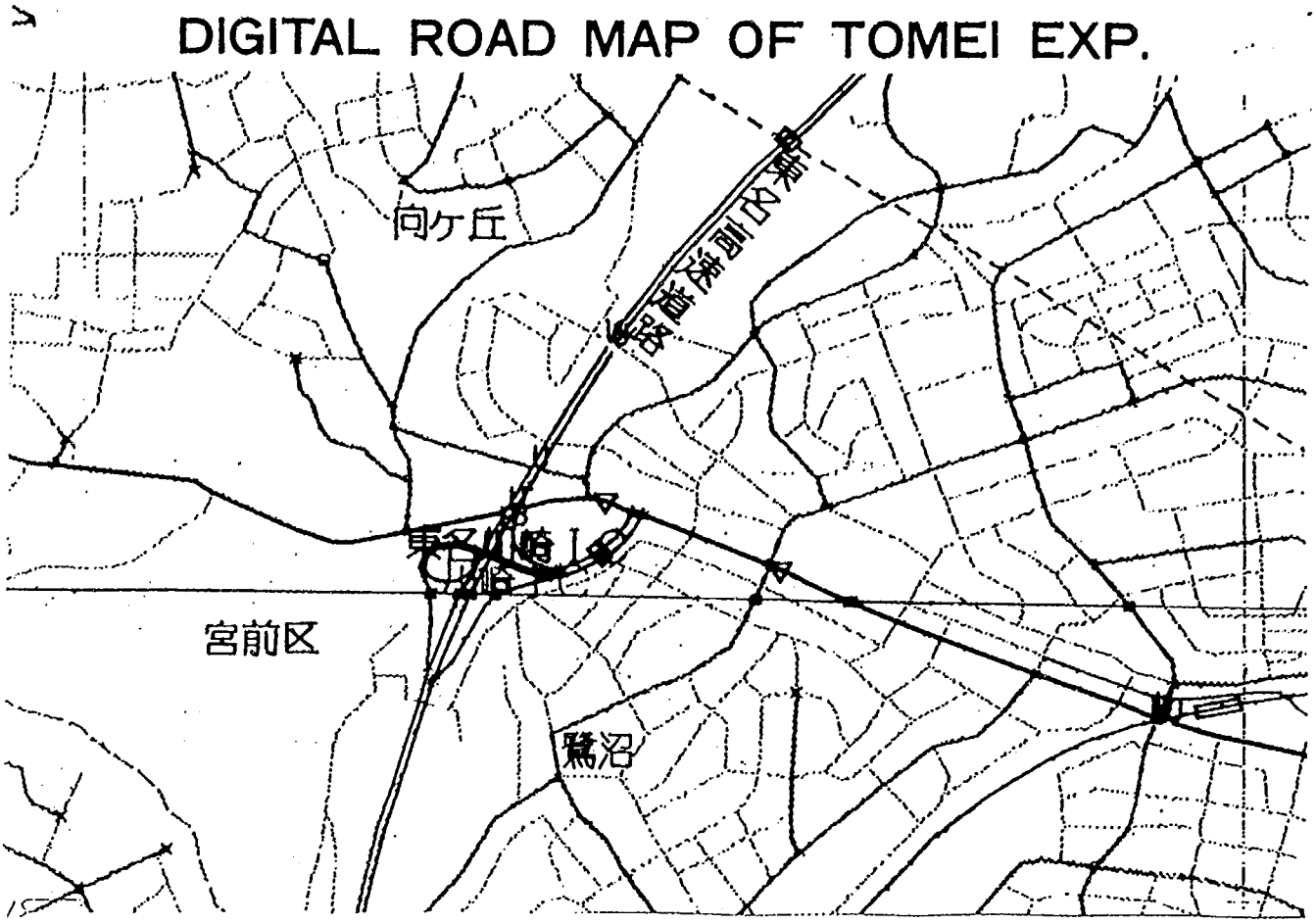
(No.12)


TOMEI EXPRESSWAY KAWASAKI INTERCHANGE

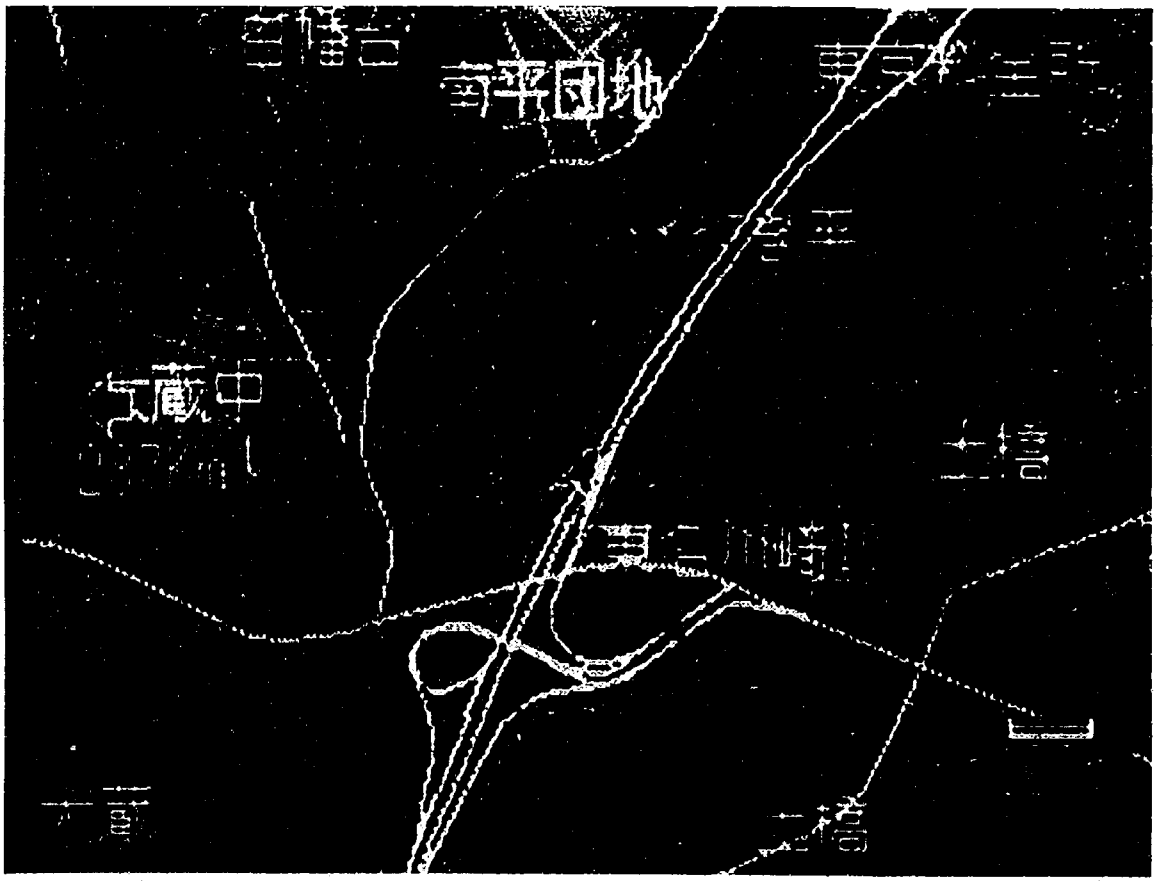
(No.13)


1:25,000 MAP OF TOMEI EXP.
南平台
けやき平
宮崎六丁目
宮前平
土橋七丁目
土橋六丁目
土橋五丁目
土橋四丁目
土橋二丁目
土橋一丁目
土橋三丁目
東名川崎インターチェンジ
大蔵一丁目
大蔵二丁目
小台一丁目
みやまえだい
生六丁目
神木二丁目

(No.14)



(No.15)



(No.16)

Data sources for DRM database

■ Topographical maps (updated every 3 ~7 years)

- 1/ 25,000 scale
- 1/ 50,000 scale

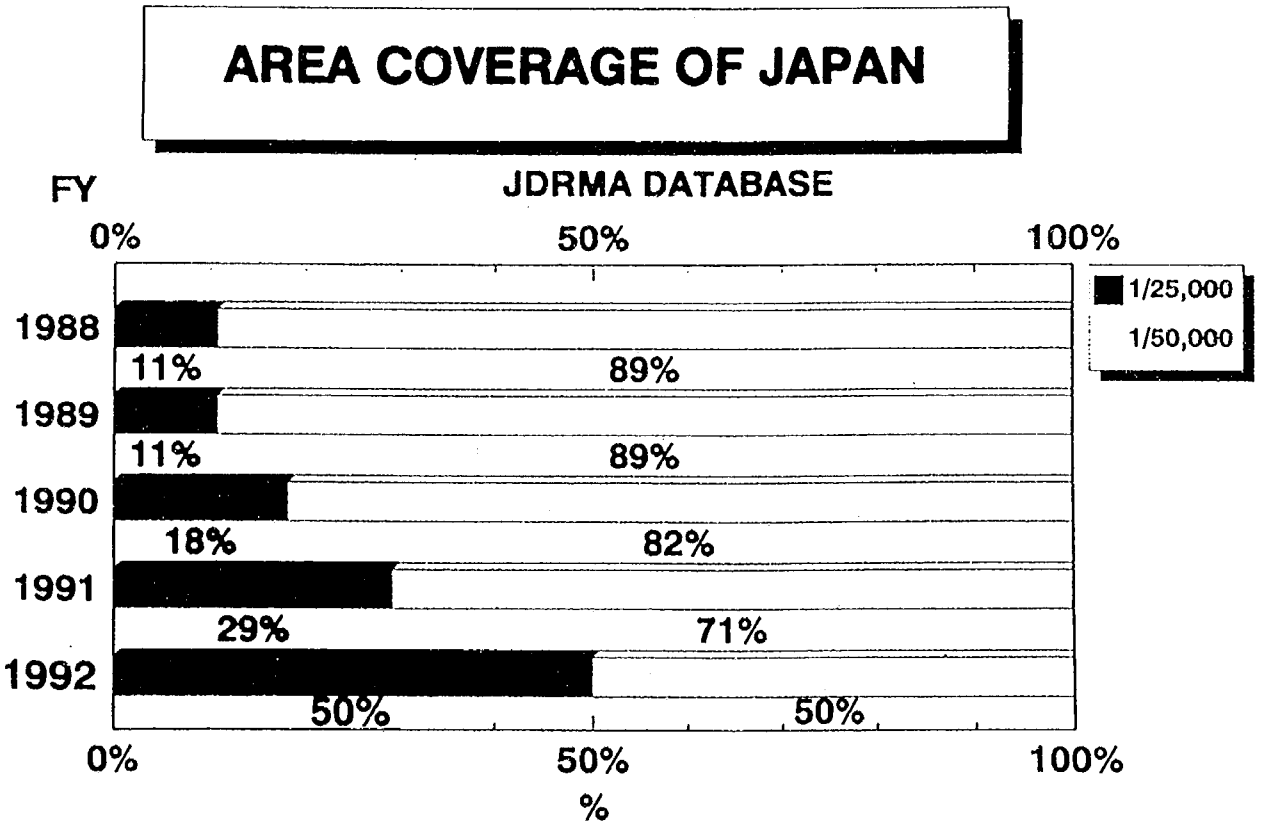
■ Road Data Provided by Road Administrators (updated every year)

- MOC's Regional Construction Bureaus
- Offices of prefectures & large cities
- Public road & highway agencies and corporations

■ Other Reference Materials and data (updated every year)

- Railroad data
- Public facility data

(No.17)



(No.18)

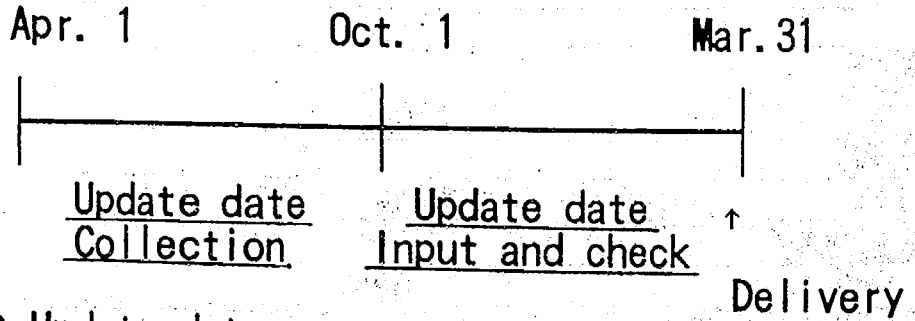
Road Administration Use

- Beacon Location Data
- Regulation Data for Special Vehicles
- Road Traffic Census Data
- Distance Markers Data
- Vehicle Detectors and ITV Data
- Road Info. Boards and Roadside Comm. Data
- Closed-in-Winter Data

(No.19)

Data Maintenance

- Update date : October 1
- Updated database made available : March 31



- Update data:
  - new topographical maps
  - road administrators data on new and renovated roads

(No.20)

JDRMA Database Supporting Member

- NISSAN MOTOR
- HONDA MOTOR
- TOYOTA MOTOR
- MAZDA MOTOR
- NIPPONDENSO
- SUMITOMO ELECTRIC
- PIONEER ELECTRONICS
- MITSUBISHI ELECTRIC
- HITACHI
- MATSUSHITA ELECTRIC
- NEC HOMEELECTRONICS
- OMRON
- FUJITSU TEN
- NTT
- ZENRIN

(No.21)

■ Vehicle Control field

- Car navigation system
- Car location system
- Freight control system
  - Optimal transportation routing
- Communication satellite based operation management system (OMNITRACS)
- Vehicle Information and Communication system (VICS)
  - Dynamic road traffic information

■ Road Planing and Control field

- Road sign checking system
- Traffic accident analysis system
- Road census reference system
- Logistics system

(No.22)

JDRMA Database Based Navigation Systems

DATABASE USER	SYSTEM NAME	CAR MODELS
●MAZDA MOTOR	●CCS	●UNOS COSMO
●SUMITOMO ELECTRIC (MITSUBISHI MOTORS)	●MMCS	●DIAMANTE, DEBONAIR GALANT, SIGMA, ETERNA
(SUZUKI MOTOR)	●SNS	●ALTO WORKS
●PIONEER ELECTRONICS	●SATELLITE CRUISING SYSTEM	●AFTER-MARKET
●HONDA MOTOR	●HONDA NAVIGATION SYSTEM	●LEGEND ACCORD
●TOYATA MOTOR	●ELECTRO MULTI VISION	●SOARER, CROWN CELSIOR MARK II, CRESTA, CHASER
●NISSAN MOTOR	●MULTI AV SYTEM	●GLORIA, CEDRIC CIMA

TOTAL 153,000 VEHICLES (the end of June, 1993)

(No.23)

Future Plans

- Digitalization by 1/25,000 scale maps of all Japan
- Adoption of larger scale maps
- Freshness and Reliability
- Enhancement of traffic information

(No.24)

Adoption of Larger Scale Maps

- 1/25,000 Scale Maps
  2,325 meshes
- 1/50,000 Scale Maps
  2,416 meshes

⇩

1/25,000 Scale Maps

⇨

Partially
- 1/10,000 Scale Maps

⇩

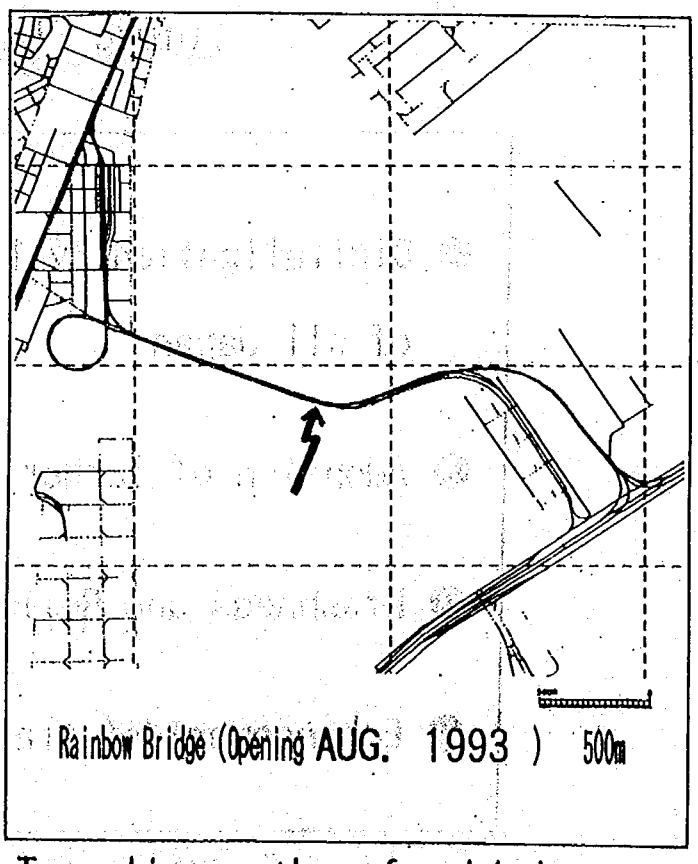
Partially
- 1/2,500 scale Maps

(No.25)

Freshness and Reliability

- Detailed plans
- Direct data input from aerial photographs
- Direct conversion from travelling paths of vehicles

  Vehicle is equiped with high-precision location detecting capability

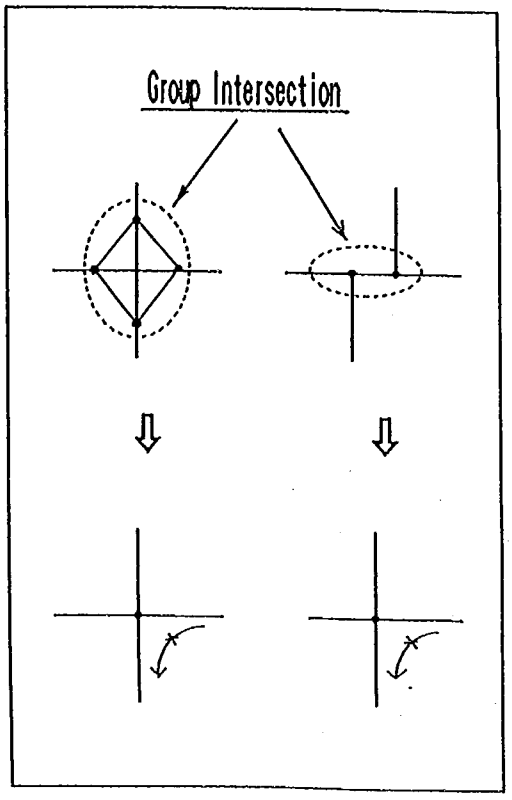


Traveling paths of vehicle

(No.26)

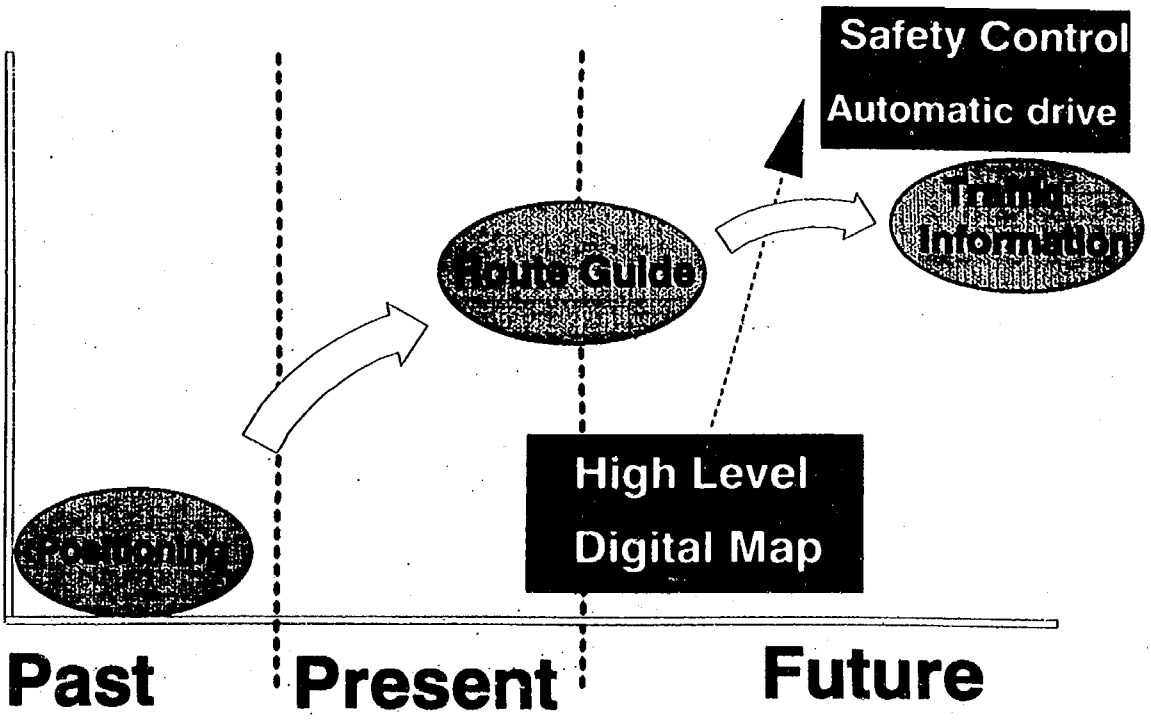
Enhancement of Guidance Information

- ● Traffic regulation information
- ● Names of intersections
- ● Information on facilities around intersections
- ■ Concept of Group Intersection
- ■ Cooperation of other organization



(No.27)

Car navigation development process



(No.28)

PRESENT STATUS OF IVHS IN CANADA

Presented to

Japan/Canada Workshop on
Advanced Highway Systems

December 5 - 12, 1993

by

M.D. Harmelink

IVHS Canada

Ontario Ministry of Transportation

1

(No.1)

IVHS Canada

- Joint body for coordinating IVHS activities in Canada
- Disseminates information and promotes the development and implementation of IVHS products and services in Canada
- Compiles databases:
  - Active IVHS projects
  - AVLN - Automatic Vehicle Location and Navigation Systems
- Responsible to TAC (Transportation Association of Canada) through the R&D Council
- Membership from industry, governments, agencies and universities

2

(No.2)

OVERVIEW OF IVHS IN CANADA

- Most activities decentralized (Jurisdictional - Federal/Provincial responsibilities)
- National coordination through IVHS Canada - not yet a national program in Canada of the type of VICS, NeGHTS, PROMETHEUS, DRIVE
- Strategic plans at provincial level
- Activities also being conducted by municipalities, private sector, universities
- Leadership at provincial level
- Many industrial players supplying Canadian and U.S. projects

3

(No.3)

SOME IVHS APPLICATIONS IN CANADA

- Applications in many areas of
  - ATMS - Advanced Traffic Management Systems
  - ATIS - Advanced Traveller Information Systems
  - CVO - Commercial Vehicle Operations
  - APTS - Advanced Public Transportation Systems
- Less in AVCS - Advanced Vehicle Control Systems

4

(No.4)

ATMS - ADVANCED TRAFFIC MANAGEMENT SYSTEMS

- Currently, Canada is implementing and operating advanced traffic management systems:
  - Advanced TOC's (Traffic Operations Centres)
  - Communications systems
  - Improved Traffic Detectors
  - Changeable Message signs
  - Real-time traffic information systems

5

(No.5)

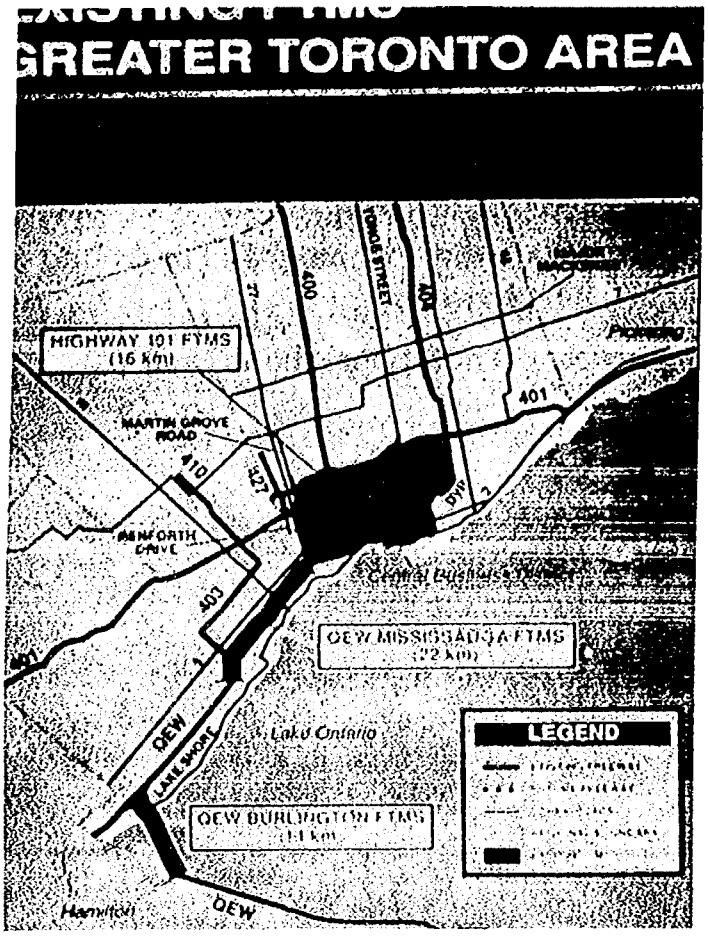
ATMS (cont'd)

TYPICAL SYSTEMS

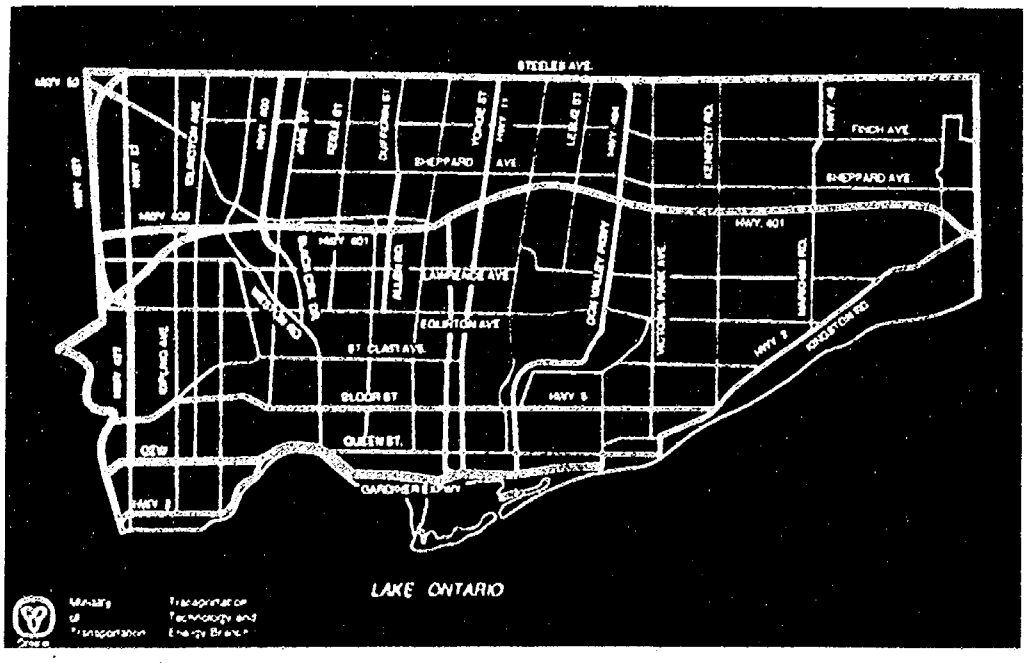
- Freeway Traffic Management Systems
  - Incorporate traffic detectors, changeable message signs, fibre optic communications, ramp metering, TOC's (Traffic Operations Centres)
  - Applications include Montreal Freeway Traffic Management System, (FTMS); Toronto's COMPASS and FTMS; Ontario's Queen Elizabeth Way
- Corridor Management Systems
  - Application - Toronto's Gardiner Expressway/Lakeshore Road
  - Managing a controlled access freeway and a major arterial as an integrated corridor
  - Uses both cameras and loop detector
  - Incorporates a "situation room" for coordinating emergency responses

6

(No.6)


GREATER TORONTO AREA
HIGHWAY 101 FTMS
(16 Km)
MARTIN GROVE ROAD
BENFORTH DRIVE
400
TORONTO STREET
401
410
427
DVP
403
QEW MISSISSAUGA FTMS
QEW
LAKE SHORE
Lake Ontario
QEW BURLINGTON FTMS
Hamilton
LEGEND

(No.7)


STEELES AVE.
SHEPPARD AVE.
FINCH AVE.
HWY. 401
EGLINTON AVE.
ST. CLAIR AVE.
BLOOR ST.
QUEEN ST.
QEW
LAKE ONTARIO

(No.8)

ATMS (cont'd)

TYPICAL SYSTEMS

- Computerized traffic control systems

  - Installed in many of Canada's larger cities
  - Pioneers in first installations - Toronto in 1963
  - Third generation types currently being implemented in several smaller cities (Populations <100 000)

- Adaptive traffic control systems

  - SCOOT - Split Cycling Offset and Optimization Technique

    - System automatically measures traffic, and activates and sequences traffic lights depending on traffic conditions
    - uses loop detectors to measure traffic, sends data to computer for processing and subsequent activation of traffic signals
    - pilot systems in Red Deer, Halifax, Toronto

7

(No.9)

ATMS (cont'd)

TYPICAL SYSTEMS

- Adaptive Timing Systems

  - Adaptive Timing Plan Calculation Program

  - A Signal Timing program for Progressed Corridors

  - Used on TransCanada and King George Highways in British Columbia

  - Uses traffic count data as well as expert systems and other specialized software to calculate optimum timing for traffic signals

8

(No.10)

ATMS (cont'd)

TYPICAL SYSTEMS

- Adaptive Systems for Reverse Flow Traffic Lanes
  - Intelligent Real-Time Contraflow System
  - Optimization of contraflow initiation and of time of operation based on real-time traffic flow
  - Currently being developed for use in British Columbia
  - Simulation results and field tests are promising

9

(No.11)

ATMS (cont'd)

ADVANCED ELEMENTS IN SOME SYSTEMS

- Traffic Detectors
  - Overhead Cameras - Montreal's FTMS, Toronto's COMPASS
  - Microwave Detectors
    - Road Traffic Microwave Sensor (RTMS)
    - Product of Ontario R&D
    - Test installations throughout Europe and North America

10

(No.12)

ATMS (cont'd)

ADVANCED ELEMENTS IN SOME SYSTEMSINTEGRATION

- Simulation

  VAPS - Virtual Applications Prototyping System - system in Montreal which uses computers to simulate and predict traffic conditions and for linking road sensors, video cameras, traffic operations centre and changeable message signs

  INTEGRATION - computerized software for simulating and optimizing traffic flow in large networks: permits testing of IVHS elements
  - test installations in several North American cities including Orlando (for TravTek) and in Atlanta

11

(No.13)

ATIS - ADVANCED TRAVELLER INFORMATION SYSTEMS

Systems available to give drivers information about weather, traffic, road construction

- Changeable message signs - in many of the freeways around large cities - Montreal, Toronto, Vancouver
- Real-time weather information service along British Columbia's Coquihalla Freeway and Okanagan Connector Freeway - which often encounter icy conditions in winter
- TRIS, Ontario's Traffic and Road Information Service - in which users may get information by fax and pagers

12

(No.14)

ATIS (cont'd)

Systems available to give transit users information about real-time bus arrival times

- In-station electronic displays of Bus Arrival Information - Ottawa, Kitchener
- Phone-in Bus Stop Information - Mississauga's Telerider
- Montreal's Visual Communication Network for the visual and hearing impaired

13

(No.15)

ATIS (cont'd)

- Several jurisdictions are expanding existing systems and planning or implementing new ones which will give the most up to date information to drivers and transit users
- Among the most advanced of these is Ontario's TravelGuide project which will bring real-time information about traffic, transit, and other travel conditions directly to the user through a hand-held computer
- It will assist drivers and transit users with navigation and route guidance
- TravelGuide is the subject of a separate presentation to be given later in the visit.
- More details will be given then.

14

(No.16)

REAL-TIME TRAFFIC INFORMATION SYSTEMS

The vital element in many IVHS systems including ATIS and ATMS (Advanced Traveller Information Systems and Advanced Traffic Monitoring Systems)

- MTIPS - Metropolitan Transportation Information Production System
  - Pilot system in Toronto for collecting, processing, and disseminating real-time traffic information in Toronto
  - Information for arterial roads (currently) extracted from transit data
  - Information for freeways based on FTMS (Freeway Traffic Management System)
  - Will incorporate data from the municipal traffic agency as well as from other sources, including emergency services

15

(No.17)

CVO - COMMERCIAL VEHICLE OPERATIONS

ACTIVITIES

- Implementing systems to
  - minimize inspections
  - reduce paperwork
  - improve border crossing activities
- Integrating relevant technologies into appropriate systems
  - AVI (Automatic Vehicle Identification)
  - AVC (Automatic Vehicle Classification)
  - WIM (Weigh in Motion)
  - RF communications (Radio Frequency)
  - Electronic Tags and Smart Cards

16

(No.18)

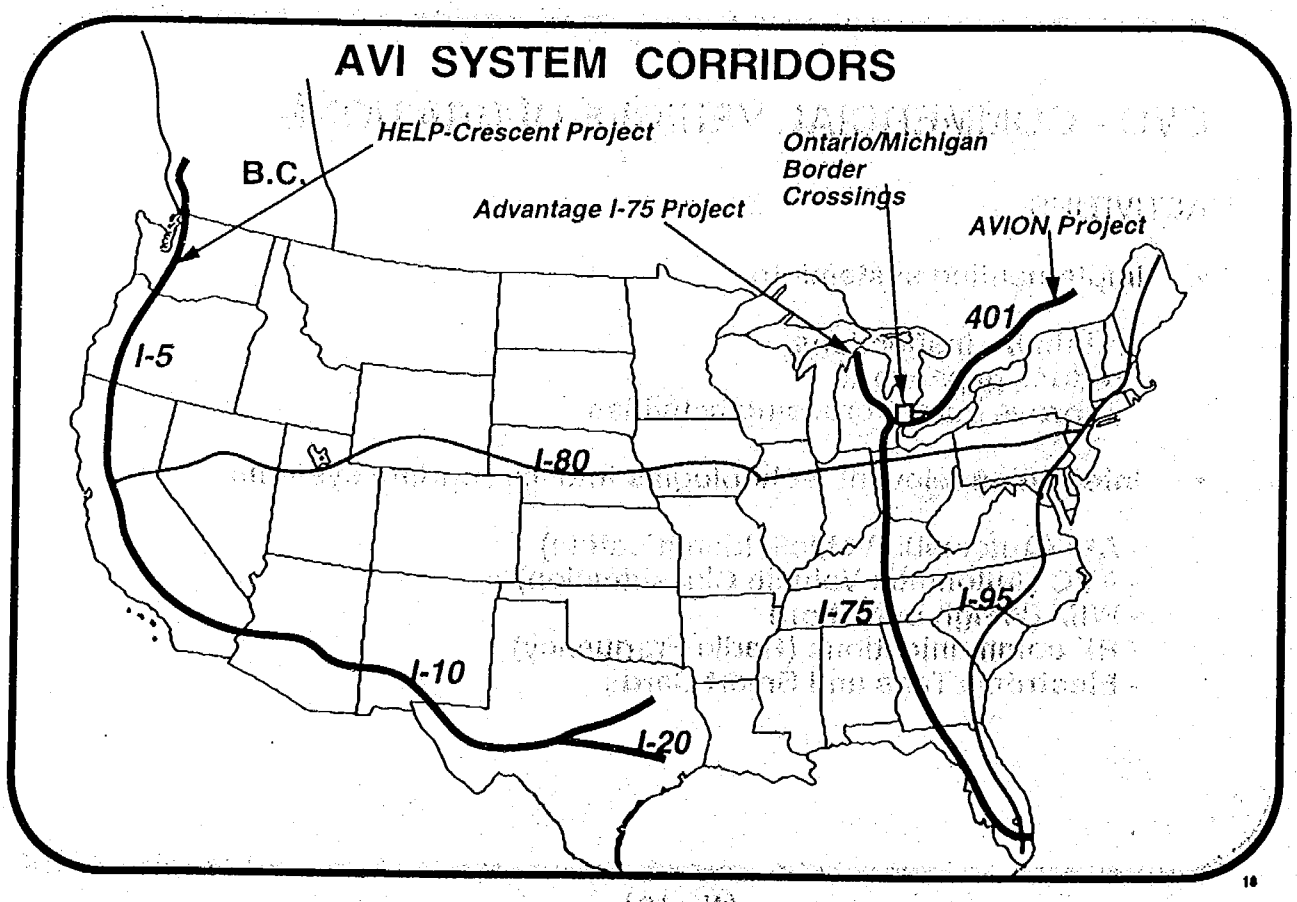
CVO (cont'd)

TYPICAL SYSTEMS

- Cooperative projects among Canadian and U.S. governments, provinces, states, trucking industry, manufacturers, and suppliers, bridge and tunnel authorities, customs and immigration departments - as appropriate
- Crescent/HELP (Heavy Vehicle Electronic Licence Plates)
  - From Texas to British Columbia through California and other States
  - Uses AVI, WIM, and Electronic tags to reduce truck inspections, to collect road taxes and to reduce paperwork
- I-75/AVION (Interstate Highway I-75 and AVI Ontario)
  - Similar to Crescent/Help project but in the East going from Florida to Ontario

17

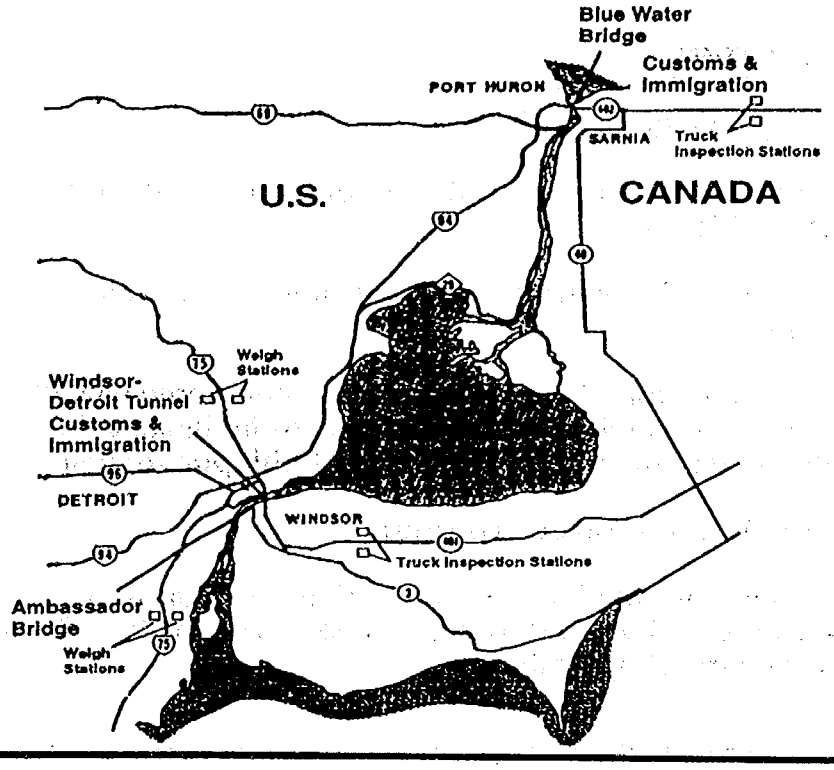
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18

(No.20)

DETROIT and ST. CLAIR RIVERS BORDER CROSSINGS



19

(No.21)

CVO (cont'd)

TYPICAL SYSTEMS

- Several Provinces have initiated projects involving AVI, WIM, and associated technologies; (AVI and WIM - Automatic Vehicle Identification and Weigh in Motion)
  - British Columbia - via the HELP project, and also an Electronic Vehicle Measurement System for their ferries
  - Alberta - via a pilot project using AVI, WIM, and electronic tags to process data and information about construction hauling trucks
  - Manitoba - via a joint project with SHRP, (the Strategic Highway Research Program) and the Long Term Pavement Performance Program to provide weight and classification data
  - Ontario - via the I-75/AVION project
  - Prince Edward Island - via a provincial traffic monitoring program of weigh in motion and automatic vehicle classification data

20

(No.22)

CVO (cont'd)

TYPICAL SYSTEMS

Cooperative projects

- Border Crossing (Canada/U.S. borders at Detroit/Windsor and Sarnia/Port Huron)

  - To improve administrative and trucking operations at border crossings

  - Pre-identification of vehicles, drivers, and cargo will allow customs and immigration authorities to facilitate vehicle processing at the border for frequent shippers/travellers

- Pearson Airport Project - Toronto

  - Integrated information system on flight arrivals and departures and ground transportation systems in order to improve airport operations

21

(No.23)

CVO (cont'd)

FLEET MANAGEMENT SYSTEMS

- Metro Ambulance - Toronto

  - System uses GPS (Global Positioning System) and two-way radio communications in an advanced vehicle location system to dispatch the closest vehicles to emergencies

- AVLN - Automatic Vehicle Location and Navigation

  - Joint Project of Vision 2000, private and government agencies in Alberta and Saskatchewan

  - To integrate real-time vehicle positioning, digital maps, and communications using cellular networks

22

(No.24)

APTS - ADVANCED PUBLIC TRANSPORTATION SYSTEMS

- Canada has several advanced systems in the area of AVLC (Automatic Vehicle Location and Control) for public transportation systems

- Toronto's CIS (Communication Information System)

  - Uses signposts and dead reckoning to give location of 2000 bus and streetcar fleet

  - Has added feature of voice communication

  - Also being used in pilot program for real-time traffic information for TravelGuide and MTIPS

23

(No.25)

APTS (cont'd)

- Most of the larger transit systems in Canada have some kind of AVLC
  - Montreal, Vancouver, Ottawa, Halifax, Hull, Hamilton

- Ontario has developed specifications which would allow small- and medium-size transit properties to semi-customize a system to their own requirements based on a standard "baseline" one

- AVLC is also an integral element in paratransit systems

  - Several Ontario cities use an automated computerized system for booking and scheduling trips and for allocating and routing vehicles to riders on a real-time basis. It features an advanced algorithm.

  - The system is also being used in other North American cities

  - Several Canadian cities use paratransit for transportation for persons with disabilities

24

(No.26)

APTS (cont'd)

- Advanced Fare Collection Systems are being used or being developed for public transit throughout Canada
- Fare integration in the GTA (Greater Toronto Area) will
  - Allow riders to move easily through a "Seamless" system without regard to mode, technology, or jurisdiction
  - Smart cards being considered as one alternative
- Systems already employ features such as
  - credit cards, debit cards, decrementing value cards
  - fare by distance, zone, time of day
  - fare and system integration among a limited number of systems

25

(No.27)

TOLL SYSTEMS - A DIFFERENT APPROACH FOR CANADA

- There are relatively few toll roads or toll bridges in Canada
- Tolls being considered for new roads
  - Consistent with user pay
  - Preferred financing for new roads
- Private/Public partnerships are being selected for
  - Financing
  - Design
  - Construction
  - Operation
- Revert to public agency after some period

26

(No.28)

TOLL SYSTEMS - A DIFFERENT APPROACH FOR CANADA (cont'd)

- An All Electronic Toll System is being considered for Highway 407 in the Toronto area
- Will embody the following All-Electronic subsystems:

  - An AVI system - with electronic "Tags" (transponders) and readers
  - A Communications system
  - A Classification system - to allocate appropriate charges
  - An Enforcement system
  - A Transaction Processing system - for toll collection, billing, deposits, revenue distribution

- British Columbia will test an all-electronic collection system on its one existing toll road, the Coquihalla Highway

27

(No.29)

DIGITAL MAPPING/GIS (GEOGRAPHICAL INFORMATION SYSTEMS)

- Canada is in the process of digitizing many of its maps
- Being done both by governments and the private sector
- Many of the larger cities have digitized maps based on street networks
- There are digital boundary files and topographic information for rural areas
- A Videolog Van which incorporates GPS (Global Positioning System) is being developed

28

(No.30)

COMMUNICATIONS

FOR WIDE RANGE COMMUNICATIONS

- Most of the advanced technologies are used

  - GPS - Global Positioning Systems - for Navigation and AVLC (Automatic Vehicle Location and Control)

  - Loran-C - for Navigation and AVLC

  - Cellular - for Fleet Management

  - Digital Audio Broadcast (DAB) - being considered for testing for data communications in real time information systems

  - Fibre Optic Network - Linking vehicle sensors to FTMS Centre

29

(No.31)

COMMUNICATIONS (cont'd)

- Satellite - Used for Vehicle Location and Voice Communications by over 100 companies in the trucking industry in Canada (RoadKit is the product for surface transportation and is distributed by Telesat). Products for marine and emergency applications are also available

- Paging - Traffic and road condition information is paged to subscribers

- Research work being done in Alberta

  - Evaluation of Loran-C and GPS technologies for use in AVL applications in Urban and Mountainous areas

  - Evaluation of GPS technologies for navigation and surveying

30

(No.32)

COMMUNICATIONS (cont'd)

FOR CLOSE RANGE COMMUNICATIONS

- Many jurisdictions use RF and fibre optics for
  - Loop detectors
  - Advanced fare collection cards

31

(No.33)

INTERNATIONAL COOPERATION

- Canada works closely with various jurisdictions and technical organizations on a variety of initiatives of mutual benefit.
  - Several Western U.S. States - Crescent/HELP
  - Several Eastern U.S. States - I-75/AVION
  - Michigan, U.S. customs and Immigration, Bridge and Tunnel Authorities - Border Crossing
  - IVHS America, SAE - ITIIS
  - ISO - TC204 - Canada is Convenor for Working Group 7, Commercial/Fleet
  - Several Western and Mid-western States in the U.S. - Enterprise
  - IVHS America - Coordinating Council, Technical Committees
- Canada is very active, and often the host country in International Conferences in which IVHS is prominent - VNIS (Vehicle Navigation and Information Systems); IRF (International Road Federation)
- All activities involve the private sector as well

32

(No.34)

CANADIAN CAPABILITIES TO SUPPORT IVHS

Canada has a well established network of Private Sector firms who are capable of supporting both its domestic and foreign markets for IVHS products and services in the areas of:

- Research and Development
- Engineering and Design
- Hardware Manufacturing
- Software Development
- System Integration
- System Delivery
- System Operation
- System Maintenance

33

(No.35)

CONCLUSIONS

- Canada has an active IVHS program
- We will maintain vigorous programs in order to take advantage of the benefits usually associated with IVHS including:

  - Maintaining and improving the efficiency of our surface transportation systems
  - Increasing safety
  - Improving productivity
  - Reducing energy usage
  - Improving the environment
  - Increasing mobility - especially for the transportation disadvantaged

- Furthermore, we will increase our activity - for competitive reasons

34

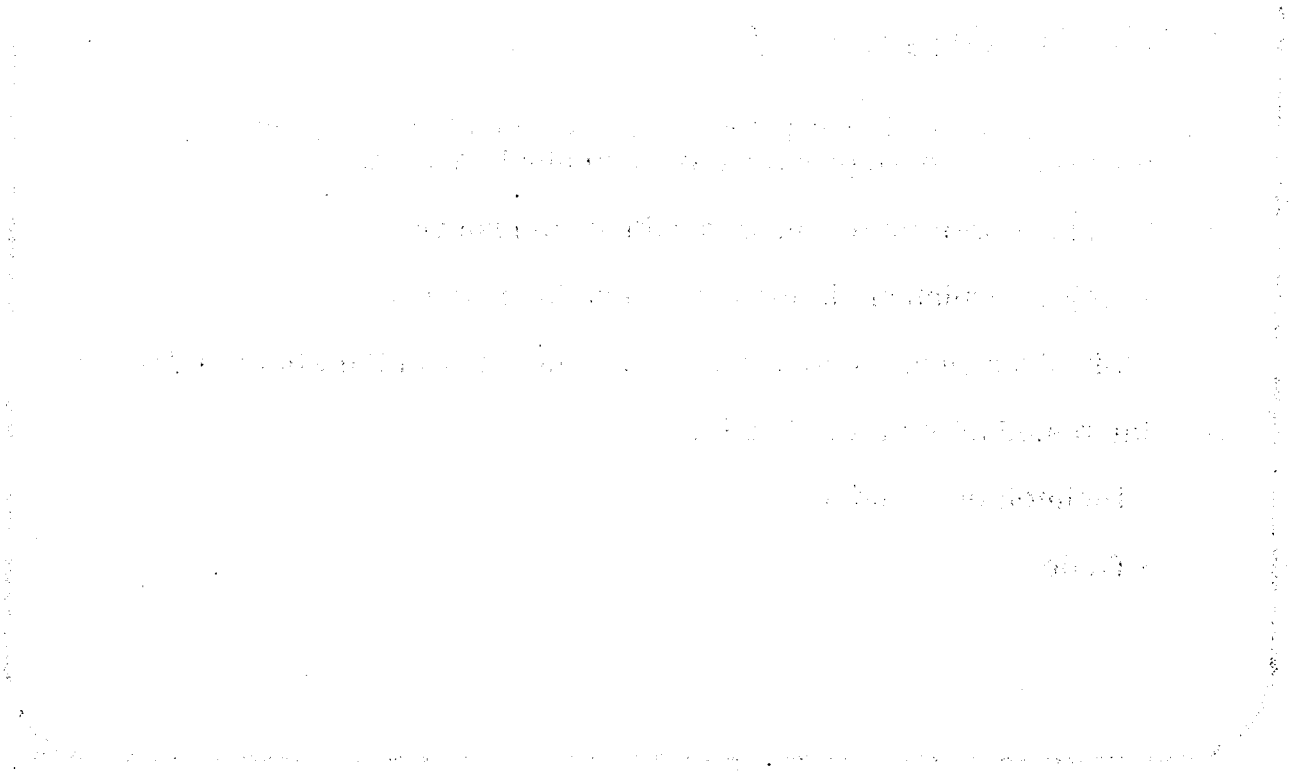
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CONCLUSIONS (cont'd)

- We will continue to work cooperatively with others as past involvements have proved to be mutually beneficial
- Seeking opportunities to work with Japanese on
  - Projects which are in the pre-competitive stages
  - Initiatives where there are similar challenges and/or shared interests
- Interested in opportunities for
  - Technology transfer
  - Trade

35

(No.37)



Intelligent Vehicle Highway System -
The universal, low cost, multi-application, vehicle to Road-side communication architecture

Presentation by R.Lewis Sabounghi, Transport Canada
In Japan, week of december 6, 1993.

HONOURABLE COLLEAGUES,

The subject of my talk today deals with IVHS strategic planning at the national level. We live in a period of financial restraint where we have to maximize the benefit of monies invested in our highway system. Each organization at a municipal/city level is concerned with solving its own transportation related problem by selecting some technological solution. Unfortunately solutions multiply and result in a multiplicity of incompatible systems, each requiring its own infrastructure serving just one application, while offering similar functions or capabilities through alternative technical approaches. Such cost is prohibitive on a national basis and denies the advantages of the economy of scale and compatibility. The implementation of several systems to support different applications or geographical locations could require motorists to install a number of redundant IVHS devices on their vehicles. This would be unnecessarily expensive, possibly unsafe, aesthetically unpleasing and inconvenient, acting as a disincentive to potential IVHS users. In addition, competing systems could potentially interfere with one another, resulting in reduced performance and loss of benefits.

The technical approach proposed for this vision is a Vehicle to Road-side Communication (VRC) originally developed for truck fleet monitoring applications. This is also known in the IVHS community as automatic vehicle identification (AVI) or Electronic Toll and Traffic Management (ETTM) technology. However, these labels have the effect of specifying the applications of the technology within strictly defined areas. The VRC title overcomes this by describing the technology's fundamental data transfer characteristics without limiting its range of application.

We are proposing for the next ten to fifteen years to implement a UNIVERSAL, LOW COST, MULTI-APPLICATION IVHS VRC ARCHITECTURE. Such vision has to be coordinated and supported on a national level, be it through the national

government or a national transportation organization.

The idea evolved from AVI development that used originally a transponder to react to some Radio Frequency (RF) signal and send the identification number. Further development turned this transponder into a low cost vehicle to road-side two way communication with connection via a serial port to the vehicle on board LAN[1] while the road side "reader" connects to the national WAN[2] through wired or non-wired transmission. Communication protocols were develloped and tested, different applications using the same technology have or are being develloped, tested and implemented. We do not have yet one North American standard however it is shaping up pretty fast.

Although this technology will not fully automate a vehicle it has the ability to support many applications in all the IVHS areas. I will take few minutes to intorduce the technology and then few more minutes to enumerate some of these applications.

VRC BACKGROUND

The technology proposed for adoption as the communications backbone of this system has been developed and tested as part of the North American Heavy Vehicle Electronic License Plate (HELP) program. HELP is a $20 million program funded by a group of 14 U.S. states, the Port Authority of New York and New Jersey, the Federal Highway Administration, Transport Canada, the province of British Columbia and various motor carrier organizations. The aim of the program is to research and develop an integrated heavy vehicle management system combining road-vehicle communications, weigh-in-motion (WIM) and automatic vehicle classification (AVC) technologies.

The HELP program was completed in september 1993 and is currently entering a commercial implementation phase known as HELP Inc. This involved the installation of the road-vehicle communications system, WIM and AVC components at 40 sites on Interstates 5 and 10 between the States of Texas and Washington, and beyond into the Province of British Columbia. Most of the sites have been integrated using a networked communication and

[1] Local Area Network

[2] Wide Area Network

processing system, which consist of roadside stations linked to regional and central computers.
The road-vehicle communications system adopted by HELP has been developed for AVI applications, to satisfy the program's vehicle identification needs. The system specification was finalized in 1989 following an extensive three-phase research and development effort. The first of these started in 1986 and involved testing initially eight and subsequently four state-of-the-art commercial systems in laboratory, test-track and field environments. A draft generic specification for highway AVI equipment was developed in Phase 2, taking the Phase 1 test results into account. The third phase then involved field trials in hot and *cold areas* of prototype equipment manufactured to the draft specifications. Analysis of data from the third phase was used as an input in preparing a final definitive generic specification of the AVI component of the HELP system.

Despite its development as an AVI system specification, the HELP system is in fact applicable to a much wider range of IVHS scenarios than simply vehicle identification. The system effectively provides a two-way high data rate channel between the vehicle-borne transponder and a roadside unit. This can be used to transmit any coded data message that can be accommodated within the system's data transfer capacity. The system is therefore more suited to the VRC title than to its original AVI terminology.

So far as possible, the communications specification developed by HELP is performance based. Only those aspects of the system required to be 100 percent compatible with other manufacturers' units are rigidly specified in complete technical detail. The principal features of the final specification can be summarized as follows:

1. Trigger/response
   - low power output
   - unique triggering signal
   - operating frequency 915 MHz in North America
   - battery-powered response

2. Data transmission rate
   - 500,000 bits per second data rate
   - short read time for multi-tag situations
   - multiple reads for error correction
   - potentially large amounts of data

3. Data encoding
   - code block length 128 bits
   - data modulated and transmitted using a Manchester coded pulsed

carrier

4. Transponder types
   - Type 1, fixed-code one-way (vehicle-to-road) transponder
   - Type 2, part variable-code two-way transponder
   - Type 3, location beacon transponder (two-way data transmission with link to onboard computer)
   - provision for up to 16 different transponder types, including high-speed two-way data communication with large amounts of data

5. Transponder programming
   - Type 1 transponders reprogrammable using manufacturer's programming device only
   - Type 2/3 transponders (variable code) reprogrammable during passage across reader antenna
   - Type 3 transponders (variable code) also reprogrammable using onboard computer

6. Roadside unit
   - decodes data from up to eight lanes simultaneously
   - transmits coded location data to onboard computer via Type 3 transponder (VRC specs.)
   - Capable of two-way, high-speed data communication with large amounts of data (VRC specs.)

7. Antennas
   - in-pavement antennas for free-flow operations
   - overhead or roadside antennas also possible
   - single antenna used to transmit/receive

8. Read accuracy
   - maximum proportion of incorrect, partial or failed decodings/encodings 1 in 10,000
   - error detection of at least 99.9 percent of decodings/encodings read differently from intended
   - maximum acceptance rate of incorrect reading/encoding of 1 in 10,000,000

9. Operating speed
   - transponder/beacon decoding at speeds up to 160 Kmph
   - transponder encoding at speeds up to 105 kmph

10. Transponder location
    - successful decoding/encoding at any lateral position within a

traffic lane
- successful decoding of messages from transponders at spacings of 15 feet or greater, at speeds up to 160 Kmph.

VRC CONCEPT APPLICATIONS

The universal VRC architecture will involve the use of a standardized generic specifications of road/vehicle communications system in a number of IVHS applications. It is not anticipated that all of these system applications would be implemented simultaneously. Rather, it is intended that the system would be introduced in a modular approach, building on the communications capabilities of the VRC. Initial elements currently under implementation or demonstration in HELP and toll installations focus primarily on the one-way vehicle-to-road communications function, providing for components such as AVI, automated toll collection and link journey time monitoring. Planned demonstrations address two-way communications and the addition of interfaces with in-vehicle units, providing increased system functionality. In this way, the system could grow gradually and logically, avoiding the risks associated with an intensive implementation process. The system can incrementally build on the installed base where every new application increases the efficiency of existing applications by adding to the number of installed mobile and fixed communication units. The unit cost per application, per information, per piece of equipment continues to decrease with the growth of this system producing a truly low cost universal communication system. It is obvious that some applications will still require real-time person to person voice/data communication. Therefore, real-time wide range systems such as cellular and satellite will coexist with VRC time window systems in the same way the telephone voice system and the fax system coexist today.

By virtue of its fixed/mobile components the VRC is also a location and positioning device, however nothing stops it from receiving and relaying location, position, and navigation information coming from any other source such as GPS.

Now let us look at some of the potential applications, we will group them by IVHS category.

Advanced Traveller Information Systems (ATIS)

Background material to Oral Presentation by R.L.Sabounghi - Japan, Dec. 1993 Universal, Low cost, Multi-application, VRC Architecture

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ATIS technologies provide travellers with current information on road conditions and route availability. They can assist travellers in making decisions before the trip begins, in selecting an appropriate route or travel mode; in route following; and through reduced uncertainty as the travel situation changes. ATIS most visible benefits accrue to individual system users. Providing drivers with accurate, real-time information may also help to remove a proportion of excess travel caused by less than optimal route choice. To the extent that this limits the overall demand for travel, wider social benefits are anticipated. By providing better interface between the driver and the infrastructure, large improvement highway characteristics can also be obtained. The greatest impact of ATIS, however, is likely to be increased driver confidence and reduced uncertainty for system users, who find these systems reassuring, and at least know what is happening when things go wrong. Potential applications of the VRC in the ATIS area are outlined below.

In-vehicle traveller information

This application would use the roadside-to-vehicle communications element of the VRC to transfer data of interest to the driver. This would be achieved by programming the roadside unit with a code corresponding to a specific message, obtained from a predefined "Travel Message Code" (TMC). The transmission would be received by the transponder and relayed to a processor unit for decoding. The processor would contain a list of messages corresponding to the transmitted codes. Messages would then be presented to the driver for consideration in his own language. Appropriate message types for this application include weather details, traffic incidents and diversion advice.

In-vehicle road signing

The in-vehicle road signing application of the VRC would be similar to the traveller information approach outlined above. The roadside unit would be installed adjacent to highway signs such as speed limits, stop signs, warnings or advisory messages. Programming of the roadside equipment would relate the system's coded message to the particular sign at the site. Decoding of this message within the vehicle would then allow the sign to be presented to the driver using a liquid crystal display (LCD), voice sinthesys or similar approach. The application would be particularly useful for presenting road sign information to drivers in conditions of poor visibility.

In-vehicle hazard warning

This application of the VRC would utilize the system to transmit warning information to motorists approaching dangerous areas. These could include accident black spots, low bridges, narrow road sections or other hazardous zones. Roadside units would be installed in advance of these areas, and would be programmed according to the particular hazard at the site. Drivers approaching the section would then receive early warning messages through in-vehicle displays or voice synthesizers, enabling them to take timely precautionary action. The system could also be used to transmit warnings concerning non-continuous hazards. For example, roadside units near schools could be activated only during open hours, while ice sensors or similar devices could be used to activate highway surface condition warning messages.

Journey time monitoring

In this application, VRC technology would be used to determine average journey times for highway network links. This would be achieved by calculating journey times between monitoring sites for individual vehicles equipped with transponders. Unique vehicle identification numbers contained within the transponder code will be used to facilitate this. Average journey speeds for road sections would then be calculated. This information would be presented to drivers through traffic information databases, variable message signs or radio broadcasts, as a basis for informed route choice decisions. Using VRC, data could also be passed back to the driver via an in-vehicle display or speech synthesizer.

Vehicle location confirmation

In this application, the road-to-vehicle communications element of the VRC would be used to send coded location data from the roadside to the vehicle. This information would be supplied to in-vehicle navigation systems that continuously calculate vehicular position using dead reckoning and map matching techniques. The coded location data received periodically from roadside units would be used to correct positioning errors that accumulate using these in-vehicle approaches. The location data could also be relayed to onboard computers installed in motor carrier vehicles. The information could then be used in conjunction with recorded odometer and time measurements to assist in motor carrier reporting and taxation activities.

In-vehicle navigation updating

As an extension to confirming location for in-vehicle navigation error correction, the VRC could supply additional data for presentation using the navigation display unit. This could include details on congestion, incidents or other information that would potentially affect driver route choice. The information would be conveyed from the roadside unit to the VRC transponder in the form of coded data messages. These would be decoded and relayed to the in-vehicle navigation system. Superimposition of the received data at suitable locations on the map display would then allow the driver to consider current conditions in formulating a preferred route.

Externally-linked route guidance

The externally-linked route guidance concept would use the two-way communications capabilities of the VRC to transfer data in both directions between the vehicle and the roadside. Vehicle identification codes received from VRC transponders would be used to calculate road section journey times, as described previously. This would be analyzed in a central computer, updating map information giving the relative impedances of alternative routes. Link impedances would then be transmitted back from the roadside unit to an in-vehicle processor via the transponder. The processor would review the received data and provide real-time dynamic routing advice using an in-vehicle display or speech synthesizer.

Advanced Traffic Management Systems (ATMS)

ATMS build on established techniques for computer-optimized traffic control in urban traffic signal networks. Related technologies for tidal flow systems, ramp metering of commuters onto congested urban highways, bus and light rail system priorities at signalized intersections, service pricing and electronic enforcement of traffic regulations can all be placed under the ATMS umbrella. Applications of the VRC in the ATMS area are outlined below.

Traffic congestion monitoring

The VRC can be used to collect highway network journey time data for driver information purposes. However, the same data can also be used for traffic management applications. Relayed to a traffic management centre, the VRC data will reveal areas of congestion and free-flowing traffic. It will also support the implementation of incident detection algorithms. Collected data will then enable highway authorities to initiate informed control actions such as alteration of signal timing plans, opening of reserved lanes and requests for police action.

Traffic signal preemption

Using the vehicle identification capabilities of the VRC, the system can be used to implement preferential activation of traffic signals for preferred vehicle types. This application could be used in support of transit services to assist in achieving improved schedule adherence. Traffic signals can also be activated in favour of emergency service vehicles. The application involves the installation of the VRC roadside unit in advance of the traffic signal. Selected vehicles are supplied with transponders containing unique identification codes. The detection of these vehicles by the roadside unit then activated a green signal, providing priority passage through the intersection. For transit vehicles, current schedule adherence can initially be verified to establish the need for the signal preemption.

Priority vehicle detection

In an application similar to the traffic signal preemption approach outlined above, the VRC can be used to provide vehicle priority in a number of other highway situations. These would generally support capacity or demand management objectives, and would again use the system's vehicle identification capabilities to detect preferred vehicles. Potential areas of application include access to restricted parking lots, bypass lanes for ramp metering schemes or barrier activation for entry to reserved highway facilities.

Interactive signal coordination

The concept of interactive signal coordination would integrate VRC-supported externally-linked route guidance with adaptive traffic signal control. The VRC

would provide real-time data on highway conditions, represented by average link journey times. In addition, the in-vehicle route guidance unit would provide data on vehicle destinations, which could be transmitted from the transponder to the roadside unit. The combination of link journey time data and information on vehicle destinations would enable traffic signals to operate in response to the actual pattern of short-term future travel demand. It would thus be possible to simultaneously optimize signal coordination and vehicle route choice within the highway network.

Automatic toll collection

VRC can be used to automate toll collection procedures, removing the need for drivers to stop at toll plazas and make manual payments. Participating vehicles are fitted with transponders containing unique identification codes, corresponding to computerized toll accounts. Funds are deposited into the account by the driver periodically, ensuring a minimum balance is maintained. The account is then decremented automatically as the vehicle is detected passing through the toll plaza. Account maintenance can also be performed on the vehicle where two-way transponders are used.

Electronic road pricing

Electronic road pricing using VRC is technically similar to automatic toll collection, described above. Road pricing is a traffic restraint / congestion management policy in which drivers pay for their road use according to how much they are contributing to congestion. It therefore depends upon charging vehicles for being in a particular place at a particular time. VRC technology linked to a computer network can be used to establish charging sites on the highway network using roadside units. Road user charges are varied by time of day and location, according to congestion levels. Vehicles equipped with transponders debit an account each time they cross a charging site. Accounting can be performed "centrally" or "on-vehicle", depending on the administrative design of the system.

Advanced Road Freight Systems (ARFS)

would provide real-time data on highway conditions, represented by average link journey times. In addition, the in-vehicle route guidance unit would provide data on vehicle destinations, which could be transmitted from the transponder to the roadside unit. The combination of link journey time data and information on vehicle destinations would enable traffic signals to operate in response to the actual pattern of short-term future travel demand. It would thus be possible to simultaneously optimize signal coordination and vehicle route choice within the highway network.

Automatic toll collection

VRC can be used to automate toll collection procedures, removing the need for drivers to stop at toll plazas and make manual payments. Participating vehicles are fitted with transponders containing unique identification codes, corresponding to computerized toll accounts. Funds are deposited into the account by the driver periodically, ensuring a minimum balance is maintained. The account is then decremented automatically as the vehicle is detected passing through the toll plaza. Account maintenance can also be performed on the vehicle where two-way transponders are used.

Electronic road pricing

Electronic road pricing using VRC is technically similar to automatic toll collection, described above. Road pricing is a traffic restraint / congestion management policy in which drivers pay for their road use according to how much they are contributing to congestion. It therefore depends upon charging vehicles for being in a particular place at a particular time. VRC technology linked to a computer network can be used to establish charging sites on the highway network using roadside units. Road user charges are varied by time of day and location, according to congestion levels. Vehicles equipped with transponders debit an account each time they cross a charging site. Accounting can be performed "centrally" or "on-vehicle", depending on the administrative design of the system.

Advanced Road Freight Systems (ARFS)

Background material to Oral Presentation by R.L.Sabounghi - Japan, Dec. 1993 Universal, Low cost, Multi-application, VRC Architecture

---

ARFS approaches represent an area of rapid IVHS developments. Technologies contained within this category include many systems that can also be applied within the ATIS or ATMS areas. However, the objective of ARFS is to improve fleet operations on a broad level, rather than seeking to optimize individual vehicle performance or network performance. Applications of VRC technology in the area of ARFS are outlined below.

Commercial vehicle location

In response to the reader's request for identification the vehicle transponder sends its Vehicle Identification Number (VIN) and a lot more information including Action Requests (AR). One of these is a code requesting to update the Central Location Computer (CLC) as to the current location of the vehicle. In turn the dispatcher' office computer connects on a regular basis to the CLC to download the latest location for the firms vehicles subscribing to that service. This type of service using expensive satellite technology is already in use and is turning profit for its users.

Hazardous material tracking

This application would require the transponder to download the hazardous material UN identification number together with its VIN. Similar to the vehicle location system the information will be routed to the local HAZMAT emergency response computer for tracking.

Cargo condition tracking

Information collected by sensors in the cargo compartment are sent to the on board computer and relayed through the VRC to the central messaging computer and distributed to the coded electronic mail box.

Paging

In its simplest forms and using regular phone lines a request to "call back your dispatcher" is routed from the dispatcher to the central messaging computer and relayed through the VRC to the vehicle. The message can appear on the driver's dashboard as an amber light that would flicker in case of an urgent message.

Messaging

In a more advanced form This application would relay through regular phone lines a small message or a coded message addressed to a vehicle number use the roadside-to-vehicle communications element of the VRC to transfer the message to the driver. This would be achieved by programming the equipped vehicle to check for messages and the roadside unit to link with the central message computer. The transmission would be received by the transponder and relayed to a processor unit for decoding if needed. Messages would then be displayed or voice synthesized.
Similarly the driver can initiate a coded message such as "I am going on break at next stop" and send it through system.

Vehicle and driver monitoring

This application would require the vehicle to be equipped with an On Board Computer (OB)C and a VRC transponder. This application would also require the carrier to equip his garage or parking gate with a reader. The OBC would maintain records of weight, mileage, fuel usage, driver performance and vehicle location and any other information required by the company. These records could be automatically downloaded from the OBC by the carrier at its own location. The reports could be used for internal management purposes. In addition the gate computer can keep track of vehicles in and out of the parking/garage area and time stamp their records.

Business data upload and download

This application is somewhat similar to the vehicle and driver monitoring but is used to upload the driver routing slip, the customers list, billing information etc. When the OBC is coupled with a printer the billing can be done at customer site, and all relevant accounting data entered on the OBC. This information is automatically downloaded when the vehicle returns to base using the VRC installed at the carrier site. This is particularly useful for multiple deliveries and pick up and deliver operations where paper work is extensive.

Border's line beacon

The national or international border line beacon uses the VRC to send a marker message from the roadside into the vehicle that would be recorded on the OBC. The beacon equipment would be installed at an interjurisdictional line and would send the site number and location information to the vehicle. This would be matched with a time and date stamp and odometer reading and

would be stored on the OBC. The information stored on the OBC could be downloaded by the carrier at its own location. If ultimately accepted as an authentic record by the appropriate government agency this could potentially replace the need for a carrier to make mileage reports and could be used by the agency for auditing and administering mileage-based taxes such as fuel tax, licence tax, etc.

Automated driver logs

This potential application would build on the line beacon concept used to provide an authentic location stamp on an OBC record. Additionally, information such as the driver's identification number and the driver's hours of work, stops, rest etc. required for log book purposes would be recorded. A uniform electronic log format has been developed. The computerized log could be automatically downloaded at a government facility using a VRC for verification and automatic clearance.

Truck management

Applications of the VRC relating to truck management are typified by the HELP program, for which the communications system was developed. The system can be used to identify trucks at mainline data collection sites and weigh stations. A computer database of equipped vehicles can be established, containing information on authorized operating weights, permits and other motor carrier details. By integrating the roadside unit with WIM or AVC technologies, it is then possible to establish a vehicle's compliance with applicable regulations, without requiring it to stop for manual review. Data collected by the system are useful for highway planning operations and for assisting motor carrier management and reporting activities.

Automated Customs clearing

By combining Electronic Data Interchange (EDI), AVI , Automatic Cargo Identification (ACI) and VRC the automated customs clearing becomes a reality while customs delays and resulting congestion is eliminated.

Other Trucking applications

The above is only a flavour of what can be done, the HELP program has identified an extensive list of applications, which include:

* government data collection
* carrier data collection
* weight enforcement
* automatic clearance (weights and dimensions, registration and operating authority, safety inspection, permits)
* vehicle and driver management
* mainline vehicle screening
* automatic regulation administration.

Advanced Public Transportation Systems (APTS)

Transit operation management and control

The use of the VRC in improving transit operations involves the installation of transponders on vehicles in the fleet and roadside units at strategic road locations. As vehicles pass these monitoring sites, coded identification details are transmitted to the roadside and then relayed to a fleet control centre. Here, a fleet supervisor can review the schedule adherence of transit vehicles in the system. Using interfaces with other devices on the vehicle, the VRC can also provide several other types of data that are of interest to the supervisor. These include vehicle loading derived from passenger counting units, vehicle component condition measured by appropriate sensors, and messages entered by the driver. Review of these data by the fleet supervisor enables intervention actions to be initiated when necessary and thus improves overall system efficiency.

Advanced Service and Emergency Systems (ASES)

Taxicab monitoring and management

Another area in which the VRC can be applied concerns the monitoring and management of taxicab operations. This is particularly true at airport locations, where landside traffic congestion introduces a need to maintain tight controls in this area. Here, VRC transponders can be distributed to all taxicabs that use the airport facility. The installation of roadside units then allows vehicles to be identified and charged for their use of the facility. Using two-way transponders, taxicab drivers can be advised on the status of various

passenger loading locations. Dispatching procedures can also be automated using the VRC.

Implementation in Pearson (Toronto) airport is scheduled for 1994

Advanced Vehicle Control Systems (AVCS)

The area of AVCS offers the greatest potential benefits and the most significant obstacles to the IVHS development effort. AVCS includes a group of technologies which can assist and support drivers in performing vehicle control functions. These systems may, in the longer term, relieve the driver of some or all of the driving tasks. Potential benefits of AVCS include substantial safety enhancements and major increases in highway capacity. Applications of VRC in this area are outlined below.

Automatic speed control

This first AVCS application of the VRC would represent an extension to the in-vehicle road signing concept. Roadside units would be installed adjacent to highway signs indicating the maximum speed, where this changes from one limit to another. The unit would be programmed to transmit the speed limit in coded form. This would be received by vehicles equipped with transponders, and would be decoded and displayed to the driver. In addition, an interface between the processor and the engine and brake controls would allow the vehicle speed to be automatically adjusted in accordance with a received message. This would assist the driver in travelling at an appropriate speed for the highway section.

Automated highway systems communication

The ultimate goal of current AVCS developments is the combination of a range of technologies to produce the automated highway system (AHS). This would completely remove vehicle control from the driver, involving automated control of steering, speed, headway, merging and diverging. Substantial elements of communication will inevitably be required to facilitate this, many of which could potentially be supported by the VRC. For example, the system could transmit a message to a driver that the vehicle is approaching the start or end of an automated section. This would enable the driver to prepare for the transfer of vehicle control responsibility. The VRC could also be used to transfer data concerning the readiness of the vehicle to enter the automated facility. This would be performed following verification of the vehicle's

condition using component sensors.

Variable speed control

This application would be similar to the automatic speed control approach outlined above. The variable speed control concept, however, would be used to select an appropriate vehicle speed for travel between signalized intersections. To implement the system, roadside VRC units would be installed at intersections and interfaced with the local traffic signal controller. As equipped vehicles passed through the intersection, the roadside unit would calculate the correct approach speed to arrive at the next signal on green. This would be based on a knowledge of the signal timing plan and the distance to the traffic signal. The calculated speed would be transmitted to the vehicle, enabling automatic adjustment of the brakes or acceleration to be performed.

IN SUMMARY, we highlighted some of the applications of the Vehicle to Road-side Communication (VRC). The system can support a number of IVHS applications in all IVHS areas. It therefore has the potential to resolve problems concerning the implementation of IVHS approaches that currently propose the use of conflicting or incompatible communications technologies. In addition, the system can be implemented in a modular fashion, increasing system functionality as early elements become widely accepted and utilized. By implementing a system that can support a multitude of applications serving many groups of customers sharing the infrastructure, the cost per application and per user will be greatly reduced . For example, using a VRC ahead of a traffic light, an emergency vehicle on call can change the intersection light thus avoiding a tragic accident and delays, while a truck driver can send and receive a message to/from his dispatcher using the same system.

Overall, this strategic vision represents a multi-application system using an existing and proven communications approach. It is therefore seen as a promising and efficient way forward for the research, development and deployment of IVHS technologies.

TravelGuide

Ontario's Portable Route Guidance System

Presented to

Japan/Canada Workshop on
Advanced Highway Systems

December 5 - 12, 1993

by

M.D. Harmelink

Ontario Ministry of Transportation
Transportation Technology and Energy Branch
Transportation Control Technology and Systems Office

1

(No.1)

ADVANCED TRAVELLER INFORMATION SYSTEMS (ATIS)

- Advanced systems that provide information to travellers about their transportation network and help them to reach their destination quickly and safely.

2

(No.2)

EXAMPLES OF ATIS

- In-vehicle route guidance systems
- Pager type devices that transmit incident information
- Automated transit arrival information systems
- Freeway traffic management system overhead signs
- Active computer map displays showing traffic conditions

3

(No.3)

KEY ISSUES

- System capabilities desired by users
- Affordability
- Transportability and international standards
- Information sources
- Private/public cooperation
- Safety

4

(No.4)

TRAVELGUIDE CONCEPT

- Portable
- Off-the-shelf PC compatible hardware
- Public sector supplied real-time information
- Service and product from private sector
- Traffic, transit, and incident data
- One-way communications
- Standard data protocol and location coding (ITIIS)
- Voice input and output
- No vehicle location initially

5

(No.5)

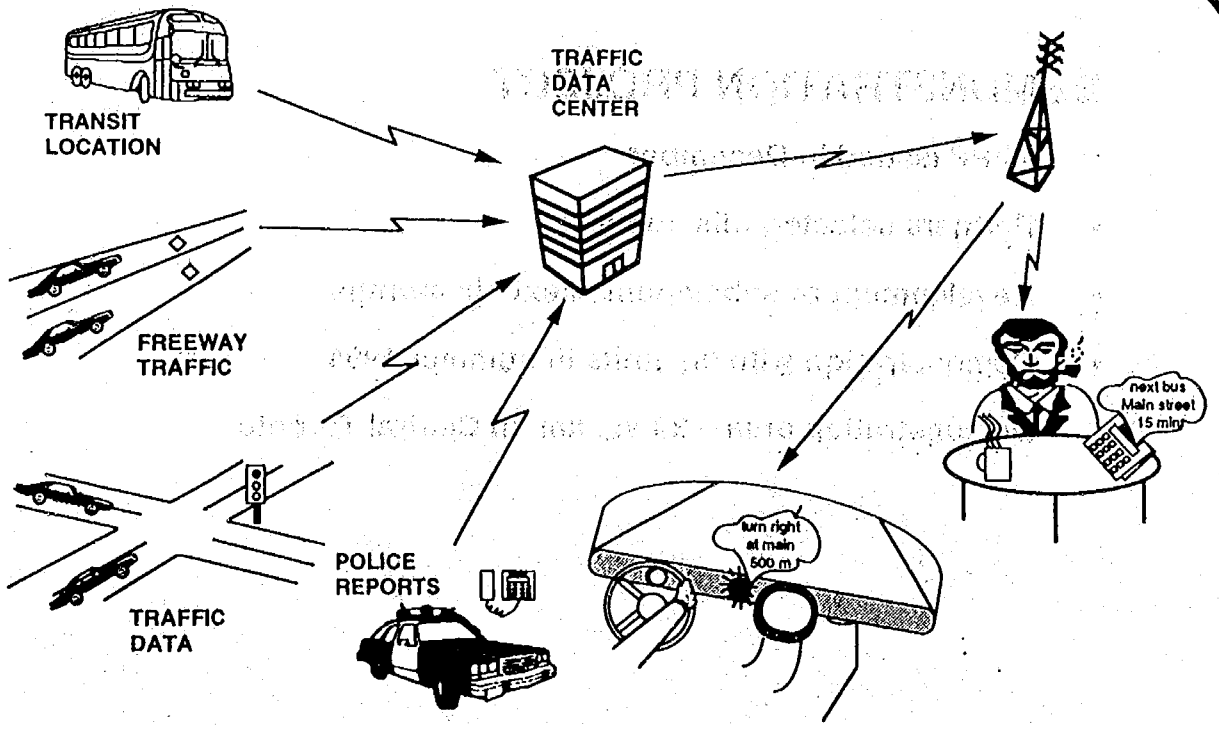


FIGURE 1/ TRAVELGUIDE CONCEPT

6

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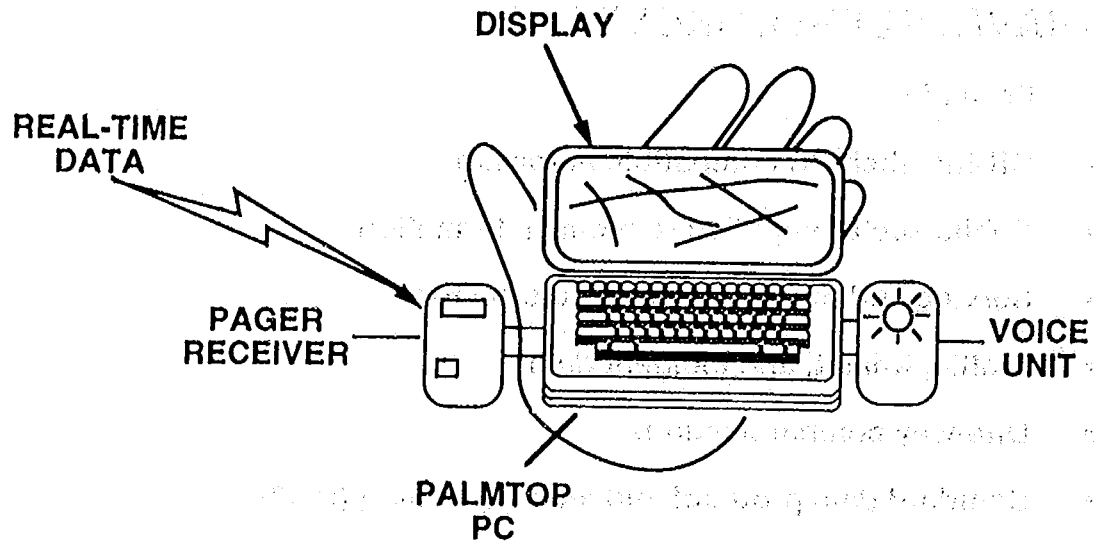


FIGURE 2/ TRAVELGUIDE UNIT

7

(No.7)

DEMONSTRATION PROJECT

- RFPP issued in December
- Partners selected this summer
- Development of subsystems next six months
- Demonstration with six units in summer 1994
- Demonstration area – 30 sq. km in Central Toronto

8

(No.8)

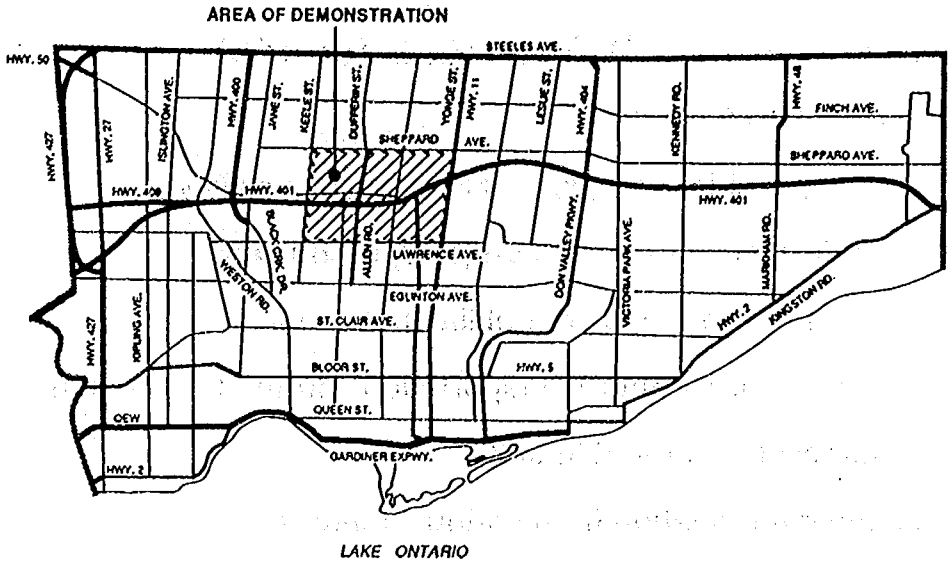


FIGURE 3/ METROPOLITAN TORONTO

9

(No.9)

TRAVELGUIDE SUBSYSTEMS

PORTABLE UNIT

- Hand-held PC compatible computer
- Routing and interface software
- Communications – EMBARC receiver
- Map data base
- Voice input/output

10

(No.10)

TRAVELGUIDE SUBSYSTEMS (cont'd)

REAL-TIME DATA (MTIPS)

- Freeway Traffic Management System for freeway data
- Toronto Transit Commission (TTC) for bus arrival
- TTC data to generate arterial link travel times
- Metropolitan Toronto Transportation – future SCOOT Data
- Historical data stored in unit
- Incident information from various sources
- Data fusion and data generation in MTIPS computer

11

(No.11)

DEMONSTRATION PARTNERS

PORTABLE UNIT

System integration and interface Software – IBI Group

Map data base – Navigation Technologies

Routing/transit software – Personal Travel Technologies

Communications hardware/channel – Bell Mobility

Voice synthesis – Pulse Data

Voice recognition – Canadian Marconi

12

(No.12)

DEMONSTRATION PARTNERS (cont'd)

REAL-TIME DATA (MTIPS)

Data fusion software – Teleride Sage

Transit to auto travel time algorithm – University of Toronto

13

(No.13)

DEMONSTRATION PARTNERS (Cont'd)

OVERALL PROJECT DIRECTION AND MANAGEMENT

- Ministry of Transportation of Ontario
- Toronto Transit Commission
- Metropolitan Toronto Transportation Department

14

(No.14)

NEXT STEPS

- Complete development and demonstration
- Project evaluation
- Private sector to investigate commercial opportunities
- Ministry to prepare for Metro-wide data collection
- IVHS Community to continue ITIIS standards development
- Other jurisdictions invited to participate

15

(No.15)

6. Wind Resistant and Seismic Structures

Current Research Activities on Seismic Design of Structures

K. Kawashima
Head, Earthquake Engineering Division, PWRI
H. Ohtsuka
Head, Ground Vibration Division, PWRI
O. Matsuo
Head, Soil Dynamics Division, PWRI

Strong Motion Observations Conducted by Public Works Research Institute

Seitaro Yoshimi[1] and Hisanori Otsuka[2]

[1]Research Engineer, Ground Vibration Division, Earthquake Disaster Prevention Department, Public Works Research Institute, Tsukuba, Ibaraki 305, Japan
[2]Head, ditto

SUMMARY

The Public Works Research Institute conducts two types of strong motion observations, general observations and array observations. General observations are conducted throughout Japan at about 350 sites to obtain strong motion records for engineering purposes. At each site two or three strong motion accelerographs are installed on civil engineering structures or on the ground. Observed strong motion records are processed and analyzed to clarify the general characteristics of earthquake ground motions, which are in turn used as the basis of earthquake resistant design.

This report describes the observation sites, data processing procedures, data base system, and data utilization of the general observation.

(No.1)

ATTENUATION CHARACTERISTICS OF NEAR-SOURCE GROUND MOTIONS

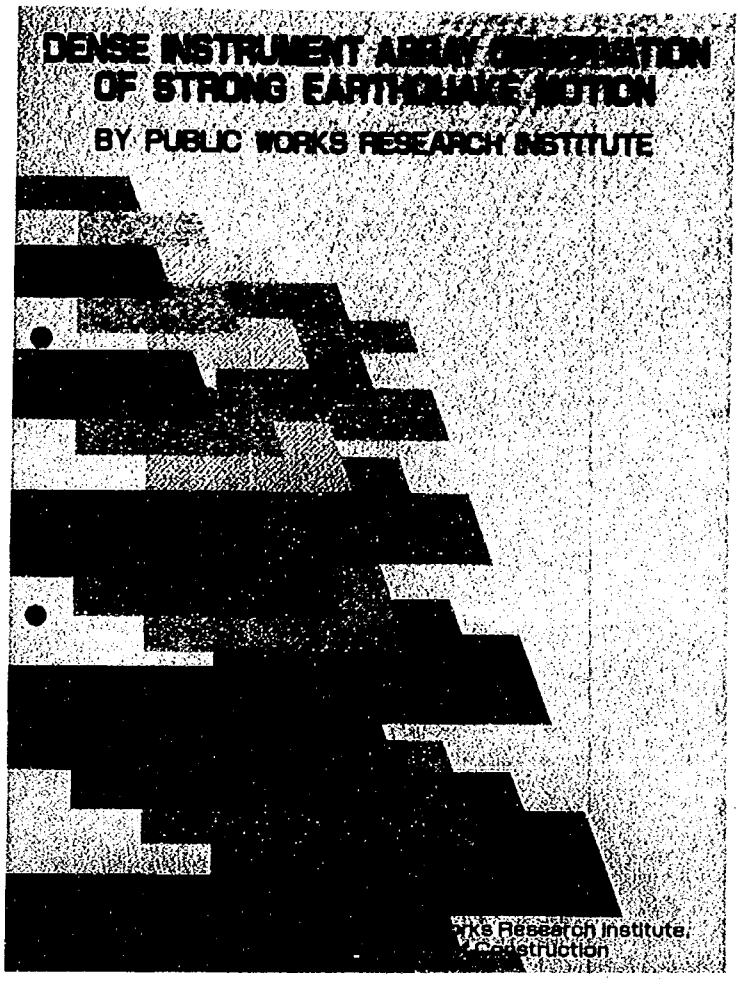
Hisanori OTSUKA[1], Hideaki IWASAKI[2], and Ryoji ISOYAMA[3]

[1]Head, Ground Vibration Division, Earthquake Disaster Prevention Department, Public Works Research Institute, Tsukuba, Ibaraki 305, Japan
[2]Research Engineer, ditto
[3]Deputy Director, Earthquake Disaster Mitigation, Japan Engineering Consultants Co., Nakano-ku, Tokyo 164, Japan

SUMMARY

Attenuation characteristics of peak horizontal acceleration in the near-source region were studied for 103 earthquakes observed in and outside of Japan. Attempts were made to derive attenuation relations not based on the functional forms of existing attenuation equations. Results are summarized as follows: (1) there is a certain distance range for an earthquake for which peak acceleration can be considered constant, and this distance range is in proportion to earthquake's magnitude; (2) the constant value for peak acceleration in this distance range is dependent upon magnitude; (3)this magnitude dependence has been expressed in a functional form of log Acc=a·M+b, where Acc is peak horizontal acceleration and M is magnitude.

(No.2)



(No.3)

CONTENTS

Two Dimensional Analysis of Ground Motion Characteristics ——— 1
on Irregularly Layered Media
Ken-ichi Tokida, K.Tamura and H.Fukada,

Liquefaction Potential and Uplift Deformation of ——— 19
Underground Structure
Ken-ichi Tokida, Y.Ninomiya and T.Azuma

Simplified Procedure to Estimate Lateral Ground Flow ——— 36
by Soil Liquefaction
Ken-ichi Tokida, H.Matsumoto, T.Azuma and I.Towhata

Liquefaction Potential and Drag Force Acting on Piles ——— 54
in Flowing Soils
Ken-ichi Tokida, H.Iwasaki, H.Matsumoto and T.Hamada

(No.4)

VOL. 3091

TECHNICAL MEMORANDUM
PUBLIC WORKS RESEARCH INSTITUTE

Jan. 1992

ASSESSMENT OF LIQUEFACTION POTENTIAL AND ITS TREATMENT FOR DESIGN AND CONSTRUCTION OF CIVIL ENGINEERING STRUCTURES

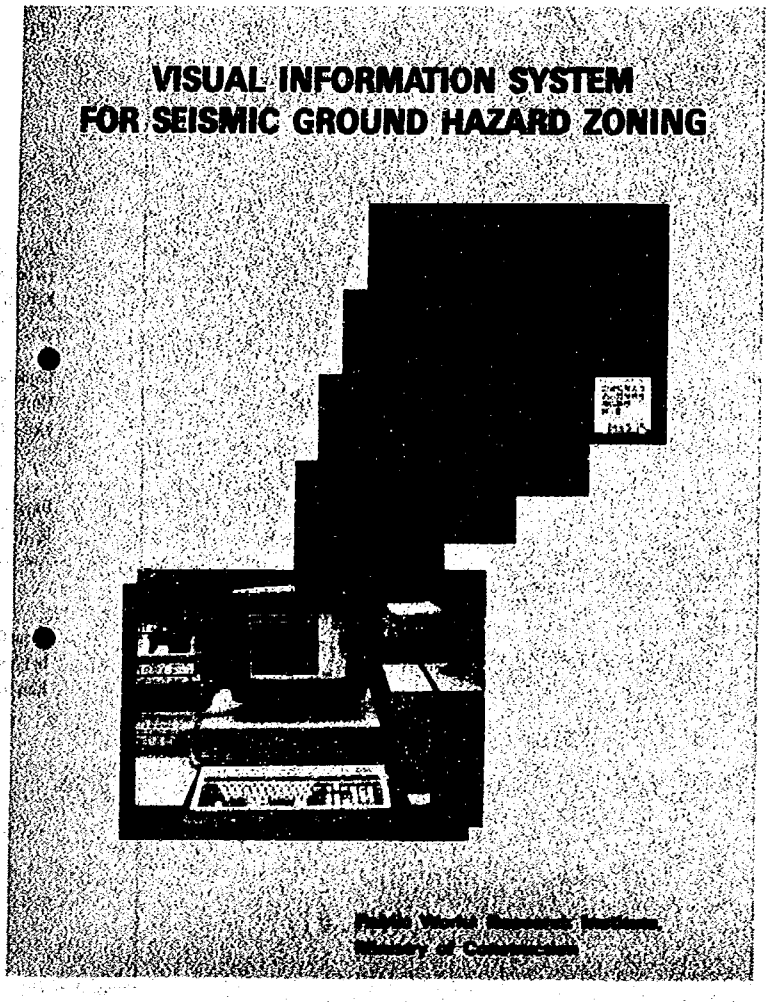
By

Ken-ichi TOKIDA

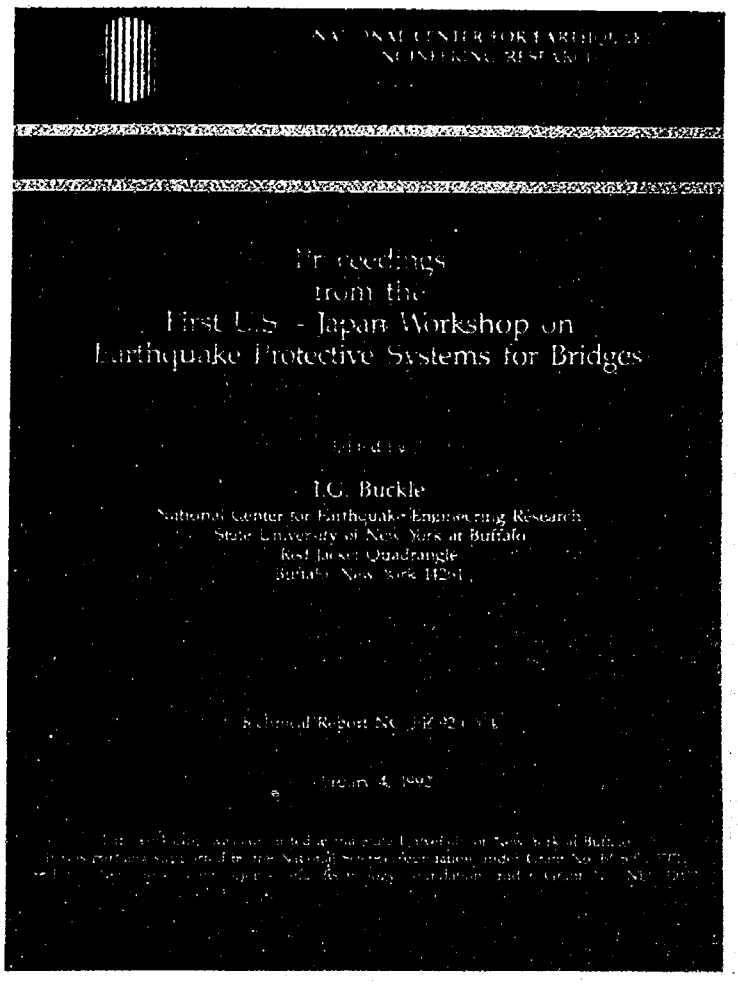
GROUND VIBRATION DIVISION
EARTHQUAKE DISASTER PREVENTION DEPARTMENT
PUBLIC WORKS RESEARCH INSTITUTE
MINISTRY OF CONSTRUCTION

1, Asahi, Tsukuba-shi, Ibaraki-ken, 305 JAPAN

(No.5)



(No.6)



Proceedings
from the
First U.S - Japan Workshop on
Earthquake Protective Systems for Bridges

Edited by

I.G. Buckle

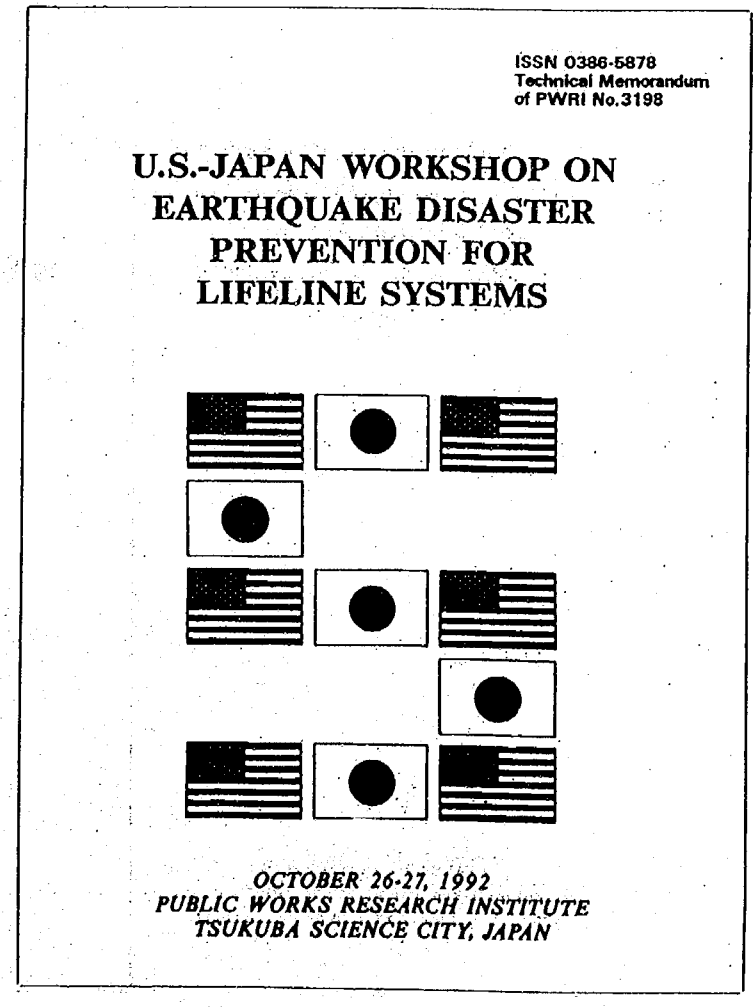
National Center for Earthquake Engineering Research
State University of New York at Buffalo
Red Jacket Quadrangle
Buffalo, New York 14261

Technical Report NCEER-92-0004

March 4, 1992

This research was conducted at the State University of New York at Buffalo and was supported by the National Science Foundation under Grant No. BCS 90-25010 and the New York State Science and Technology Foundation under Grant No. NCEER-92-0004

(No.7)

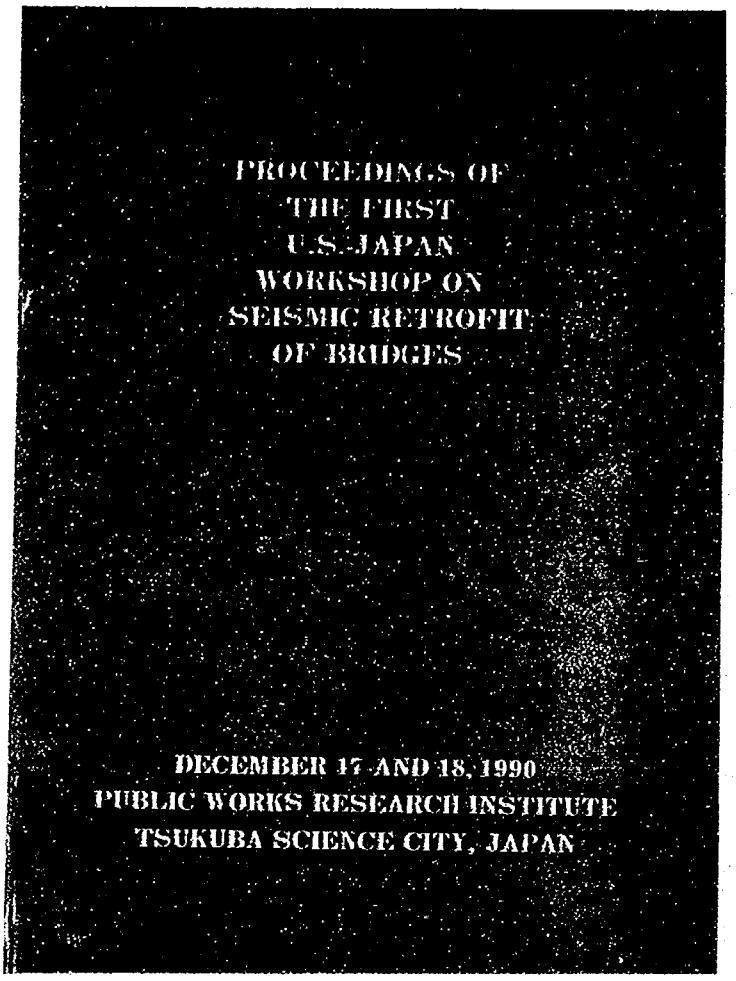


ISSN 0386-5878
Technical Memorandum
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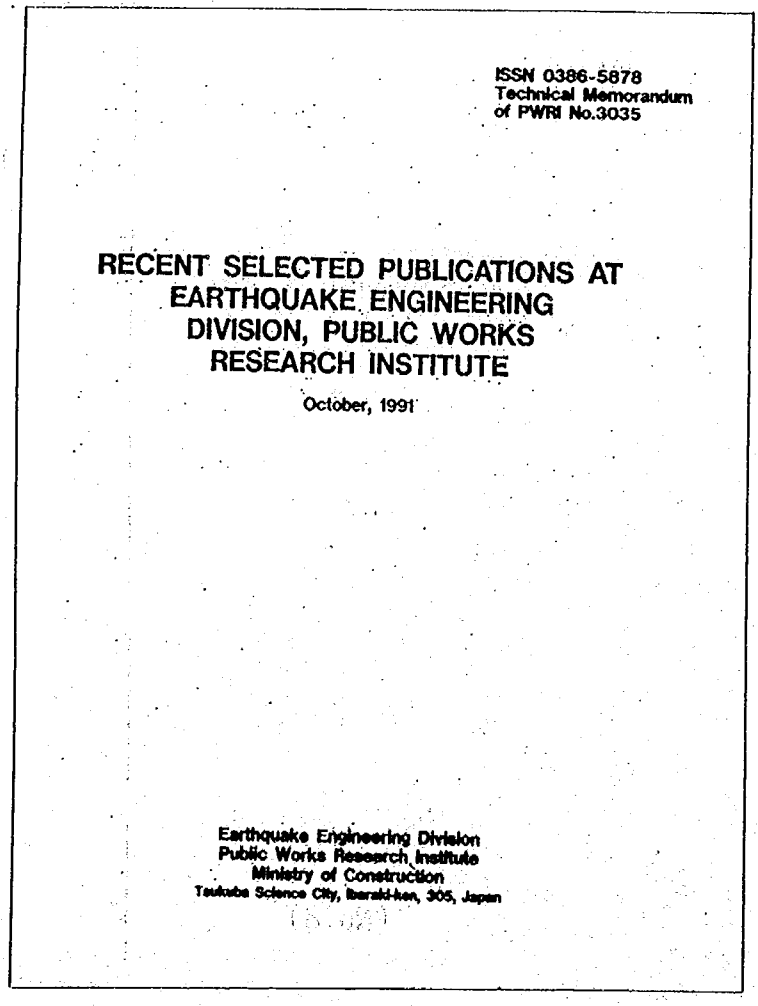
U.S.-JAPAN WORKSHOP ON EARTHQUAKE DISASTER PREVENTION FOR LIFELINE SYSTEMS

OCTOBER 26-27, 1992
PUBLIC WORKS RESEARCH INSTITUTE
TSUKUBA SCIENCE CITY, JAPAN

(No.8)



(No.9)


ISSN 0386-5878
Technical Memorandum
of PWRI No.3035

RECENT SELECTED PUBLICATIONS AT
EARTHQUAKE ENGINEERING
DIVISION, PUBLIC WORKS
RESEARCH INSTITUTE

October, 1991

Earthquake Engineering Division
Public Works Research Institute
Ministry of Construction
Tsukuba Science City, Ibaraki-ken, 305, Japan

(No.10)

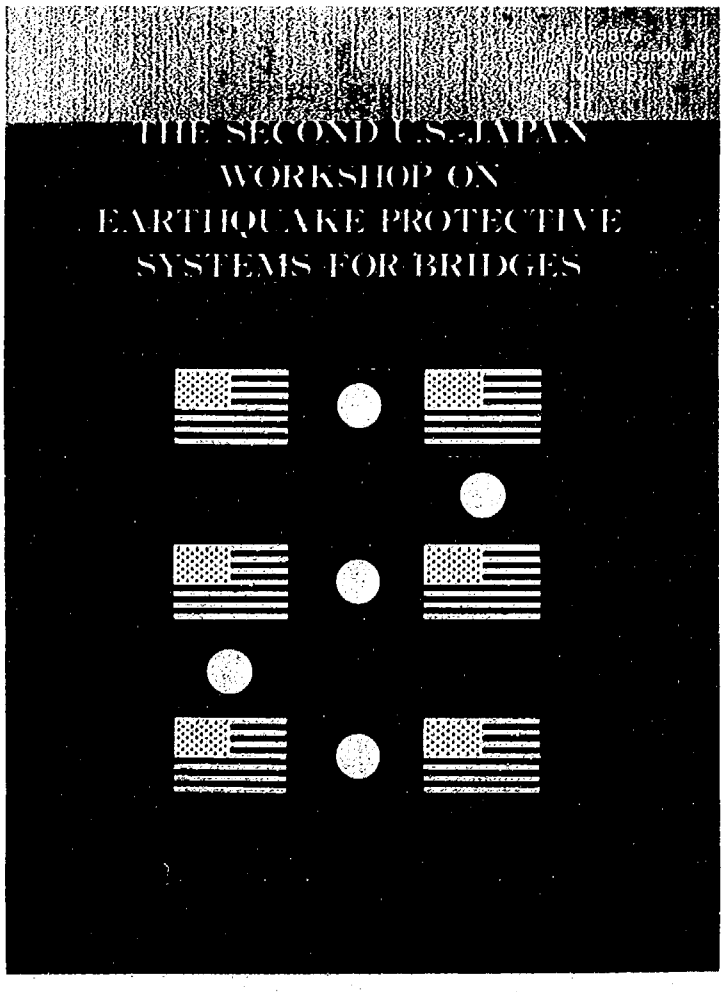
ISSN 0386-5878
Technical Memorandum
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RECENT SELECTED PUBLICATIONS AT EARTHQUAKE ENGINEERING DIVISION, PUBLIC WORKS RESEARCH INSTITUTE (No. 2)

May, 1993

Earthquake Engineering Division
Public Works Research Institute
Ministry of Construction
Tsukuba Science City, Ibaraki-ken, 305, Japan

(No.11)



(No.12)

SEISMIC BRIDGE RESEARCH IN CANADA

DR. DONALD L. ANDERSON
PROFESSOR
UNIVERSITY OF BRITISH COLUMBIA
DEPARTMENT OF CIVIL ENGINEERING
VANCOUVER, B.C., CANADA

- Behaviour of reinforced concrete bridge structures of older design to large seismic motions. This concerns the lack of ductility caused by poor confinement or of poor shear reinforcement, insufficient lap lengths and dowel lengths. Methods of retrofitting to overcome such deficiencies is vitally needed.

(No.1)

- Development of reliable methods for estimating the shear capacity of reinforced concrete members in regions of high ductility (plastic hinge regions).
- Use of prestressing to increase shear capacity.
- Joint response in concrete bridge supports.
- Ground motion estimates at sites with deep soft soil layers. Soil structure interaction at soft sites.
- Prediction of liquefaction and the estimation of ground displacements caused by liquefaction. This is a particularly relevant topic to bridges as they are quite often located on sloping alluvial sites that consist of layers of loose sands and silts.

(No.2)

Development of methods to improve soils to prevent liquefaction; how much improvement is required.

- Use of strong motion data to characterize variations in earthquake ground motions over distances typical of bridges

Response of long bridges in the longitudinal direction. This is complicated by the possibility of having differing ground motion at each pier and by having friction and impact at expansion joints.

- Vulnerability of substructure components. Development of retrofit design details.

(No.3)

- Base isolation and energy dissipation methods.
- Steel bridges - energy dissipating mechanisms, friction braces.
- Strengthening of existing prestressed segmental bridges.
- Specialized software for analysis of cable-stayed and suspension bridges.
- Dynamic testing of bridges to determine mode shapes and frequencies. Use of ambient vibrations.
- Precast modular bridges in regions of high seismicity. Dynamic testing of joints - steel pipe piles to precast beams.

(No.4)

- Methods of estimating risk, and methods of decision making, that would aid in arriving at decisions about the level of bridge retrofit that might be needed.

  Cost benefit studies.

(No.5)

CANADIAN UNIVERSITIES INVOLVED IN BRIDGE SEISMIC RESEARCH

University of B.C.
- R.G. Sexsmith
- D.L. Anderson
- Carlos Ventura
- W.D. Liam Finn
- P.M. Byrne

McMaster University - Hamilton Ontario
- John Wilson

University of Ottawa
- Michel Brunea
- M. Saatcioglu

(No.6)

McGill University - Montreal Quebec
- Denis Mitchell

Ecole Polytechnique de Montreal
Rene Tinawi
Andre Filiatrault
Bruno Massicotte

Universite de Sherbrooke - Quebec
Patrick Paultre

(No.7)

EARTHQUAKE ENGINEERING AND SEISMIC DESIGN IN CANADA

John C. Wilson[1]

In 1991, and again in 1992, I visited Japan as a guest researcher with the Earthquake Engineering Division of the Public Works Research Institute (PWRI), Ministry of Construction, in Tsukuba, Ibaraki Prefecture. These visits provided an exceptional opportunity to learn about earthquake engineering in Japan. As well, they provided me with many interesting and memorable experiences of Japan, its people, and some of the many intriguing cultural and social customs that are uniquely Japanese.

My first four-month visit to Japan in 1991 was part of a sabbatical leave from McMaster University where I am an Associate Professor of Civil Engineering. In 1992 I returned for two months during the university summer term. McMaster University is a medium-sized Canadian university located in Hamilton, Ontario (about 100 km from Niagara Falls and Toronto). I joined the faculty of McMaster University after completing a PhD in structural dynamics and earthquake engineering at the California Institute of Technology in 1984. At McMaster my principal research interest is earthquake engineering, with special emphasis on seismic and dynamic behaviour of cable-stayed bridges.

In the first part of this two-part article I present some overall aspects about earthquake engineering in Canada, give an overview of seismic zoning in Canada, and discuss provisions for lateral seismic forces for buildings contained in the National Building Code of Canada (NBCC). In the second part of this article (to appear in the next issue) I will give some impressions of my visits to Japanese engineering and construction companies and project sites. I will also describe some of my travel and social experiences, as they too are an integral part of my whole experience in Japan.

EARTHQUAKE ENGINEERING IN CANADA

Japan is one of the most densely populated countries of the world, and also one of the most seismically active. By contrast, Canada's population density is very low, and its record of historical seismic activity is limited. Thus, the number of people and the total economic investment exposed to seismic risk in the two countries are very different.

In 1991 the population of Canada was 26,835,500 people, similar to the population of the Tokyo area. By physical size Canada is the second largest country in the world with an area of 9,975,000 km^2; 30% larger than the continental United States and approximately 25 times larger than Japan. However, despite Canada's immense size, most of the population lives within about 100 km of the US border where the three largest cities, Toronto, Montreal, and Vancouver, are located.

In Canadian universities earthquake engineering is a specialized field of study. It is introduced in a few senior year courses in undergraduate civil engineering, and the real specialization occurs at the graduate level. For example, at McMaster University graduate level courses are offered in structural dynamics, earthquake engineering, and in other related topics such as design of tall buildings. At McMaster there are five faculty members with active research and professional interests in earthquake

[1] *Associate Professor of Civil Engineering, McMaster University, Hamilton, Ontario, Canada L8S 4L7*

engineering and structural dynamics. Each year McMaster has approximately fifteen graduate students involved in earthquake engineering research at the Master's and PhD levels.

The number of earthquake engineers and researchers in Canada is relatively small, although interests and activities span a wide range and include university, government, and consulting engineering firms. The principal Canadian forum for presentation and discussion of earthquake engineering issues is the Canadian Conference on Earthquake Engineering. This conference is held every four years (the seventh conference will be held in Montreal in 1995) and attracts several hundred people, many from outside of Canada. Papers of particular relevance to Canadian aspects of earthquake engineering are published in the Canadian Journal of Civil Engineering.

SEISMIC CODES

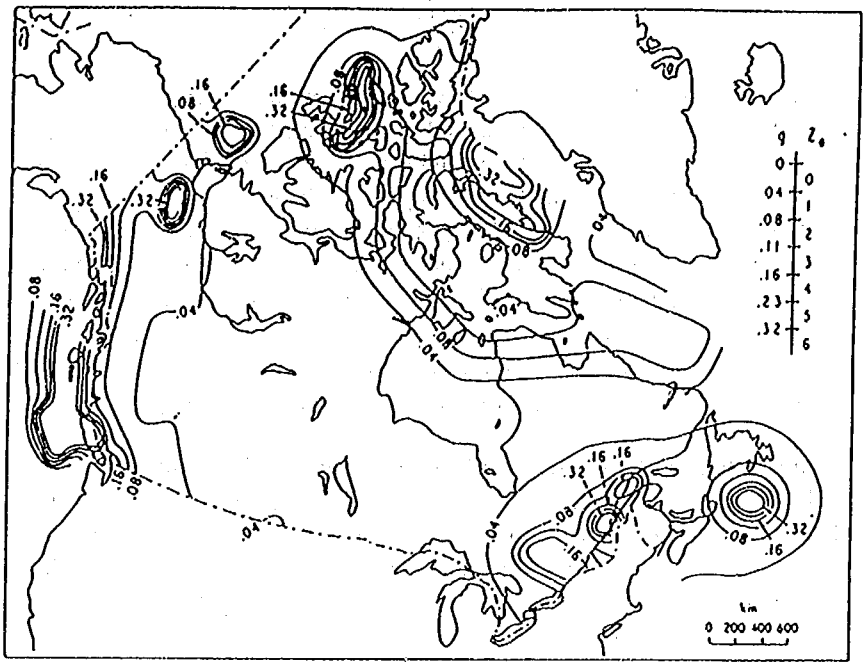
By comparison to Japan, Canada's problems in earthquake engineering are smaller and are concentrated in only a few geographical areas. The prime motivations for addressing earthquake issues in Canada however, are the same as in other countries; to protect life, economy and infrastructure in regions exposed to earthquake risk. The National Building Code of Canada contains seismic design provisions for buildings that are applicable to all regions of Canada. These provisions have been developed by the Canadian National Committee on Earthquake Engineering through consultations with representatives from industry, government and university sectors. In addition to the NBCC, seismic design provisions are also contained in other codes such as the Canadian Standards specifications for design of concrete structures for buildings. Seismic design provisions also exist for specialized facilities such as nuclear power plants, offshore structures, and liquified natural gas facilities.

Seismic design procedures for bridges are not specified by a national code in the same way as for buildings. Rather, regional (provincial) jurisdictions often specify the provisions that are necessary, either in the form of local codes, or adaptations of other codes such as the Applied Technology Council ATC-06. Since the 1989 Loma Prieta earthquake there has been considerable review and development of strategies for seismic bridge assessment, retrofit and new design.

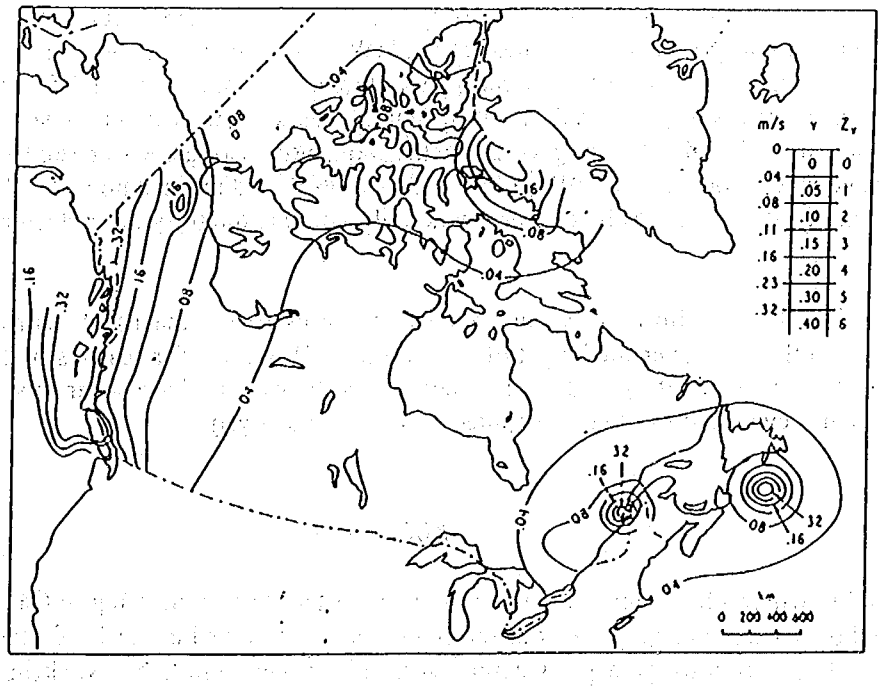
SEISMICITY AND ZONING

Canada uses two ground motion parameters for seismic zoning: peak horizontal ground acceleration, and peak horizontal ground velocity. For each parameter, Canada is zoned into seven seismic zones (zones 0-6) as shown on the accompanying maps. The zoning contours on the two maps are similar and clearly show that the severity of expected ground shaking varies considerably across the country. The regions of highest seismicity are along the west coast of British Columbia, through the St. Lawrence River Valley in the Montreal and Quebec City regions, offshore in Atlantic Canada, and in the north-west part of the country. The seismic zoning has been developed using risk analysis methodologies incorporating historical and seismo-tectonic information. Western Canadian earthquakes of significant size are likely to result from subduction zone processes. In eastern Canada, intraplate mechanisms are thought to be the main source of earthquakes. The seismicity of central Canada is very low and this region is placed in zone 0. More will be said about the dual-parameter zoning in the section on seismic design.

Although there are several regions of known or suspected seismicity, few records exist of seismic events within Canada. The three most notable recent events are: (1) 1982 Miramichi, New Brunswick $m_b=5.7$, (2) 1985 Nahanni, Northwest Territories $m_b=6.9$, (3) 1988 Saguenay, Quebec $m_b=5.9$. Recently, the 1989 Loma Prieta earthquake served as a lesson and stimulus to Canadian engineers, especially on the west coast, of the possible consequences of a similar event striking a Canadian city.



Contours of peak horizontal ground accelerations in Canada in units of g; (reproduced with permission, National Research Council of Canada)



Contours of peak horizontal ground velocities in Canada in units of m/s; (reproduced with permission, National Research Council of Canada)

SEISMIC DESIGN

The minimum base shear for seismic design of buildings, as stipulated by the NBCC, is formulated explicitly in terms of peak horizontal ground velocity (PHGV). Furthermore, the base shear is related implicitly to the peak horizontal ground acceleration (PHGA) through a seismic response factor (in spectrum form) that is a function of structural period. The use of the dual parameters of acceleration and velocity attempts to account for the expected frequency content of earthquakes resulting from different seismic environments across the country. Using this approach, earthquake ground motions in the vicinity of small or moderate earthquakes are considered to be velocity-related events. These are distinguished from the acceleration-related ground motions of large earthquakes occurring at a greater distance. The two ground motion parameters, acceleration and velocity, affect the behaviour of structures in the short period (0.2 sec) and long period (1 sec) range, respectively.

The seismic zoning of PHGA and PHGV contours on the maps are based on a 10% probability of exceedance in 50 years (an equivalent return period of 475 years). For the three largest cities the PHGA and PHGV values are: 0.21 g and 21 cm/sec for Vancouver; 0.18 g and 9.7 cm/sec for Montreal; 0.056 g and 3.8 cm/sec for Toronto. The code-specified peak ground acceleration and velocity in zone 6 are 0.4 g and 40 cm/sec, respectively, but it is recognized that site specific values within zone 6 may exceed these values by substantial margins.

The minimum design base shear is determined from an equivalent static lateral seismic force representing elastic structural response. This elastic level force is then reduced by a force modification factor "R" to determine the base shear corresponding to an ultimate limit state when the structure is assumed to be at the point of collapse. The R-factor accounts for energy absorption capacity of the structure due to damping and inelastic response. For short-period buildings (with periods less than 0.25 sec) that are detailed for full ductile behaviour, and are located in an acceleration-related zone 6, the design base shear is 0.25W (W = total weight of the structure). The same structures located in a velocity-related zone 6 will have a design base shear of 0.125W. This assumes structures of normal importance and foundation conditions. In certain circumstances the use of importance and foundation factors of up to 1.5 and 2.0, respectively, can result in substantial increases to the design base shear. The design base shear for short-period buildings designed as ductile moment-resisting steel or reinforced concrete space frames located in Vancouver is 0.09W, in Montreal is 0.06W, and in Toronto is 0.03W. For steel braced frame or reinforced concrete wall structures with only nominal ductility these design base shears would be doubled.

The NBCC also allows a dynamic analysis to be used as a means of distributing the statically determined lateral forces over the height of the building. However, for reasons of code calibration and overall intended levels of safety, NBCC does not permit the use of a base shear lower than the statically calculated value, even if it has been computed by dynamic analysis.

SUMMARY

In this article I have outlined some aspects of earthquake engineering in Canada. The discussion has focused on seismic design provisions for buildings, as contained in the 1990 National Building Code of Canada. In addition to the aspects described in this article, significant work in many other areas of earthquake engineering is undertaken by consulting engineers, government and universities. Much of this work is regularly reported in forums such as Canadian and international engineering journals, and in conferences (Canadian and others) on earthquake engineering.

7. Road Environment

Road Environment
道路環境

Jun Ando
Assistant Director
Road Environment Research Section
Planning Division, Road Bureau, MOC

1. History

Since the latter half of the 1960's, various environmental problems resulting from the remarkable increase in automobile transportation demands began to draw attention in Japan. At the same time, Japan was suffering from a lag in the improvement and capacity of social overhead capital in relation to the rapid concentration of population and industries in urban areas.

In order to cope with environmental problems caused by automobile traffic such as noise and air pollution, a wide range of efforts have been made in the past to preserve harmony between roads and their environment, for example: (1) improvement of the motor vehicle itself (mechanism and design improvements to control automobile exhaust gas and noise); (2) traffic restrictions and controls; (3) development of a systematic road network which incorporates design improvements such as bypasses and ring roads; (4) measures to improve the road structure such as the installation of noise barriers and buffer zones, and the promotion of tree planting; (5) roadside improvements which aim at modifying land utilization to bring it in harmony with roadside living environment; and (6) execution of environmental impact assessments prior to the implementation of large-scale road construction. However, the environmental problems such as noise and air pollution primarily around trunk roads in urban areas still remain one of the most important tasks of the road administration.

Today global-scale measures to deal with environmental problems such as the control of CO_2 emissions are urgently needed. Achievement of harmony with the natural environment has become an overwhelmingly important issue in the field of roads and traffic management.

1)Environmental Quality Standards

The Basic Law for Environmental Pollution Control was enacted in 1967. Its aim was the establishment and enforcement of comprehensive measures to combat environmental pollution. Under this law, environmental quality standards were set. These represent the standards which must be maintained in order to protect the public's health and welfare and to preserve a healthy living environment. The environmental standards which are closely related to the implementation of road works are those concerning air pollution and noise (refer to Table 1 and 2).

In addition to the above basic law, others concerning air pollution, noise pollution and vibration were separately enacted. Examples are the Air Pollution Control Act, Noise Regulation Act and Vibration Control Act.

2)Environmental Impact Assessment

If the prevention of environmental pollution and the preservation of the natural environment are truly desired, then consideration for the environment must become an indispensable factor in the determination of road plans. Environmental Impact Assessment is one of the most effective ways to implement this consideration in road improvement.

The government took appropriate steps and the Cabinet passed a resolution "For the implementation of the environmental

1. 経緯

1960年代後半から、自動車交通需要の著しい増大と人口、産業の急速な都市への集中に対する社会資本の整備の相対的な立ち遅れの結果、自動車交通によるさまざまな環境問題が提起された。

以来、自動車交通による大気汚染、騒音等の環境問題に対し、(1)自動車構造の改善(自動車排出ガス規制および自動車騒音規制)、(2)交通規制および取り締まり、(3)バイパス・環状道路等の体系的道路ネットワークの整備、(4)遮音壁・環境施設帯等の設置、緑化の推進等の道路構造面での対策、(5)沿道と調和した土地利用への転換を図る沿道整備、(6)大規模な道路事業の実施に際しての環境影響評価など、道路と環境の調和を図るべくさまざまな努力が重ねられてきた。しかし、都市部の幹線道路を中心とした大気汚染、騒音等の環境問題は依然として道路行政上の重要課題の一つである。

また、現在、地球規模での環境問題への対応が必要とされ、地球温暖化防止に向けたCO_2排出量の抑制や、さらには自然環境との調和も自動車交通分野の大きな課題となっている。

1)環境基準

公害対策の総合的推進を図ることを目的として、1967年に公害対策基本法が制定され、この法律に基づき、人の健康を保護し、および生活環境を保全するうえで維持されることが望ましい基準、いわゆる環境基準が設定されている。道路事業の実施に際し、特に関係する環境基準としては、大気汚染、騒音にかかる環境基準がある(表1、2)。

また、大気汚染、騒音、振動については「大気汚染防止法」「騒音規制法」「振動規制法」等の個別法が制定されている。

2)環境影響評価

道路計画を決定するに際し環境への配慮が必要不可欠であり、環境影響評価はそのための有力な手段の一つである。

政府は1984年8月28日に「環境影響評価の実施について」の閣議

Table 1 Environmental Quality Standards for Noise
騒音にかかる環境基準

(Unit dB (A))

Category of area	Noise Level Ceiling by Time Period		
	Daytime	Morning & evening	Night time
Type A areas bordering on a two-lane road	55	50	45
Type A areas bordering on a more than two-lane road	60	55	50
Type B areas bordering on a not more than two-lane road	65	60	55
Type B areas bordering on a more than two-lane road	65	65	60

Note: A Primarily residential areas
B Areas where a substantial number of residences are located among shops and factories

impact assessment system" in August 28, 1984. According to the resolution, it was decided that uniform environmental impact assessments would be implemented for certain projects which are carried out, licensed or approved by the government. In accordance with the above cabinet resolution, the Vice-Minister of the Ministry of Construction issued notification "For the implementation of the environmental impact assessment system for projects under the administration of the Ministry of Construction" on April 1, 1985. This was followed by the issuance of the "Technical Guidelines for the Environmental Impact Assessment System" by the Vice-Minister of the Ministry of Construction on September 26, 1985. Based on such official notification and official directives, environmental impact assessment for road projects was smoothly and fully implemented. The flow of work, starting with the projects subject to this assessment and the environmental factors which are studied to the preliminary surveys and final assessment, is shown below (include Fig.1).

Projects Subject to Assessment

(1)Construction or reconstruction of national expressways (excluding small-scale reconstruction such as additions of interchanges, etc.)

(2)Construction of national highways with 4 lanes or more, construction of national highway bypasses with 4 lanes or more, or widening of national highways involving addition of four lanes or more (provided the section subject to new construction, addition of a bypass, or widening is longer than 10 km).

決定を行った。結果、国が実施し、または免許等で関与する一定の事業について統一的に環境影響評価を実施することとなった。

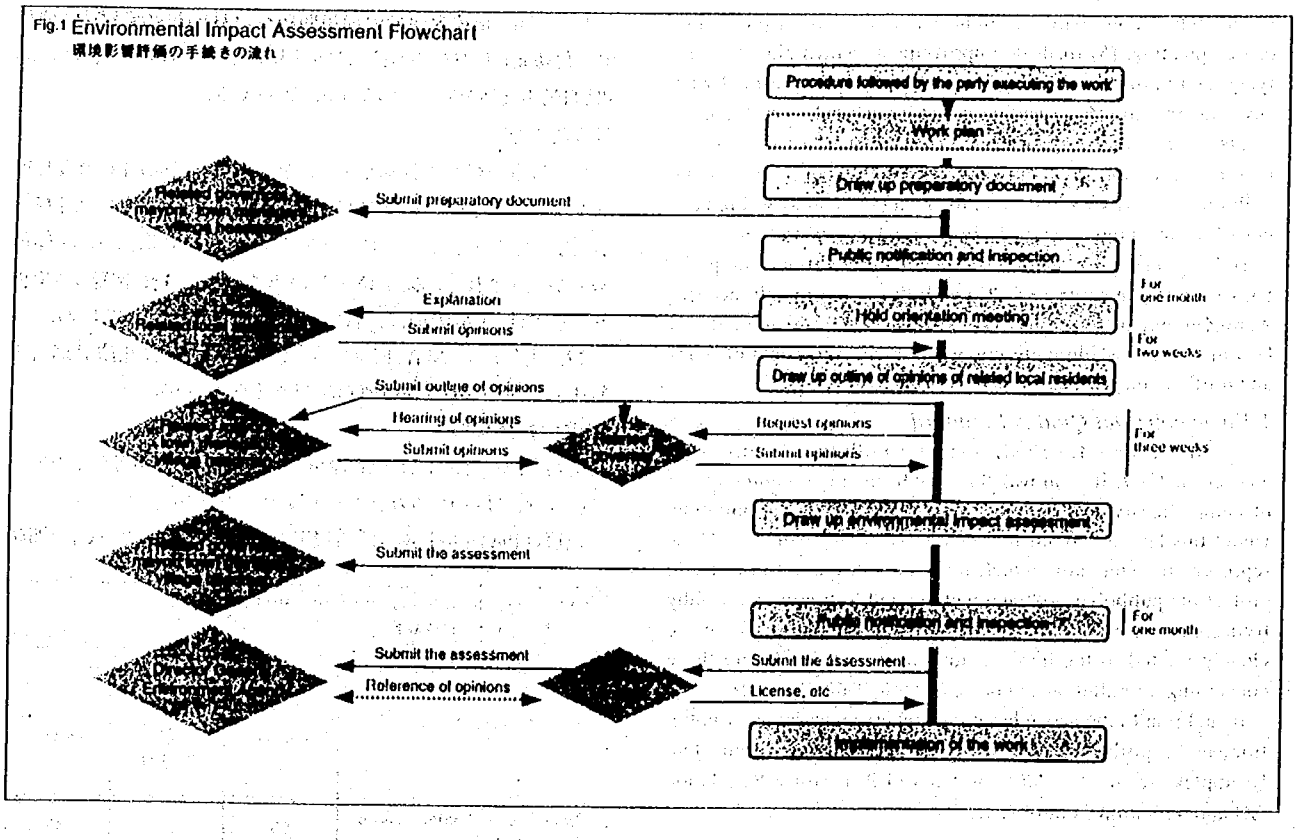
この閣議決定を受けて、建設省においては、1985年4月1日に「建設省所管事業に係る環境影響評価実施要綱」が建設事務次官通知されている。

Table 2 Ambient Air Quality Standards
大気汚染にかかる環境基準

Substance	Standards
Sulfur dioxides	Daily average of hourly values shall not exceed 0.04 ppm, and hourly values shall not exceed 0.1ppm.
Carbon monoxide	Daily average of hourly values shall not exceed 10ppm, and average of hourly values in eight consecutive hours shall not exceed 20 ppm.
Suspended (1) particulate matter	Daily average of hourly values shall not exceed 0.10 mg/m³, and hourly values shall not exceed 0.20 mg/m³.
Nitrogen dioxides	Daily average of hourly values shall be between 0.04 ppm, and 0.06 ppm, or less
Photochemical (2) oxidants	Hourly values shall not exceed 0.06 ppm.

Note: (1)Suspended particulate matter shall mean airborne particles of 10 microns or less in diameter.
(2)Photochemical oxidants are oxidizing substances such as ozone and peroxiacetyl nitrate produced by photochemical reactions (only those capable of isolating iodine from neutral potassium iodide, excluding nitrogen dioxides)

Fig.1 Environmental Impact Assessment Flowchart
環境影響評価の手続きの流れ



(3)Construction or reconstruction of the Metropolitan Expressway, Hanshin Expressway, and designated city expressways of 4 lanes or more (excluding small-scale reconstruction such as addition of street lamps, etc.)

Environmental factors subject to study, preliminary survey, and assessment

1.With respect to environmental pollution prevention
1)Air pollution (CO,NO2), 2)Water pollution, 3)Traffic noise, 4)Traffic vibration, 5)Ground subsidence

2.With respect to the preservation of the natural environment
6)Geographical change, 7)Effect on plants, 8)Effect on animals, 9)Landscape

(3)Roadside Law

Each administration has adopted comprehensive and diverse steps as measures against road traffic noise in the past. These include improvement of the motor vehicle itself and traffic controls. The Ministry of Construction has also implemented aggressive improvement of road structures, etc., such as improvement of bypasses and ring roads, installation of noise barriers, buffer zones, and planting zones.

However, in the case of many urban trunk roads, it is difficult to implement these measures due to the state of roadside land utilization. Therefore, in order to establish effective and adequate measures against noise that will continue to perform their role in the future, establishment of measures based on the enhancement of harmony between trunk roads and roadside land utilization are required. According to carefully considered plans, it is necessary to guide the utilization of land along trunk roads in a direction appropriate for roads. Enacted in 1980, the "Law for the Improvement of Areas Along Trunk Roads"– commonly referr-ed to as the "Roadside Law"– aims at creating a more attractive urban environment for the future and supporting trunk road functions. Full enforcement of this law commenced in October of the same year.

The law includes a broad variety of measures such as designation of roads for roadside environment improvement, the drawing up of roadside improvement programs (city planning) and assorted regulations based on the Building Standard Law. Based on these measures, a new policy to promote an improved roadside environment consisting of a series of new systems has been established.

As of the end of February 1993, five routes with a length of 83.5 kilometers (total: 7 routes; length: 103.4 km) have been targeted for improvement of the roadside environment. Of these roads, the plans for the improvement of a total of 63.3 kilometers have been decided in accordance with urban planning.

また、1985年9月26日には「建設省所管道路事業環境影響評価技術指針」が建設事務次官通知されている。道路事業にかかる環境影響評価は、これらの通知等に基づき適切に実施されており、対象事業、調査・予測・評価の対象とする環境要素、手続きの流れは図1のとおりである。

対象事業

1)高速自動車国道の新設または改築(インターチェンジの追加等の小規模な改築を除く)。

2)4車線以上の一般国道の新設、一般国道の4車線以上のバイパスの設置または新たに4車線以上を付加することとなる一般国道の拡幅(新設、バイパスの設置または拡幅にかかる部分が10km以上のものに限る)。

3)4車線以上の首都高速道路、阪神高速道路および指定都市高速道路の新設または改築(ランプの追加等の小規模な改築を除く)。

調査・予測・評価の対象とする環境要素

1.公害の防止にかかるもの
1)大気汚染(CO、NO2)　2)水質汚濁　3)騒音
4)振動　5)地盤沈下

2.自然環境の保全に関するもの
6)地形・地質　7)植物　8)動物　9)景観

3)沿道法

道路交通騒音対策として、従来から自動車構造の改善、交通規制等の各種施策が各行政機関により総合的に講じられている。建設省においてもバイパス・環状道路の整備、遮音壁・環境施設帯・植樹帯の設置等の道路構造の改善等を積極的に推進してきた。

しかしながら、都市部の幹線道路においては、沿道の土地利用の状況等からこれらの対策を講ずることが困難な場合が多い。そのため将来にわたって有効適切な騒音対策を講ずるためには、幹線道路と沿道土地利用との調和を図ることを基調とした施策の確立が要請された。

このため、幹線道路の沿道の土地利用を道路にふさわしい方向に計画的に誘導することが求められる。そして、将来にわたる望ましい街づくりを行うとともに幹線道路の機能を確保することを目的として、1980年に「幹線道路の沿道の整備に関する法律」(いわゆる「沿道法」)が制定され、同年10月から施行された。同法においては沿道整備道路の指定、沿道整備計画(都市計画)の策定、建築基準法による条例等について定められた。また、これらを踏まえた沿道整備促進のための施策という一連の新たな沿道整備制度が創設された。

なお、1993年2月末現在で、沿道整備道路は5路線83.5km(延べ7路線103.4km)が指定されており、このうち沿道整備計画については合計63.3kmが都市計画決定されている。

2. Present Status and Roles for the Road Environment, and the Future Direction of Road Environment Measures

1)Countermeasures for the Greenhouse Effect

Around the world, countries are urgently adopting measures to stop the rise in the earth's temperature. Japan must also commit its resources to the stabilization of CO_2 emission levels. Japan produces about 5% of the global volume of CO_2 emissions, of which the transportation sector is responsible for about 20%. It is estimated that about 90% of this amount can be attributed to motor vehicle traffic (refer to Fig. 2).

In the area of motor vehicle traffic, promotion of energy conservation can be accomplished from a variety of standpoints: by improving road networks, by seeking more efficient use of motor vehicles, and by technological enhancement of the vehicles themselves. Improvements in the road networks of Japan have not been able to keep up with the sharp growth in motor vehicle usage, and this has resulted in traffic congestion which not only wastes fuel but is a major factor in the increase of CO_2 emissions. However, because there is still much room for improvement, the elimination of congestion through enhancement of roads will significantly contribute to the correction of the high energy inefficiencies. The resolution of traffic congestion will require improvement of road networks by the addition of bypasses, ring roads and improved intersections. The resulting increase in average driving speed will not only provide users with greater efficiency but help to create a better environment.

A modal mix policy must also be aggressively promoted to obtain maximum benefit from the unique advantages of each of the various modes of transportation. Reinforcing the linkage between motor vehicles, railways, and coastal shipping, Japan will be able to realize a transportation system which is both responsive and energy efficient. The improvement of fundamental facilities to enhance the efficiency of physical distribution is another area that requires attention.

In urban districts, fixation of CO_2 and the alleviation of the phenomenon the heat islands is becoming a pressing issue. To respond to this concern, greater efforts must be made to not only preserve existing trees but to substantially increase the greenery in areas along roads by tree planting when road improvements are executed.

2. 道路環境の現状と問題、今後の道路環境政策の方向

1)地球温暖化の防止

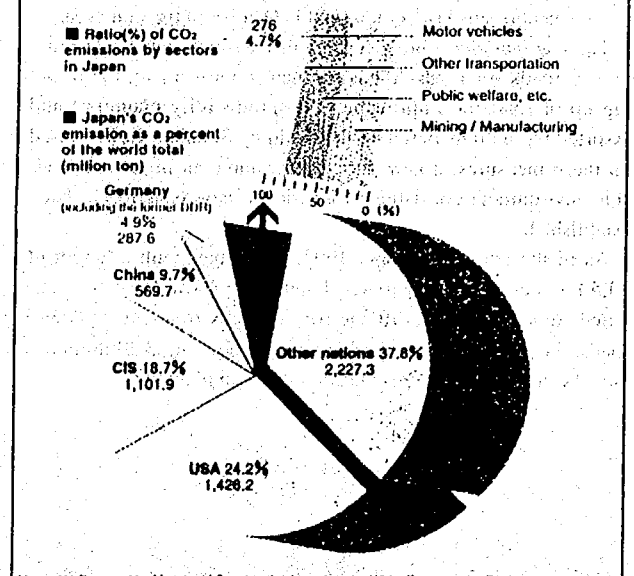
地球温暖化防止に向けての世界的取り組みのなかで、日本においても、CO_2(二酸化炭素)排出量の安定化を図る必要がある。日本は世界のCO_2の約5%を排出しているが、国内のCO_2排出量のうち、約2割程度を運輸部門が占めている。また、そのうち約9割を自動車交通が占めると試算されている(図2)。

自動車交通分野においては、道路ネットワーク、自動車の利用方法、自動車構造など、さまざまな側面から省エネルギーに取り組んでいく必要がある。わが国の自動車交通は道路ネットワークの立ち遅れを背景とした渋滞など、エネルギー的に非効率な部分がいまだ多く残されており、渋滞による燃料消費が、CO_2排出量増大の大きな要因となっている。このため、渋滞の解消に向けて、バイパス、環状道路をはじめとする道路ネットワークの整備や交差点改良を推進し、環境面からも適切な走行速度を実現する。

また、地域特性、交通特性に応じて、自動車、鉄道、内航海運等各種交通機関のそれぞれが特性を十分発揮し連携を強化して、エネルギー効率面でも適切な輸送体系を確保するモーダルミックス政策を積極的に推進する。

さらに、物流の効率化を図るための基盤施設の整備を進める。また、CO_2の固定化、都市部のヒートアイランド現象の緩和等の観点から、道路整備にあたっては、既存の樹木の保全に努めるとともに、緑化の一層の充実により道路の緑量の大幅な増大を図る。

Fig 2 Share of CO_2 Emission Volume by Country (unit : million tons)
日本は世界の約5%を占めるCO_2排出大国



Note : (1) Prepared by Ministry of Construction based on the White Paper on the Environment,1991.
(2) Japan's emission quantity is under reexamination.

2)Harmony with Natural Environment

In the past, road improvement projects in regions with a rich natural environment have proceeded with special attention paid to the conservation of endangered fauna and flora and to the achievement of harmony with landscape. Today, however, it is necessary to extend this care to the entire ecological system. The task of conservation of the natural environment does not focus on only a few rare and precious species; it encompasses all animals and plants which comprise the rich ecosphere.

In the execution of road improvement projects in the future, it will be very important to continue conducting accurate environment impact assessments; however, it is equally necessary to promote further harmony with the natural environment. Some of those actions are:

(1)Promote road projects in harmony with natural environment: Detailed study concerning the natural environment and data collection should be conducted. Based on the findings, routes should be selected which provide maximum conservation of nature's abundant resources; structural patterns which avoid substantial change to topography and vegetation should be adopted.

(2)Promote special measures at key natural areas such as national parks: By setting up parking lots in the peripheral areas of key natural areas and reducing intrusion by switching from private vehicles to buses, road utilization which harmonizes with nature can be achieved.

(3)Prevent division of animal habitats and preserve a growth environment for plant life: This can be realized by establishment of road crossing structures for animals (animal trails) and wildlife caution signs, and by conducting work for the popularization of roads ("eco-roads") equipped with infrastructure which gives full consideration to the ecological balance of the area.

(4)Compensate for cutting of slopes and creation of embankments which accompany road works: Efforts must be made to return the area to its original natural condition as much as possible following road works. Measures include replanting and utilizing vegetation which best harmonizes with the natural condition of the local weather and soil, (natural vegetation).

(5)Take active steps to encourage the growth of fauna and flora: In accordance with the characteristics of the respective region, active efforts to create a living and growing environment of fauna and flora should be made in the course of road improvement execution. For example, when conducting planting of flora, careful selection of the species of plants to be planted with consideration for the present condition of the peripheral natural environment should be made.

2)自然環境との調和

これまで自然環境の豊かな地域における道路整備に際しては、主に貴重な動植物の保全や、自然景観との調和に留意しながら事業を進めてきた。しかし現在、自然環境の保全については貴重種のみならず、普通に見受けられる動物や植物も含めた生態系全般との調和が必要である。

このため、今後の道路整備にあたっては、引き続き的確な環境影響評価を進めるとともに、次のような視点から、自然環境との一層の調和を図っていく必要がある。

(1)自然環境と調和した道路計画を進めるため、自然環境に関する詳細な調査の実施、データの集積に取り組むとともに、それを踏まえて、豊かな自然を保全できるような路線の選定や、地形・植生の大きな改変を避けるための構造形式の採用に努める。

(2)国立公園等特に自然環境の豊かな拠点では、周辺部にマイカーからバス等に乗り換えるための駐車場を整備するなど、自然と調和した道路利用を誘導する。

(3)動物の生息域分断の防止や、植物の生育環境の保全を図る観点から、動物の道路横断構造物(けもの道)の設置や、動物注意の標識等を設ける。さらに、生態系にきめ細かく配慮した構造を備えた道路(エコロード)の普及に努める。

Photo. 1 An underground tunnel is installed to avoid division of wildlife habitats.
野生動物の生息域分断を避けるために道路下に設けられたトンネル

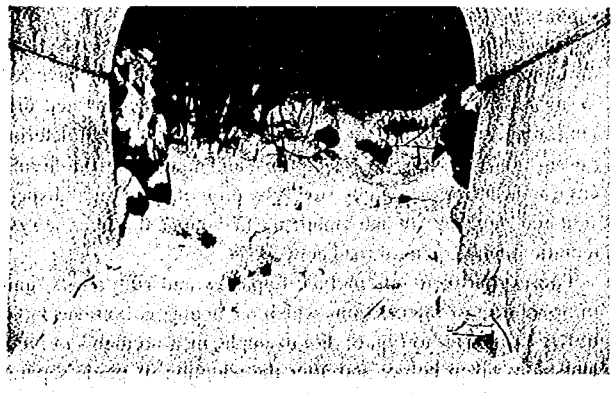
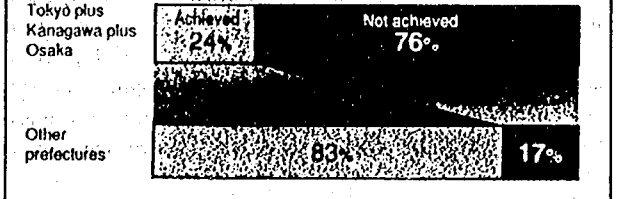
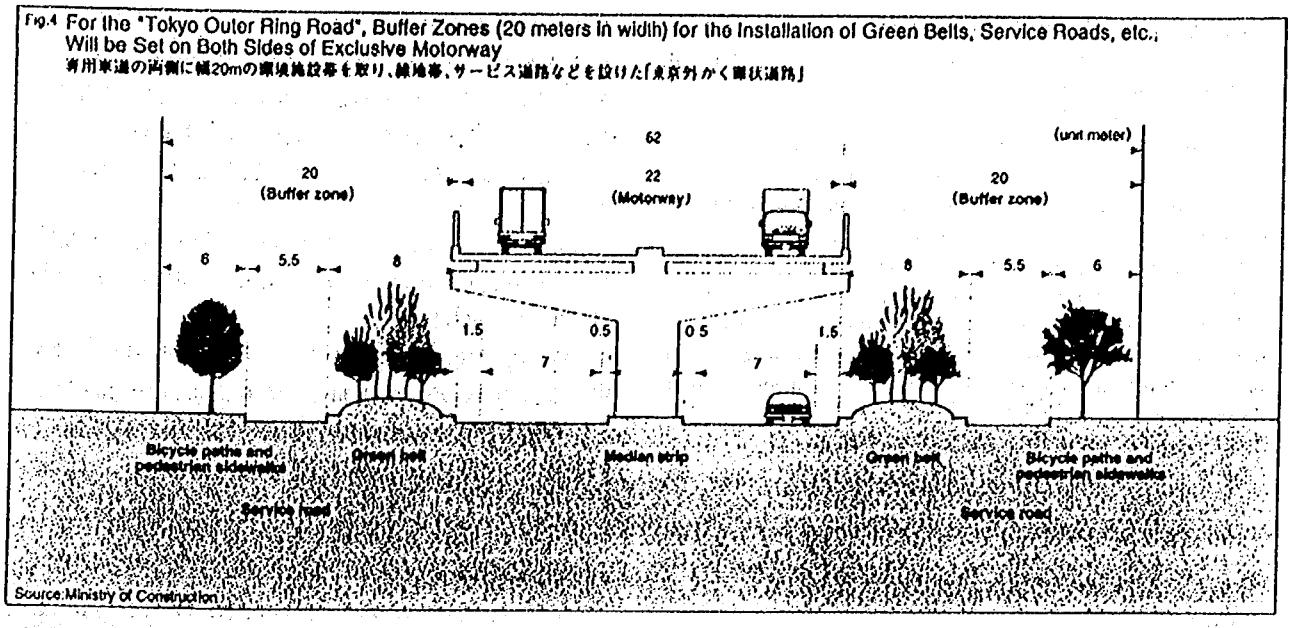


Fig.3 Achievement of NO_2 Environmental Standards (1990)
NO_2環境基準達成状況(1990)



Note: Prepared by the Ministry of Construction based on measurement results reported by the Automobile Emission Gas Measurement Bureau (Environment Agency), Fiscal 1990

Fig.4 For the "Tokyo Outer Ring Road", Buffer Zones (20 meters in width) for the Installation of Green Belts, Service Roads, etc., Will be Set on Both Sides of Exclusive Motorway
専用車道の両側に幅20mの環境施設帯を取り、緑地帯、サービス道路などを設けた「東京外かく環状道路」



3)Conservation and Creation of a Roadside Living Environment

In order to preserve the roadside living environment, measures have been taken with an emphasis on road structures such as the installation of buffer zones and noise barriers. However, basic measures which focus on the root causes of NOx and noise levels and realize their reduction are urgently needed for areas along trunk roads in major cities (refer to Fig. 3)

Automobile traffic congestion caused by excessive concentration of population, industries and traffic in urban areas have led to an increase in NOx and noise generated by accelerated driving, both of which are leading causes of environmental deterioration. It is necessary to protect and maintain the roadside living environment of existing city streets by promoting optimal dispersion and "leveling" of automobile traffic volume through the systematic improvement of road networks.

These improvements include bypasses and ring roads, and improvement of intersections which are acting as bottlenecks to traffic flow (refer to Fig. 6). For example, measurements of NOx emissions taken before and after the adoption of grade separations show that levels decreased about 30% decrease.

In the case of new construction of trunk roads, it is necessary to escalate the installation of environmental conservation measures such as buffer zones and noise barriers. For existing trunk roads, measures must be expanded to deal with sections which are the cause of intolerable levels of noise (refer to Fig. 4). In addition, plans to promote research and development of new environmental countermeasure technology including low-noise pavement and efforts to bring them into practical application must be pushed forward.

A majority of the sections suffering from noise levels which exceed the environmental standard can be found in the roadside

(4)道路事業に伴い発生した切土や盛土ののり面については、既存ストックも含めて、地域の機構や土壌などの自然条件に最も調和した植生(潜在自然植生)の活用等により再緑化を行い、できる限り自然に近い状態に復元する。

(5)地域によっては、道路整備にあたって、周辺の自然環境の現状に配慮しながら、植栽の樹種などを工夫することにより、動植物の生息・生育環境の形成に取り組む。

3)良好な生活環境の保全・形成

沿道の生活環境を保全するため、これまでも環境施設帯・遮音壁の設置など主に道路構造対策を中心に進めてきた。しかし、窒素酸化物(NOx)や騒音は、大都市部の幹線道路沿道において、改善を要する状況にある(図3)。

都市部への人口、産業、交通の過度な集中に起因する自動車交通の渋滞は、窒素酸化物や加速走行騒音を増大させ、環境悪化の大きな原因となっている。

このため、バイパス・環状道路をはじめとする道路網の体系的整備や、ボトルネック箇所における交差点改良により、自動車交通の適正な分散・円滑化を図り、既成市街地の沿道生活環境を保全することが必要である(図6)。例えば、交差点立体化の整備の前後におけるNOx排出量について見ると、約3割程度の低減効果が報告されている。

また、幹線道路の新設にあたっては、環境施設帯や遮音壁の設置など、十分な環境保全対策を講じるとともに、既存の幹線道路についても騒音の著しい区間については対策の拡大を行う必要がある(図4)。さらに、低騒音舗装をはじめとする新たな環境対策技術の研究・開発を推進し、その実用化を図っていくものである。

areas of residential district. Promotion of amendments to land utilization suitable for the areas along trunk roads as well as measures for road structure are clearly necessary.

4)Promotion of Comprehensive Measures Based on the Road Environment Program

In the execution of road improvement projects in the future, the "Road Environment Program" has been established to promote comprehensive road environment measures for each region in accordance with the special characteristics of each area as they pertain to roads. (e.g., geographical conditions, land utilization, traffic conditions, etc.) This program aims at playing a very active role in the creation of sound environment by integrating various measures from three viewpoints of global environment, natural environment and roadside living environment.

さらに、騒音にかかる環境基準の超過区間については、住居系の沿道地域がその多くを占めている現状である。そのため、道路構造対策の推進とともに、幹線道路の沿道に適した土地利用への転換を促進していく必要がある。

4)道路環境計画に基づく総合的な施策の推進

今後の道路整備にあたっては、地域ごとに、その地理的条件、土地利用、交通条件等、道路をめぐる地域の状況に応じて、総合的な道路環境施策の推進に関する「道路環境計画」を策定し、同計画に基づき地球環境、自然環境、沿道環境の三つの視点から各種施策を総合的に組み合わせ、良好な環境の創造に向けて積極的に取り組んでいくこととしている。

Fig.5 Improved Traffic Energy Consumption (reduction of CO_2 emissions)
自動車交通のエネルギー効率向上（CO_2の低減）

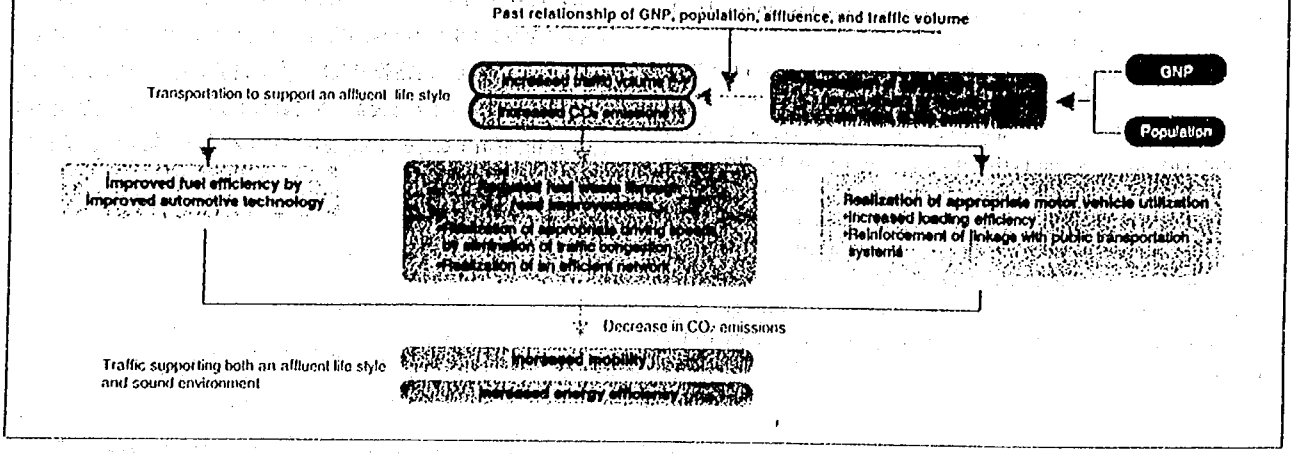
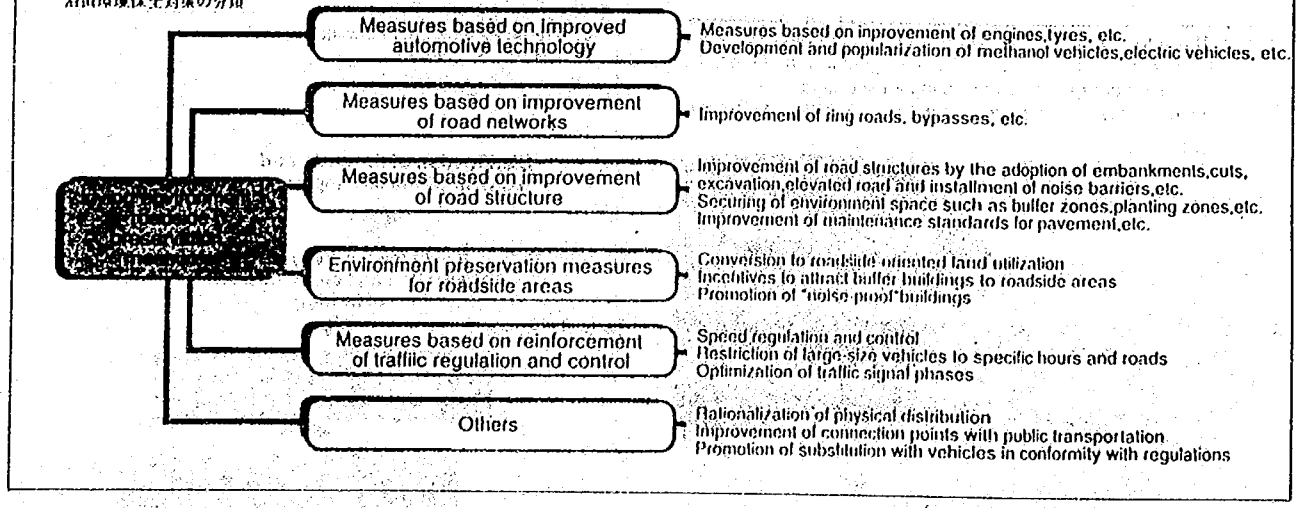


Fig.6 Classification of Living Environment Roadside Preservation Measures
沿道環境保全対策の分類



TOPIC Traffic Assessment
交通アセスメント

Recent years have seen the realization of many large-scale development projects such as the construction of new large-scale commercial facilities, redevelopment of urban areas, and the development of new urban areas. The activities of such projects have generated a new and substantial amount of vehicle traffic, resulting in increasing instances of heavy traffic congestion on peripheral roads. In order to ensure the smooth flow and safety of road traffic, it is necessary not only to steadily promote road works, but also to implement comprehensive measures to mitigate or resolve hindrances to road traffic caused by these development projects. (refer to photo 1)

When there is a possibility of considerable impact on the flow of road traffic by the implementation of large-scale development projects located near or along roads, it is necessary to conduct preliminary surveys and perform an assessment of the impact in the planning stage prior to implementation. Subsequently, necessary preventive measures need to be planned and performed by the cooperative efforts of the development undertaker and relevant road administrator. The "Traffic Assessment System" is currently under examination with objective of mitigating or resolving hindrances to road traffic through such measures. (refer to Fig. 1)

近年、沿道における大規模商業施設の新設、既成市街地の再開発、新市街地の開発等の大規模な開発事業に伴い相当量の自動車交通が新たに発生し、周辺道路に著しい渋滞を発生させる場合が増加している。道路交通の円滑および安全を確保するためには、道路事業の着実な推進を図るほか、これらの開発事業による道路交通への支障を緩和、解消するための総合的な対策の実施が必要となっている(写真1)。

このため、沿道における大規模開発事業が道路交通の円滑に著しい影響をおよぼす恐れがある場合、その計画段階において影響を事前に予測、評価し、道路管理者および開発事業者等が協力して必要な予防的対策を講じる必要がある。それによって、その道路交通上の支障を緩和、解消することを目的に交通アセスメントを行うことが必要である(図1)。

Photo 1 The effect on peripheral road traffic by the development of large-scale commercial facilities is primarily manifested in increased congestion and parking lot shortages.
大規模商業施設の開発では渋滞や駐車場不足など周辺道路交通への影響が問題となっている

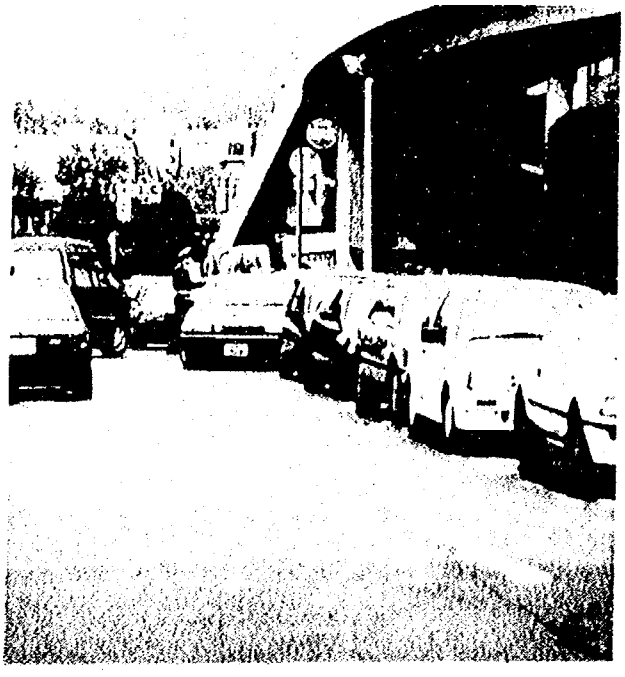
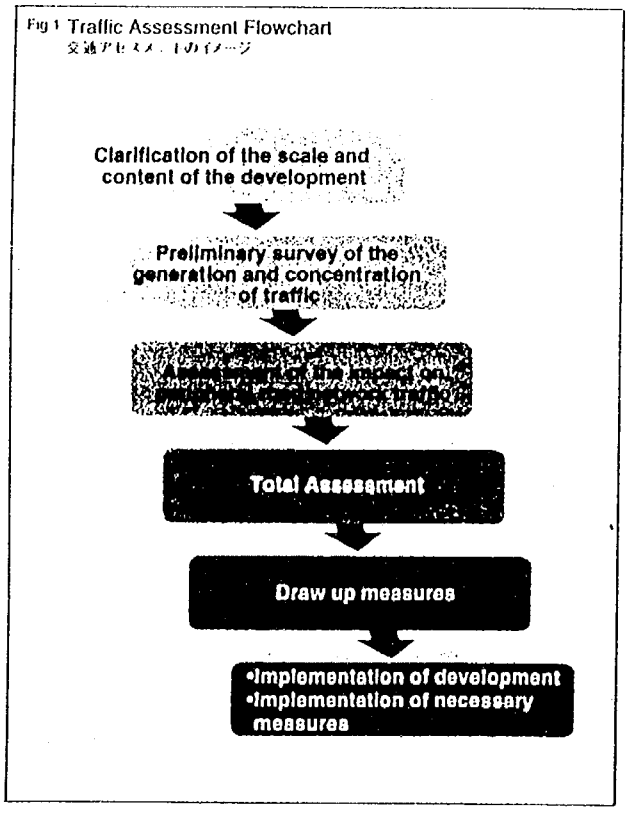


Fig 1 Traffic Assessment Flowchart
交通アセスメントのイメージ



HIGHWAY-ENVIRONMENTAL TECHNOLOGY TRENDS IN JAPAN

Minoru Ishida
Head; Traffic Environment Division
Public Works Research Institute
Ministry of Construction

1. Introduction

To cope with the environmental problems that became evident in Japan from around 1960, concerned persons have been striving to uphold a high-quality, comfortable environment in the areas along highways. As part of these endeavors, environmental-protection measures have been taken with regard to individual vehicles by each auto manufacturer. And research and development has been conducted for technologies needed to estimate and evaluate roadside environmental impacts prior to utilizing and/or improving highways. Environment-protection technologies by means of highway structure, facilities, etc. have also been developed and applied by many interested organizations.

As results of the above, when a highway has been newly improved, a certain degree of success in environmental conservation has been achieved. Despite these endeavors, however, the concentrations of some air pollutants still have not been improved in principal large cities and in their surrounding areas. The traffic-noise problem also remains for some existing highways. Conversely, higher-level methods than ever before are required for the prediction of roadside-environmental conditions, as are more stringent environmental-protection measures. And these are needed to accompany the increased complexity of the road structures for large-scale highways and the higher vehicle speeds. And, there are promlems of countermeasure for the Greenhouse Effect and promotion of the consideration to Nutural Environment, etc. These problems according to change of times appears.

This paper will introduce trends in the technologies used to cope with highway-environmental problems in Japan.

2. Elements of Roadside-Environmental Technology

Environmental factors relating to highway transportation include noise, air pollution, and the natural environment. A wide range of technological elements correlate with these factors. Table 1 lists highway technologies, roughly classified into measures for prediction, assessment, and protection.

Trends for major technologies related noise and air pollition among those shown in Table 1 will be presented below. The natural environment is not dealt with in this paper because it is discussed in another report.

3. Environmental Impact Assessment Technology

(1) Highway-Traffic Noise

The Noise-Control Law and "Environmental-Quality Standards for Noise" (Determined by Cabinet Meeting) stipulate that evaluation of the noise of vehicle traffic in Japan basically uses the central value (Leq) of that noise. Accordingly, the prediction items in the "Technical Guidelines for Environmental Impact Assessment for Highway Projects Administered by the Ministry of Construction" also employ Leq. The prediction method presently used is based on a method that uses what is known as the linear-isometric power-model system of the Acoustical Society of Japan. This method, with the inclusion of additional data such as vehicle-power levels in consideration of noise restrictions and the differences in height between the individual factors used for prediction, is included in the above-mentioned guidelines and in the accompanying explanatory document, the "Highway Environment Improvement Manual."

This method is applied when highway surfaces such as plane areas, embankments, cuts, and elevated highways are continuous and vehicles transit these highway structures constantly. The use of the simulation method and other techniques has been studied to predict highway noise in the areas around interchanges, depressed highways, and tunnel openings. At present, the final operations for determining the best method are being conducted.

Leq has generally been adopted worldwide for evaluating highway-traffic noise. This value is considered easier to use for noise estimation, and more rational than the use of Leq Accordingly, research on Leq is now in progress.

(2) Air Pollution

The "Technical Guidelines for Environmental Impact Assessment for Highway Projects Administered by the Ministry of Construction" stipulate that prediction of the air pollution caused by vehicle-exhaust gas in Japan is to be done using the concentrations of carbon monoxide and nitrogen dioxides. These "Technical Guidelines" and the "Highway Environmental Improvement Manual" also stipulate the use of the "plume-puff model" formula as the diffusion formula for prediction. Exhaust coefficients and diffusion parameters have been prepared for each of these air-pollutants.

This method is applied when the highway structure is the continuation of individual highway structures; planes, embankments, cuts, elevated highways, and depressed highways; and when vehicle highway traffic is constant. Methods for predicting air pollution at interchanges, in partially covered depressed highways, and at the openings of tunnels are presently being determined.

Sometimes highway structures and topography are more complicated. We therefore confirm air pollution using a model experimental method that can reproduce the changes of topography and ground details (Photo 1). Trial prediction of air diffusion have also been conducted by numerical simulation, using large computers.

Table 1 Elements of Highway-Environmental Technologies

	Prediction and evaluation elements	Protective-measure elements
Traffic noise	Method of the Acoustical Society of Japan Prediction of traffic noise in complicated topography and highway structures Vehicle-power levels Factors that affect noise propagation Simulation method Prediction using Leq	Vehicle noise-prevention measures Low-noise tires Improvement of highway networks and traffic control, etc. Highway structure Buffer zones Noise barriers Low-level urban noise-barriers New soundproofing systems Active noise control Attenuation and absorption of noise using trees and other vegetation Low-noise and noise-absorbing pavement Noise-absorbing materials and systems Noise-absorbing boards on elevated-highway undersides Noise-absorbing structures Psychological noise-control measures
Air pollution	Analysis methods Prediction, in complicated topography and highway structures Wind tunnel experiment method Numerical simulation method Broad-area simulation method Grasping vehicle-exhaust-gas quantity Various factors affecting the diffusion of pollutants Influence of single and compound pollutants on air pollution	Exhaust-gas-control measures for diesel- and gasoline-powered vehicles Energy-saving vehicles Vehicles using alternate forms of energy (electric-, hydrogen-, methanol-powered, and other types of vehicles) Improvement of highway network and traffic control Highway structures Buffer zones Vegetative absorption and diffusion of NOx, etc. Vegetative immobilization of CO_2 Using biotechnology for development of vegetation that absorbs large volumes of NOx Energy-economy and use of clean energy in highway construction and control Low-concentration denitrification systems
Traffic vibration	Statistical Prediction method	Omitted
Natural environment	Methods of Predicting and determining present conditions for each topic	Ecosystem-conservation methods Buffer zones Highway structures that minimize changes in the natural environment Slope-surface treatments Highway-Crossing facilities for animals Protective measures, using ditches for small animals Transference of vegetation and small animals
Other items	Overall prediction, study of influences, and preventive measures relating to scenic views, low-frequency air vibration, water pollution, soil contamination, land subsidence, etc.	

Note) Scenic views and planting technology are handled separately, and therefore have been omitted or handled herein as "other items."

4. Roadside Environmental-conservation Technology

(1) Improvement of vehicle structures

The most basic control measures for air pollution from vehicle-exhaust gas, and for highway traffic noise, are the measures for controlling the sources of these problems.

Concerning noise control, engine-acceleration noise control began in 1971. in addition to the exhaust noise control and regular engine-noise control already in practice. Since then, these control measures have become stricter by three successive amendments. Vehicle noise can be divided into engine noise, cooling-fan noise, intake/exhaust noises, tire noise, etc. The noise-reduction measures taken for these must be conducted thoroughly and comprehensively, concentrating first on the factors that have the greatest influence on noise generation.

Restrictions on vehicle exhaust gas have been gradually intensified.
Exhaust-gas control measures for gasoline-powered passenger vehicles have advanced greatly since before restrictions were first imposed, mainly because of systems using ternary catalysts. only a limited number of exhaust-control measures, however, have been adopted for diesel-powered vehicles such as large trucks, and no decisive measures for these have yet been adopted. Further technological developments are anticipated that can reduce the amount of exhaust gas from diesel-powered vehicles to the level produced by gasoline-powered vehicles.

It is desired that low-pollution vehicles using other fuels than petroleum and light oil should be developed, nut to practical use, and widely spread. The popularization of these vehicles is eagerly awaited. Among the public low-pollution vehicles that have already been developed, electric, methanol, and natural-gas-powered vehicles have already reached the level where they can be used on public highways. The performance, however, of each of these types of vehicles is unsatisfactory for regular practical use, and we are awaiting their further technical development.

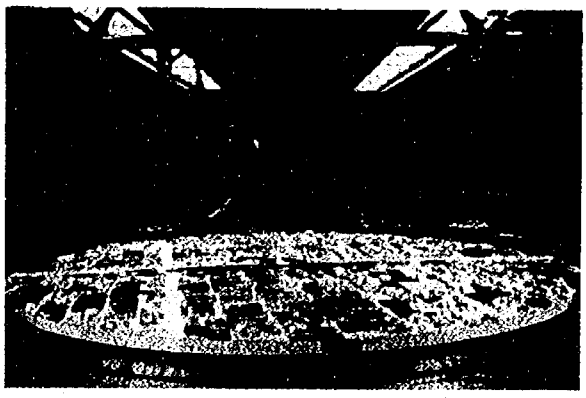


Photo 1 Air-Diffusion-Model Experiment Using a Wind Tunnel

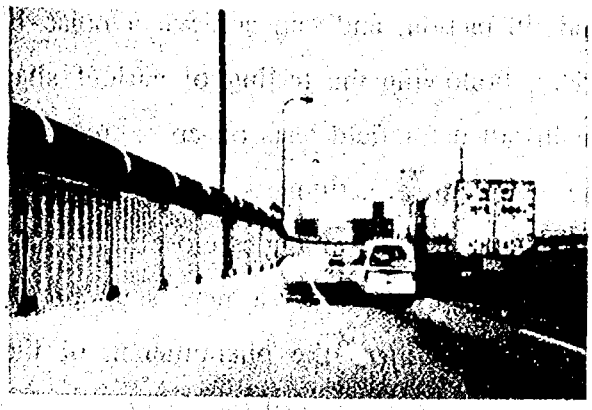


Photo 2 Noise Reducer

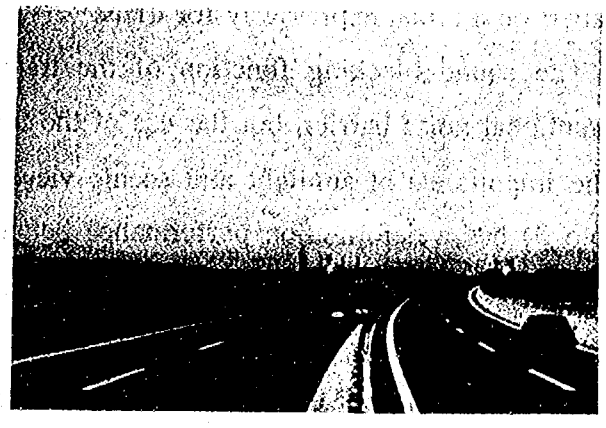


Photo 3 Curved, Translucent Noise Barrier

(2) Noise Barriers

The efficacy of a noise barrier is certainly great and it is easy to install. Many noise barriers have therefore been installed in Japan, mainly along motorways, and the total length of these barriers reached 2.082 km in fiscal 1990. [1] The conventional noise barrier is a wall that has noise-blocking or noise-blocking + noise-absorption performance. When, however, the height of a noise barrier is increased to ensure greater noise reduction, problems arise such as insufficient sunlight and the blocking of scenic views, as well as problems with the foundation structure. R&D is therefore underway to produce noise barriers with transmittance capability, to reduce the problems of blockage of sunlight and scenic views; and to develop a soundproofing facility of the same height as a conventional noise barrier, but with greater soundproofing efficacy.

The noise-reducer [2] developed by the Japan Highway Public Corporation and manufacturer is one example of a new sound-blocking system (Photo 2). This new noise-reducer uses a sound-absorbing unit that is installed on the top the barrier to diminish

sound diffraction, and can achieve a noise-blocking effect equivalent to that of higher noise barriers. Following the testing of various shapes of prototypes, this type of noise-reducer has been installed for field tests on an expressway. The results of measurements of efficacy show a noise-reduction effectiveness of 2 - 2.5 dB better than with a noise barrier alone, at sections having large diffraction angles close to the noise barrier.

Another example of a new soundproofing system is the interference type (cam zone) system. This utilizes the phenomenon of the generation of interference when a discrepancy exists between the phase of the delay wave that has passed through the system and the phase of the wave that is diffracted by the top of the system. This cam-zone system has also been installed on a urban expressway for trials.

The sound-blocking function of the translucent noise barrier is the same as that of a conventional noise barrier, but the use of the translucent barrier is expected to increase because of the importance of sunlight and scenic views, etc. Curved translucent board [3] in particular (Photo 3) has a deformation performance better than that of flat translucent board, and allows both wide-area visibility and economical installation. Curved translucent noise barriers are also extremely stylish.

Tall noise barriers can be installed on expressways, but it is very difficult to install these high barriers on highways in areas within cities where there are no access control. In such cases, when the green belt between the sidewalk and the highway is changed to a structure 80 - 100 cm in height, a degree of noise-blocking effectiveness can be expected. According to the results of experiments using models, a noise-blocking effect of approximately 3 dB can be expected in the height range of 1 - 2 m above ground, equivalent to the head height of a standing person, when a noise barrier 1 m in height is used as shown in Fig. 1. We are now conducting a study of this, including the feasibility of using for noise barriers materials that have even minimal sound-absorbent capacities.

(3) Low-noise and sound-absorbent pavement

The use of drainage pavement is now attracting attention as a low-noise and sound-absorbent pavement. Tests of this paving have been conducted in each area concerned with highway construction. Measurement of the noise-reduction effect is conducted simultaneously with research on the drainage function. The many voids (porous gaps) in this drainage pavement are considered to reduce air-pumping noise, one factor in reducing noise. Increased sound-absorbency is also considered to be a noise-reduction factor. Experiments to determine the noise-reducing mechanism of drainage pavement are conducted on the test course

at the Public Works Research Institute. Fig. 2 shows the power levels for passenger vehicles and large trucks in powered-by-running condition for each variety of pavement. The power level used when vehicles run on drainage pavement with a large void ratio is smaller than on pavement using dense graded asphalt. The difference increases as the running speed rises.

Fig. 3 shows the results of the sound absorption coefficient measurements of drainage pavement.

With the selection of appropriate materials, lower noise than with conventional pavement can be expected when drainage pavement is used. According to data obtained thus far, however, the noise-reducing effectiveness of most pavement decreases as time passes; therefore, the next task is to obtain a continuous noise-reducing effect for pavement.

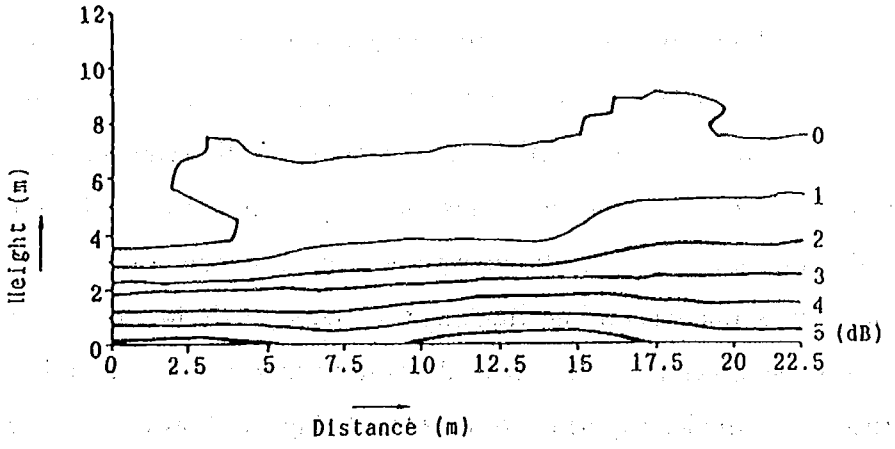


Fig.1 Noise-Blocking Effect of Low-Level Noise Barrier

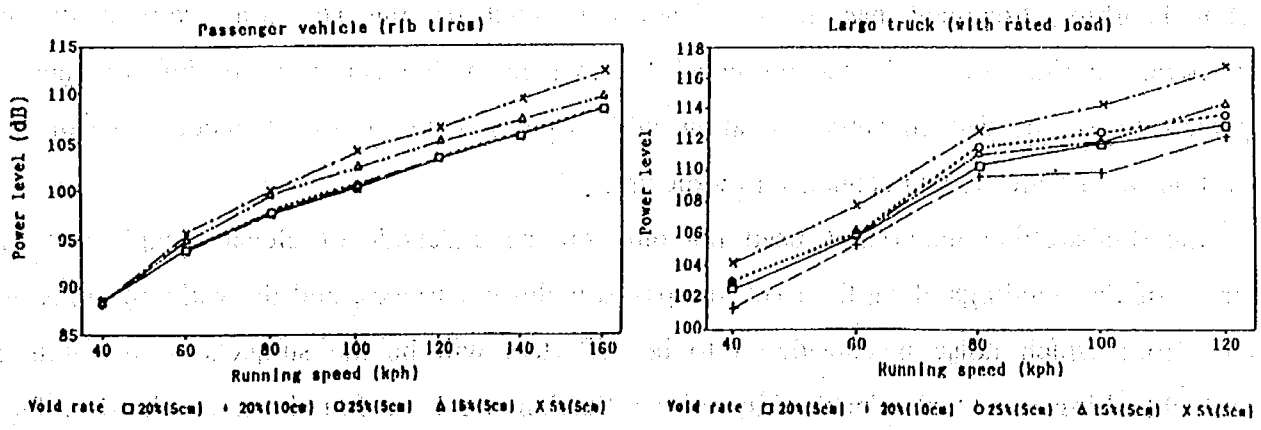


Fig.2 Power Levels of Vehicles Running on Each Type of Pavement

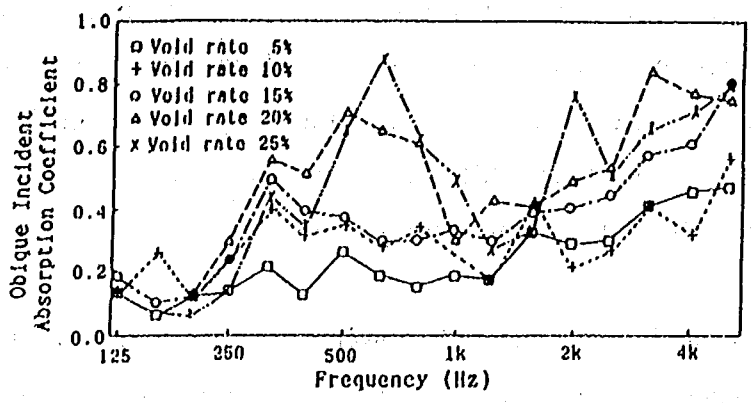


Fig.3 Oblique Incident Absorption Coefficient (Incident Angle 80 Degree)

(4) Measures for prevention of noise reflection from elevated highways

Many double-decked and dual-level highway structures have been constructed in Japan producing an elevated highway that is constructed above a street. This has been done to make effective use of highway sites in and around urban areas. on such a route, the noise from vehicles running along the lower-level highway is assumed to be reflected by beams, etc. in the understructure of the elevated highway. This noise is also considered to exert an adverse influence upon the roadside area from the viewpoint of environmental noise.

The efficacy of sound-absorbing treatment to cope with the noise reflected onto the roadside from the understructure of an elevated highway of the above-mentioned configuration, has been confirmed by model experiments (Photo 4). Fig. 4 shows the noise-reducing effect when sound-absorbing boards were installed on the entire underside of an elevated highway. The efficacy of the sound-absorbing treatment is particularly high in sections close to the highway, near the ground surface, and in the upper section. Field-test work on sound-absorbing treatment has already been conducted on the Hanshin Expressway and elsewhere. Continuation of the technological development of this sound-absorbing treatment is expected to be needed in future, dealing with aspects such as maintenance, control, the provision of fine views, and economy of structure.

Sound-absorbing material is used not only on the underside of elevated highways. All surfaces of the buildings along the road, the paved highway surfaces, and the walls of depressed roads, from which noise is considered to be reflected, will be the subjects of research on sound-absorbing treatment. Concerning noise reflection, we have found among these surfaces that drainage pavement increases the rate of sound absorption. We hope to conduct research on

sound absorption regarding wall-finishing materials for buildings, etc., on the roadside.

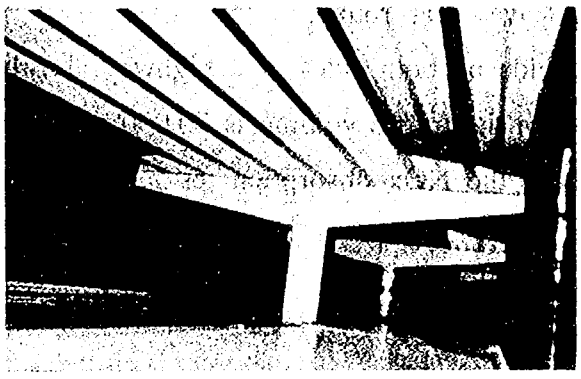


Photo 4 Model Experiment to Determine the Effects of Sound-Absorbing Treatment Beneath an Elevated Highway

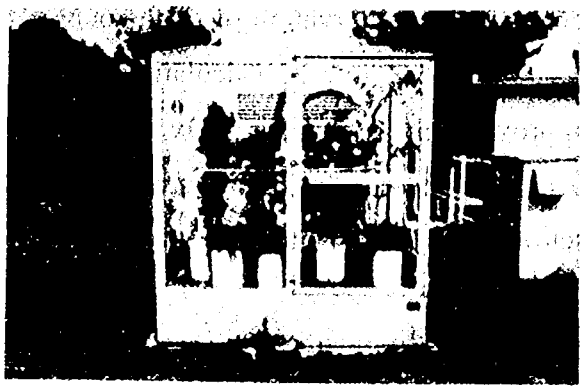


Photo 5 Experiment on NOx-Absorption by Plants

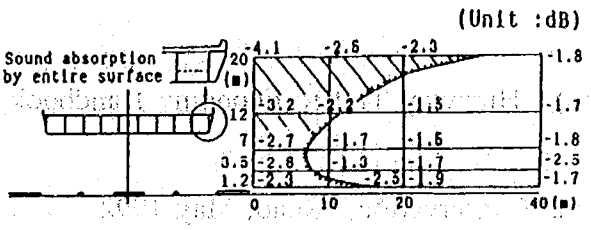


Fig.4 Noise-Reducing Effectiveness of Sound-Absorbance

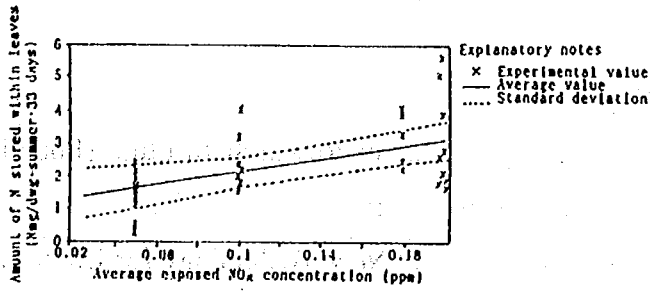


Fig.5 Exposed NOx Concentration, and Amount of N Stored within Leaves

(5) Absorption of NOx by trees, etc.

Vegetation is generally considered to have the function of absorbing and absorbing air pollutants. Green belts, as highway facilities, are expected to provide an effective absorption function.

Exposure testing (Photo 5) was conducted using a gas chamber to determine the NOx gas-absorbance capacity of plants. [6] The test results show that when the NOx concentration to which the plant is exposed is higher, the amount of N stored in the plant increases. The amount of stored N also varies depending on the season and the plant species. The seasons, in declining order of the amount of N stored, are spring, summer, autumn, and winter. Observation of the amount of N stored in leaves by each plant species showed that the amount of N stored in

summer was, in descending order, tall deciduous trees, herbs, and tall conifers. The leaves of herbs and broadleaf trees, however, are dormant in winter. The above results therefore cannot be applied to observation of the amount of N stored in leaves year-round.

According to trial calculations, green belts 7 m wide on both sides of a highway absorb approximately 5% of the NOx emitted by vehicles when the traffic volume is 30,000 vehicles per day. These calculations are based on the results of the NOx-absorption testing done by setting up a green belt model as a highway facility.

5. Postscript

Despite the fact that large numbers of people in many organizations have been continuing R&D related to highway-environmental technology, many major problems remain that are associated with highway environments. In the future, therefore, we must make even greater efforts to develop preventive measures. A large number of feasible and effective measures can be effected using existing technology, and have already been done. It will be necessary in the future to develop many new technologies. We must attempt even methods that were previously considered excessively difficult.

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Construction of Roads Harmonized with Natural Environment

= Eco-road =

By: Minoru Ishida, Takashi Nishio

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1. Introduction

Careful attention has been paid to the protection of the natural environment in constructing roads. With an increasing concern of the public about the natural environment, it comes to a social requirement for road construction not only to protect rare species but to harmonize with the overall ecosystem including ordinary species of fauna and flora that can be seen here and there. With this background, the 11th Road Construction Program for 5-Year Term <1> states in its "(3) Promoting road construction to create favorable environment" that harmonization with the natural environment is the primary issue. Thus, construction of roads will require more appropriate methods, careful attention and suitable measures for minimizing effect of roads to the natural environment.

The term "eco-road" in the title of this paper is an abbreviation of "ecological road", which can be defined as a road kind to the nature with full of opportunities for meeting with the nature <2>, or a road with full of considerations given to the ecosystem or the lives of familiar wild plants and animals <3>. In order to achieve this objective in road construction, it is intended in the Road Construction Technology 5-Year Plan <4> to prepare an eco-road guideline as a part of promotional activity for developing the road construction technology in consideration of the ecosystem (popularization of the eco-road). Up to this date they have already collected some data on the cases in which various protective measures are taken for the natural environment. However, effect or quantitative evaluation of those measures are yet to be studied. It is only a list of measures that have been collected and thinkings applicable to eco-road. The following outlines those measures and thinkings.

2. Flow of Measures for Natural Environmental Protection in Constructing Roads

Road construction consists of a number of procedures, starting from basic design stage to rough design, detail design, execution, and to final management stage. In order to provide appropriate measures for the natural environmental protection of a specific site, it is necessary to investigate the present condition and determine the design in accordance with the accuracy of each construction stage. Flow of the eco-road construction is summarized in Figure 1.

As known from the figure, it is necessary to research the natural environment and examine the protective measures at every stage of the construction including investigation and planning stage, design and execution stage, and management and maintenance stage so as to construct a road in harmonization with the natural environment. It is important at every stage to understand the nature in the planned construction site and manage to take an appropriate measure for each objective that needs to be protected.

In Chapter 3 and on, measures to be taken at each stage are explained with representative examples.

Stage of road construction	Investigation and measure	Item
Investigation and planning stage		
Setting planning conditions	Investigation by literatures	—To know the habitat of rare species —To avoid the nature conservation area specified in laws —To avoid the area full of rich natural environment
	Site investigation	—To know brief condition of the natural environment in the site
Rough design	Planning of routeway	—To plan the routeway and structure a) Adoption of elevated bridge b) Adoption of tunnel c) A routeway requiring less banking and cutting
Design and execution stage		
Design	Conservation	—Examination of detailed road structure (to minimize the degree of alteration) a) Examination of shapes of piers of bridge b) Examination of shapes of tunnel c) Partial change of routeway —To secure a transit path for animals —Planting to lead to an animal trail or to shelter from enemy —Lighting in consideration of the nature —To place shading panels in consideration of the nature —Consideration to a fishway when replacing drains —To relocate the habitat of animals or transplant existing plants —To plant appropriate floras on the slope of banking or cutting (Potential natural vegetation, afforestation according to the existing vegetation, transplanting of grown trees on a less inclined slope) —Afforestation to protect tall trees —Reuse of surface soil —Ditches allowing small animals to creep out —Protection fence against entry of animals —Sign board of "Watch animals jumping out"
	Creation	—To create a new biological habitat —To increase green coverage —Place with full of opportunities for meeting with the nature
Execution	Measures during execution	—To appropriately allocate a work place during the construction —To install anti-pollution equipment for water —To restore the vegetation over temporary roads of the construction —To manage various unexpected happenings during the construction
Maintenance and management stage		
Maintenance and management	Investigation maintenance, and management	—Follow-up investigation —To maintain and/or improve measures

Figure 1 Flow of the Eco-Road Construction

3. Measures at Investigation and Planning Stage

Investigation and planning stage is the beginning stage in constructing a road, where the construction conditions are set up in 1/50,000 to 1/10,000 scale and the rough design is prepared in 1/5,000 to 1/2,000 scale. It it an important stage not only for proceeding with the road construction but with the natural environment protection.

3.1 Investigation of actual condition and planning of routeway

The first to do is to thoroughly investigate the natural environment in the site covered by the construction plan and understand the actual condition correctly. It is possible to know briefly from literatures as to whether the site includes a legally designated area or whether rare or important species are living in some area of the site. It is recommended to avoid those areas by changing the routeway at an earlier stage. Since investigation by literatures may not always be sufficient, it is advisable to investigate the site as well for the purpose of confirming and supplementing the information of the literatures. When the site investigation reveals an area with full of rich natural environment, it is again necessary to change the routeway.

3.2 Planning of road structure

When further consideration is required in addition to the above measures, it is necessary to examine how to minimize the alteration area by employing a suitable road structure. To give an easy example, employing a bridge structure (Figure 2) for a long distance to be filled up by banking will help minimize the alteration of the slope, and employing a tunnel structure (Figure 3) for a long distance to be cut open by digging will help maintain the existing environment to some extent. It is necessary to conduct an overall and comprehensive examination in actual planning, including a minor change of the routeway. This examination is very important to provide appropriate measures not only for conserving existing plants but for giving no threat to the life patterns of animals.

4. Measures at Design and Execution Stage

Work in the design and execution stage includes preliminary design and execution design (1/1,000 to 1/500 scale) as well as various investigations and actions according to the progress in the construction. If taking all satisfactory measures was impossible in the previous stage, it is recommended to take additional and more careful measures in this stage for conservation of the natural environment to a highest possible extent including conservation of ordinary species. In particular, since relatively full investigation is conducted at this stage with regards to the design of the road, it is necessary to carry out a parallel investigation of the natural environment around the site and determine more effective measures for the conservation. It is also necessary to examine the adaptability of each measure because there are a number of measures available to be considered at this stage. The following discusses some of the typical measures.

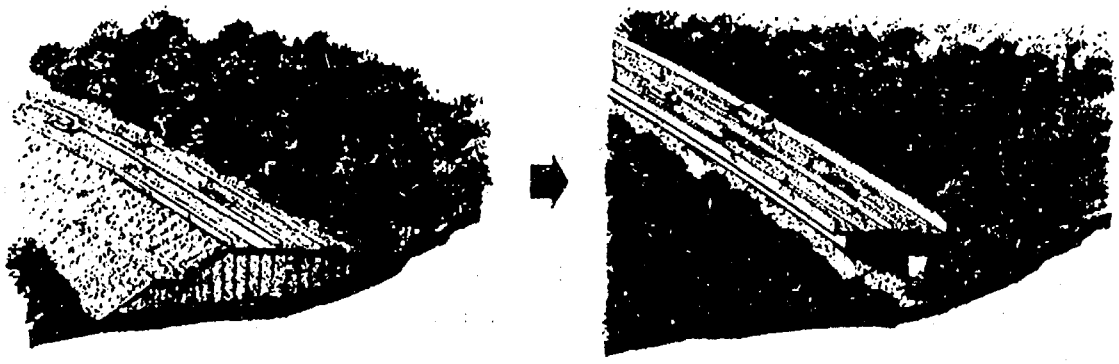


Figure 2 Conservation of Natural Environment by Selecting Bridge Structure

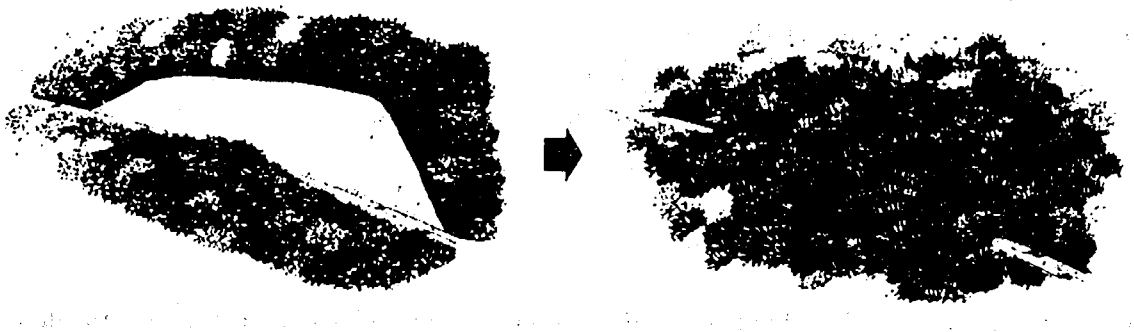


Figure 3 Conservation of Natural Environment by Selecting Tunnel Structure



Figure 4 Transit Path for Animals (Over Bridge)

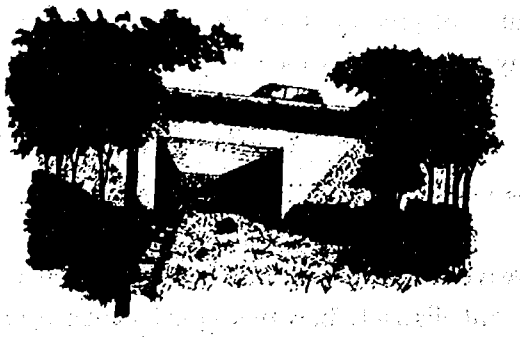


Figure 5 Transit Path for Animals (Culvert Box)

4.1 To secure a transit path for animals

When the planned routeway runs through an animal habitat, it is possible that the routeway crosses the daily transit paths of animals, thereby separating their living area. In this case, it frequently occurs after the road is put into service that animals collide with automobiles on the road.

Proving a transit path for animals to move across the road will eliminate this trouble. Typical examples are bridges across the road (= over bridge) on Oita Expressway <5> and Chugoku Expressway <6>.

Possible structures of the transit path are shown in Figures 4 and 5. Before determining to install these transit paths, it is necessary to investigate behavior patterns of animals and make clear what kinds of animals to be taken care of and where to install. For smaller animals it is possible to employ drainage pipe for the path.

When installing a transit path for animals, it is also necessary to take a suitable measure for assuring the animals of the safety such as planting around the installation so as to lead the animals to the path or shelter them from enemy.

4.2 Lighting in consideration of the nature

Illumination lights on the road or headlights of automobiles may give adverse effect to plants and animals. These lights may disturb natural growth of plants because difference in the quantity of light between the day and the night is made smaller, and may harm the living environment of animals. Moreover, as the insects may be attracted by those lights, small animals that eat those insects may gather around the lights, adding to the chances of collision with automobiles.

Possible measures to avoid the above include illumination with no leak of light out of the road (Figure 6), shading panels to shut out leak of headlight, or illumination by lights of specific wave length which gives little effect to the insects.

4.3 To relocate the habitat

If it is impossible to conserve the living environment within the planned site, it is planned as an alternative measure to move the habitat to other place. In doing this, be it for plants or for animals, it is essential to investigate the natural environment of the destination thoroughly so that the relocated habitat should not give another effect to the new environment. In the case of Nikko–Utsunomiya Freeway, spawning area for polypedatids has been moved to another location <7>.

4.4 To plant appropriate floras on the slope

It seems less frequent that native floras of the site were planted on the slopes alongside the road. Using plants from different district, however, may cause a change to the ecosystem of the site. Thus, it is desired to plant native plants so as to restore the vegetation as close to the original state or the adjacent as possible.

Meanwhile, the stability of soils to grow plants depends on the inclination of the slopes. To

restore tall trees it is necessary to less incline the slopes, and Table 1 shows a guideline of inclinations <8>. If the slopes are steeper than those, it is normally necessary to provide special foundation work for planting.
Photo 1 shows an example on Nikko–Utsunomiya Freeway, where the inclination of the slope is designed 1:2 (about 27 °) in consideration of the native vegetation. There can be seen little difference between the planted slopes and the native vegetation.

4.5 Reuse of surface soil

The existing surface soil in the site is very useful for conservation of the natural environment. It physically maintains gas permeability and water retentivity necessary for the life as its living base, chemically contains organic matter and other effective components suitable to grow the life of the region, and biologically contains a lot of soil organisms, seeds of plants and eggs of animals peculiar to the region. For this reason it is recommended, even when the ground is altered for the construction, to conserve the surface of soil and place it over the slope after construction.

4.6 Ditches allowing small animals to creep out

It sometimes happens that reptile animals like turtle or lizard drop in the ditches provided on both sides of the road and cannot escape from there but die. Because of this, ditches designed to allow the animals to creep out have been invented. In addition to using those ditches, it is recommended to take a preventive measure such as putting covers on them.

4.7 Protection fence against entry of animals

When the routeway runs through an area with full of rich natural environment, it possibly crosses the behaviors of the animals living in that area, causing collision with automobiles and giving injury to them. Installing protection fence against entry of animals will be effective in order to eliminate the chances of crossing between the animals and the road or to lead the animals to a safe transit path. It is important to design appropriate fences according to the animals to protect. For example, since deers are the object to protect on Nikko–Utsunomiya Freeway, fences installed there are higher than the standard. On Ise Freeway, on the other hand, protection fences are installed over the ditches so as to prevent small animals from crossing the road <6>.

4.8 Necessary considerations during the construction

Negative effect to the natural environment during the execution of the construction must also be avoided. It is necessary to be equipped with suitable anti–pollution equipment for the waste water during the construction and to restore the vegetation over the temporary roads of the construction later. Photo 2 shows an example of Gassan Freeway where planting was given over the temporary roads after the construction. The site has recovered its original condition to almost full extent since there is no difference from the vegetation around it.

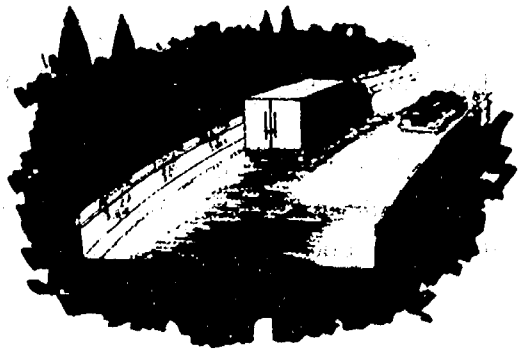


Figure 6 Illumination with no Leak out of the Road

Table 1 Inclination of Slope and Targeted Afforestation

Inclination	Targeted Afforestation
30 °	Restore a stock of plants where tall trees are dominant.
45 °	Restore a stock of plants where medium and low trees are dominant.
60 °	Restore a stock of plants where low trees and grasses are dominant.



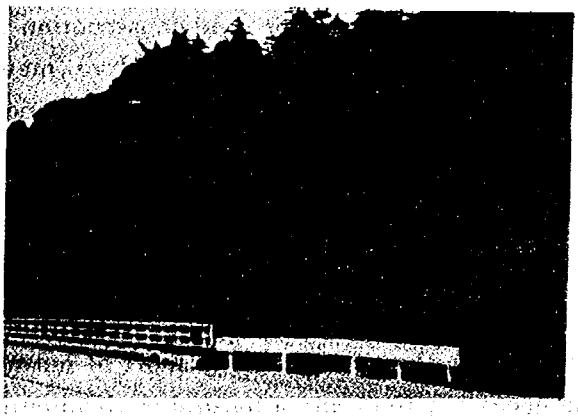
Photo 1 Planting on the banking of highway (right side) and natural vegetation (left side)



Figure 7 Ditch Allowing Small Animals to Creep out



(a) Condition during the construction



(b) Condition after 10 years from the construction

Photo 2 Restoration of the Vegetation over Temporary Roads of the Construction

5. Measures at Management and Maintenance Stage

In order to allow the road and its adjacent to restore the stable ecosystem closer to the original condition, it seems better to leave the planting basically under the management by the nature.
On the other hand, it is necessary to conduct follow-up investigation and provide appropriate maintenance so as to achieve the objective of the natural environment protection in a strict sense.

5.1 Follow-up investigation

Because many of the preventive measures contained in this paper have not yet been proved of their actual effect and because the effect may possibly differ from place to place, it is very important to conduct follow-up investigation and see if the intended effect or function is really achieved.
Since the follow-up investigation will help understand effectiveness or problem of each preventive measure, which in turn will help develop more effective measures, it is highly recommended to conduct the follow-up investigation.

5.2 Maintenance and improvement of measures

It will be necessary to improve the given measures according to the result of the follow-up investigation. For example, if there are some animals that still can jump into the road over the protection fences or if the vegetation is affected by coarse grasses that are left as they are, these problems must be completely eliminated at this stage.

6. Closing

Examples of the natural environment protection for road construction have been reported from time to time but it is rare that the effect of the protective measures has been clearly demonstrated. With a combination of taking the measures and conducting the follow-up investigation, we need to accumulate the knowledge on the natural environment protection and develop more appropriate measures or methods.
This paper studied how to take measures to conserve existing natural environment. Recently, however, there is an increasing demand for more opportunities for meeting with the nature, and a mere preservation of the natural environment is not regarded sufficient in some cases.
In an urban area, for example, where they are normally short of natural environment from the beginning, it will probably be necessary to create a natural environment at the same time when constructing a road. Even in an area with full of rich natural environment, it will be acceptable to create a space for meeting with the nature if it gives no negative effect to the existing environment.
At the last of this paper, we would like to express our gratitude to all people in the Ministry of Construction, Regional Construction Bureaus, and Japan Highway Public Corporation for their kind comments and advice, all of which helped us complete this paper.

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Transport Canada

Highway Environmental Research in Canada

Canada-Japan Advanced Systems Workshop

Tsukuba, Japan
December 6th, 1993

Michael Kent
Director, Highway Environment
B.C. Transportation and Highway

What is environmental assessment?

- A planning tool
- Preventative and proactive
- Often first point of contact between regulators and proponent
- Often environmental education for proponents

The assessment process considers:

- Potential biophysical environmental effects;
- Social and economic effects; and
- Concerns of the public.

Basic elements of environmental assessment

- Early identification of potential impacts
- Incorporation of mitigation into design
- Monitoring and evaluation of mitigative measures
- Monitoring project implementation for unanticipated impacts
- Documentation, follow-up and corrective action, where necessary

Environmental assessment in Canada

- Self assessment process established in 1974
- Updated in 1977
- Environmental assessment and review process (EARP) guideline order issued in 1984
- Rafferty-Alameda and Old Man River court decisions in 1989,1990, and 1992

The Canadian environmental assessment act (CEAA)

- Will replace EARP
- Introduced in legislature in June 1990
- Royal assent on June 23,1992
- Procedural manual and guides in late 1992
- Regulations being drafted
- Awaiting proclamation

Triggers are:

- Federal funding
- Federal lands
- Federal decisions

Self Assessment

Initiating Department

- Responsible for ensuring that activity is assessed
- A federal department which:
  - Undertakes the project
  - Provides the funding, or
  - Issues the approval or permit.

Motivation...

- Project can be stopped

Initial assessment phase

- Screening
- IEE – Focuses on specific areas where information is lacking

EARP – Public Review

- Panel appointed
- EIS prepared and submitted
- Public hearings
- Panel draws conclusion and makes recommendations to Minister of Environment and Minister of Initiating Department
- Decision rests with initiating department

CEAA – Key advances

- Regulations:
  - Exclusion List
  - Inclusion List
  - Comprehensive study list
  - Law list
- Mediation as an alternative to panel
- Federal Role in transboundary issues
- Minister of environment controls process
- Public registries

CEAA process overview

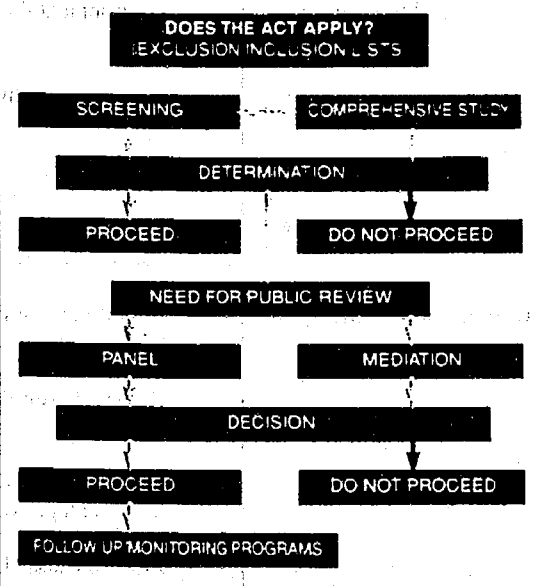


TABLE 4 - 1
FORMALIZED MOTH
HIGHWAY DEVELOPMENT PROCESS - PROCEDURES

STUDY COMPONENT	ENGINEERING ASPECTS	ENVIRONMENTAL ASPECTS
Pre-project Planning	Identify MOTH highway development mandate and policy Formulate goals and objectives for short-term and long-term development Conduct systems monitoring	Incorporate environmental considerations into mandate and policy Integrate environmental aspects into goals and objectives Ensure environmental concerns considered during systems monitoring
Transportation Needs Study	Identify and rank requirements for highway network improvements and/or municipal street roadworks Produce performance goals and objectives for highway improvements	Briefly examine major environmental issues, if corridors identified List input to be addressed in more detail at later stage
Project Registration and Prospectus	Initiate consideration of a project Complete project prospectus form	List environmental considerations
Environmental Classification and Screening	Screen and complete project environmental classification form Determine highway standards and dimensions of new project	Conduct initial environmental scan of project to assess potential for adverse impacts Determine environmental classification for project Consider terms of reference for environmental studies
Reconnaissance Study	Identify all possible corridors between two nodes Review feasibility of each corridor Identify advantages and disadvantages of corridors Prepare Class "D/E" cost estimates	Identify technical constraints, natural hazards, areas of significance, and major environmental concerns for each corridor List environmental advantages and disadvantages Initiate agency contacts Contact key public representatives Conduct preliminary environmental studies to determine pros and cons of corridors

STUDY COMPONENT	ENGINEERING ASPECTS	ENVIRONMENTAL ASPECTS
Corridor Study	Evaluate preferred corridor or identify requirements for further study of selected corridors Prepare Class "D" cost estimates	Initiate data inventory and collection Conduct terrain analysis using air photo interpretation Obtain public input Prepare overview study of environmental issues and constraints Consider environmental feasibility and acceptability of corridor Assist evaluation of preferred corridor through comparison of environmental factors
Route Study	Develop plans for feasible locations of roads and/or interchanges and intersections Prepare and review single line sketches Select appropriate concepts (two or more) for further study	Determine acceptability of impacts Obtain public input Consult with agency representatives Consider environmental feasibility and acceptability of route alternatives Aid in selection of appropriate concepts
Preliminary Design	Prepare geometric design Develop preliminary design drawings Prepare Class "C" cost estimates Perform "fine-tuning" of alignment Determine suitability of selected locations and configurations Recommend preferred alignment	Consider property requirements and impacts on individual parcels Conduct public involvement programs Assist development of preliminary design alternatives Collect detailed environmental inventory information Conduct site-specific studies Identify site-specific impacts and possible mitigation measures Prepare mitigative measures

STUDY COMPONENT	ENGINEERING ASPECTS	ENVIRONMENTAL ASPECTS
Construction	Implement various construction activities to prepare road surface for paving Supervise construction operations (Ministry Representative) Complete bridge construction Conduct paving operations Prepare project completion report	Conduct environmental monitoring Conduct environmental surveillance (environmental agencies such as DFO, BCE) Undertake adjustments to design as required Implement rehabilitation measures
Post-construction	Operate and maintain highway Conduct post-project evaluation	Evaluate rehabilitation measures Conduct post-construction monitoring program Assist with post-project evaluation

STUDY COMPONENT	ENGINEERING ASPECTS	ENVIRONMENTAL ASPECTS
Functional Design	Prepare horizontal and vertical geometric design Develop functional design drawings Prepare Class "B" cost estimates	Develop necessary mitigative and erosion control Review drainage details
Detailed Design	Identify and evaluate detailed design alternatives Select alternative for detailed design Initiate property acquisition Prepare contract documents Develop construction contract, drawings, and technical specifications Prepare final quantity estimates and Class "A" cost estimates, general specifications and special provisions	Resolve outstanding issues Identify specific environmental effects Finalize mitigation and compensation strategies with design engineers Apply for permits and approvals Assist with preparation of documents and special provision Deal with environmental agencies on site-specific issues Gather and update detailed environmental data (if ne essary) Determine if environmental monitoring is required Collect baseline data if post-construction monitoring is required
Pre-construction	Advertise tender documents Review submitted bids Select contractor Conduct pre-construction meeting	Become familiar with environmentally sensitive areas Address questions and concerns from bidders Conduct site-orientation meeting for bidders Participate in pre-construction meeting

BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION AND HIGHWAYS

FIGURE 4 - 2

PROJECT PROSPECTUS

PROJECT NO. REGISTRATION NO. DATE

TERMINI FROM: TO: LENGTH (km) PAVING LENGTH (km)

TITLE

LEVEL OF DEVELOPMENT PLAN OR PROPOSED ACTIVITY

ROADWAY GEOMETRIC DATA	EXISTING	PROPOSED	STANDARDS	PROJECT TYPE
TOTAL NO. THROUGH LANES				
NO. LANES THIS PROPOSAL				
LANE WIDTH (m)				
SHOULDER WIDTH LT. (m)				
SHOULDER WIDTH RT. (m)				
ROADWAY WIDTH (km)				
AUX. LANE LENGTH (km)				
AUX. LANE WIDTH (m)				
DESIGN SPEED (km/h)				

STATEMENT OF PROBLEM & PROPOSED SOLUTION

ENVIRONMENTAL CONSIDERATIONS

IS THIS PROJECT CONTROVERSIAL? ☐ NO ☐ YES ☐ MAYBE

IF YES OR MAYBE, WHY?

ARE PERMITS OR APPROVALS FROM OTHER AGENCIES LIKELY TO BE REQUIRED? ☐ NO ☐ YES ☐ MAYBE

IS ADDITIONAL RIGHT-OF-WAY REQUIRED? ☐ NO ☐ YES ☐ MAYBE

INDICATE APPLICABLE IF ANY OF THE PROPERTY INVOLVED IS KNOWN OR PROPOSED AS

☐ PUBLIC PARK ☐ RECREATION AREA ☐ WILDLIFE OR WATERFOWL RESERVE ☐ HISTORIC SITE ☐ ARCHAEOLOGICAL SITE

INDICATE APPLICABLE IF THERE IS A POTENTIAL TO IMPACT OR FOR ENCROACHMENT ON

☐ WETLANDS ☐ FLOODPLAINS ☐ BODIES OF WATER ☐ HAZARD/MATERIALS SITE ☐ FARMLANDS ☐ NATIVE LANDS

PROBABLE ENVIRONMENTAL CLASSIFICATION

☐ ENVIRONMENTAL IMPACT STUDY - CLASS 1 (HIGH LEVEL OF CONCERN)

☐ ENVIRONMENTAL INVESTIGATION - CLASS 2 (MODERATE LEVEL OF CONCERN)

☐ PROJECT EXEMPTION - CLASS 3 (INSIGNIFICANT LEVEL OF CONCERN)

REGIONAL ADMINISTRATOR DATE

HEADQUARTERS COMMENTS

HEADQUARTERS APPROVAL DATE

FIGURE 4 - 3

BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION AND HIGHWAYS

PROJECT ENVIRONMENTAL CLASSIFICATION

REGION/DISTRICT | REGISTRATION NO. | PROJECT NO.

PROJECT TITLE (ATTACH A VICINITY MAP, INCLUDE APPROXIMATE MILEPOSTS)

PROJECT DESCRIPTION

ALIGNMENT
☐ NEW ☐ EXISTING ☐ BOTH

IS ANY PART OF THIS PROJECT CONTROVERSIAL? IF YES, ATTACH AN EXPLANATION
☐ YES ☐ NO

TYPICAL SECTION:

EXISTING NUMBER OF LANES	EXISTING LANE WIDTH	EXISTING SHOULDER WIDTH
PROPOSED NUMBER OF LANES	PROPOSED LANE WIDTH	PROPOSED SHOULDER WIDTH

TRAFFIC		
	EXISTING YEAR	
	EXISTING ADT	%T
	DESIGN YEAR	
	DESIGN YR ADT	%T

ADDITIONAL RIGHT OF WAY
☐ YES ☐ NO

APPROXIMATE ACREAGE

APPROXIMATE NO. OF PARCELS

BRIEF DESCRIPTION OF R/W TAKE OR EASEMENT

PERMITS OR APPROVALS

	YES	NO
WATER APPROVAL		

	YES	NO

BORROW/WASTE DISPOSAL SITES?
☐ YES ☐ NO IF YES, LIST THE SITE(S)

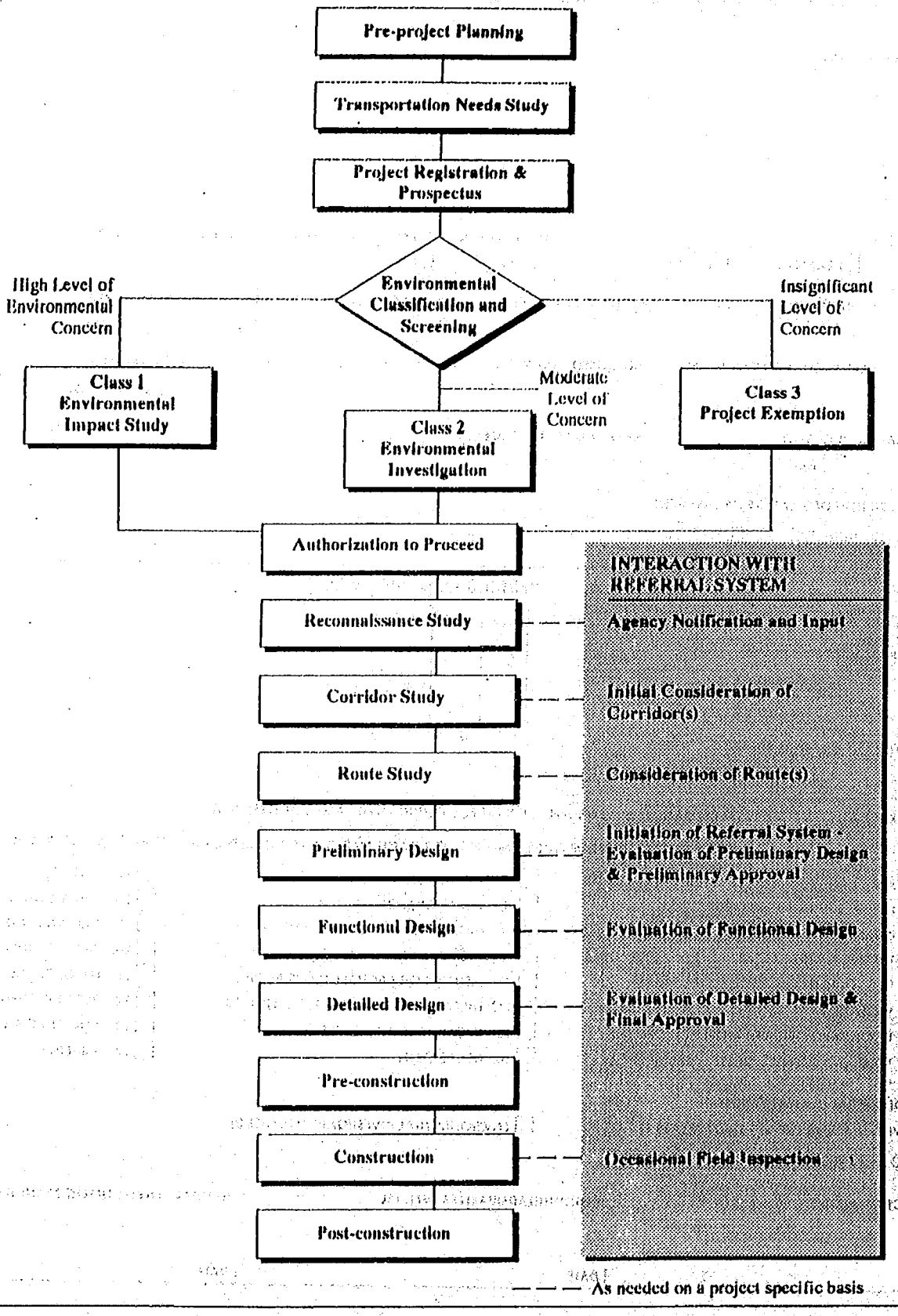
WILL THERE BE ANY TEMPORARY OR PERMANENT ADVERSE EFFECT ON THE FOLLOWING ENVIRONMENTAL ELEMENTS?
☐ YES ☐ NO IF YES, CHECK THE APPROPRIATE ELEMENTS AND ATTACH AN EXPLANATION/REPORT UNLESS AN EA OR EIS WILL BE PREPARED.

☐ 1. AIR QUALITY
☐ 2. NOISE
☐ 3. LAND USE
☐ 4. TRAFFIC OR TRANSPORTATION
☐ 5. VEGETATION
☐ 6. WETLANDS
☐ 7. ECONOMIC GROWTH AND DEVELOPMENT
☐ 8. WILD AND SCENIC RIVERS
☐ 9. WATER QUALITY
☐ 10. VISUAL QUALITY
☐ 11. NATURAL RESOURCES AND ENERGY
☐ 12. PUBLIC SERVICES AND UTILITIES
☐ 13. HISTORIC OR ARCHAEOLOGICAL SITES
☐ 14. THREATENED OR ENDANGERED SPECIES
☐ 15. HAZARDOUS WASTE SITES
☐ 16. RECREATION
☐ 17. WILDLIFE
☐ 18. PRIVATE LAND
☐ 19. CROWN LAND
☐ 20. PRIME OR UNIQUE FARMLAND
☐ 21. FLOODPLAINS
☐ 22. BUSINESS DISPLACEMENTS
☐ 23. RESIDENT DISPLACEMENTS
☐ 24. FISHERIES

ENVIRONMENTAL CLASSIFICATION
☐ ENVIRONMENTAL IMPACT STUDY (CLASS 1)
☐ ENVIRONMENTAL INVESTIGATION (CLASS 2)
☐ PROJECT EXEMPTION (CLASS 3)

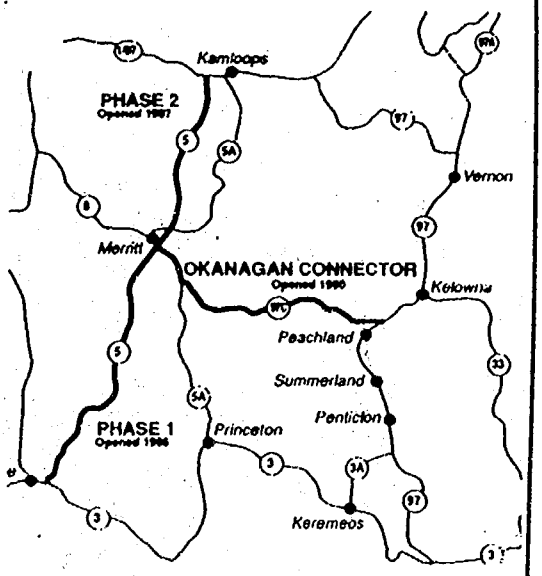
DISTRICT OFFICIAL	REGION/HEADQUARTERS OFFICIAL	HIGHWAY ENVIRONMENT BRANCH OFFICIAL
DATE	DATE	DATE

FIGURE 4 - 1
FORMALIZED MOTH
HIGHWAY DEVELOPMENT PROCESS



Okanagan Connector: Environmental Issues

Okanagan Connector Map

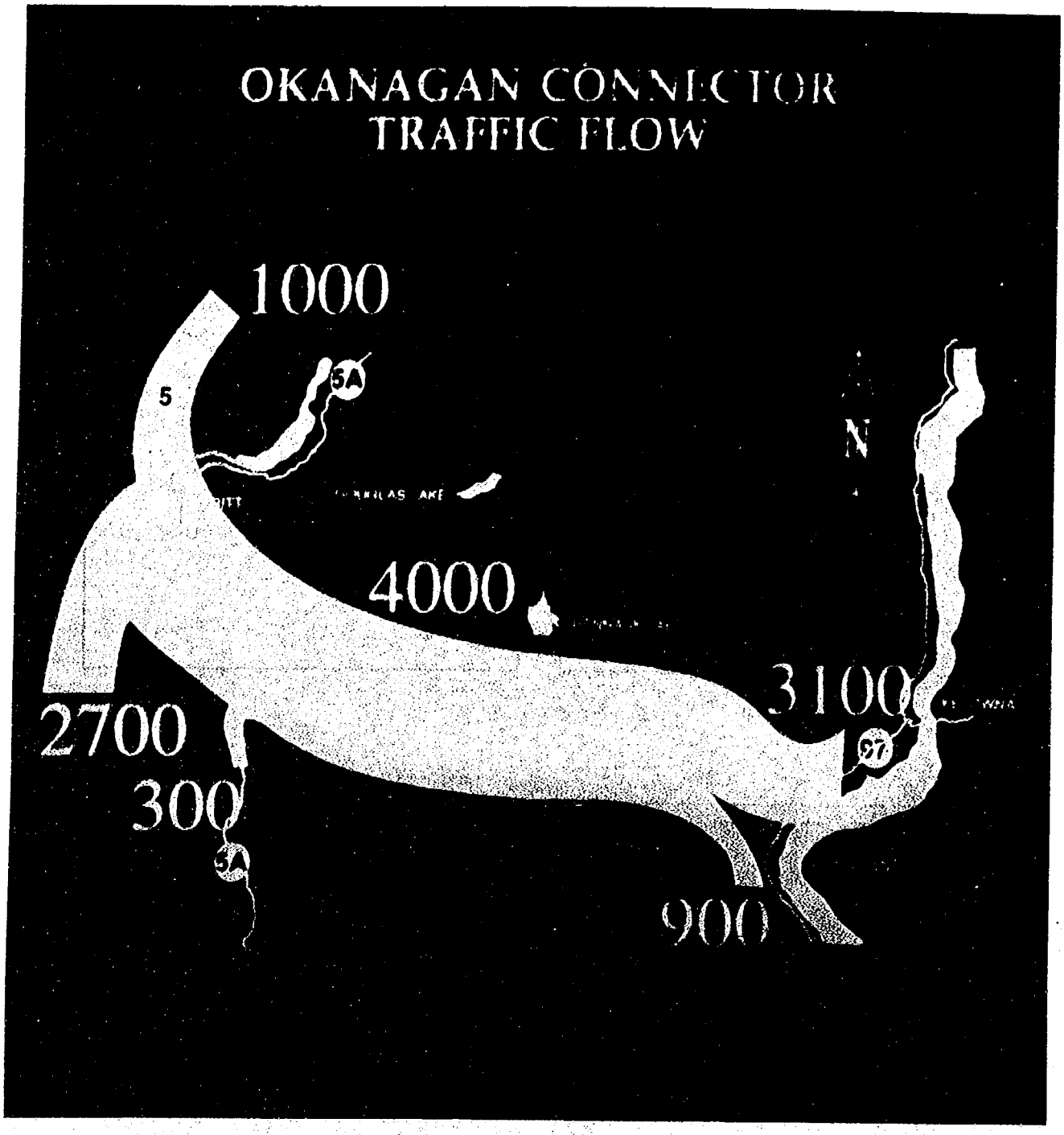


ECONOMIC BENEFITS

1. Reduces Travel Times and Costs
2. Increases Safety
3. Increases Accessability to/from the Lower Mainland
4. [illegible]

KELOWNA - VANCOUVER

ROUTE	DISTANCE (km)	TIME (hrs)
via Kamloops & Coquihalla	520	5.75
via Hope / Princeton	475	6.25
[illegible]	[illegible]	[illegible]


OKANAGAN CONNECTOR
TRAFFIC FLOW
1000
5
5A
N
4000
3100
2700
300
900
97

Agriculture

- Cattle ranches: movement of cattle from their winter lands to the summer grazing areas.
- Loss of grazing land.
- Transport of cattle under the highway.

Wildlife

- Large populations of deer (10,000>) and Moose (650>)separated from their critical winter/and summer land ranges.
- Large numbers of collisions with highway vehicles involving death of motorists and animals.
- Loss of land critical to their survival.
- Access under/over the highway.

Fisheries

- Important lakes containing large populations of sport fish and the highway causing access and overfishing.
- Water licences on rivers critical for acricultural use.
- Protection of fish hatchery source from highway construction runoff and post construction.

Recreational Use

- Too many people fishing, hunting and snowmobiling, disturbing the protected resources.

Community water supply

- Protect the water quality from construction and use of mined waste rock as an open-graded pavement source.
- Protect the water supply to local farmers.

Environmental Process to Address the Issues

Corridor Study Stage

- 2 day meeting with all the stakeholders: Government Ministeries, Cattle Ranch Owners, Fish Camp Operators, Forestry Companies, Trappers, Local Residents, Municipalities.
- Collect their concerns and positions on highway location and effects.
- Develop Study Terms of Reference on the issues outlined by stakeholders.

Environmental Process to Address the Issues...

Corridor Study Stage

- Avoid sensitive environmental features in the corridor study.
- Develop mitigation plans in the Functional/Detailed Design phase.
- Carry out environmental monitoring during construction phase.
- Follow-up on post-construction monitoring of mitigation and compensation structures.

8. Advanced Composite Materials (ACM)

Tests and Research on Carbon Fiber Strengthening of Existing Bridges

Norio Ogata [1] Yoshifumi Maeda [2] Hirofumi Ando [3]

Summary

At present, highway bridge substructures must be strengthened against major earthquake. The Conventional strengthening methods include lining with reinforced concrete and steel plate bonding. We have reviewed a new method of bonding newly developed carbon fiber sheets, which may replace the existing methods. Bridge pier model testing indicated that ductility of specimens reinforced with the carbon fiber was improved, and that this method of reinforcement is suitable for practical use.

The need to strengthen superstructures has also become necessary as a result of increased motor vehicle weight and traffic volume. We reviewed the carbon fiber strengthening method to the superstructure and verified its potential through beam model testing.

1. Introduction

Although ordinary reinforced concrete bridge piers have a cut-off (transitional position) for longitudinal reinforcing bar to achieve an economic design of steel bars, some piers do not have sufficient anchorage length for the longitudinal reinforcing bar or enough stirrups, so that damage may occur at the cut-off part during major earthquake. Traditional countermeasures include the reinforced concrete lining method and the steel plate bonding method. Reinforced concrete lining is inexpensive but has problems such as increased sections and weight, chipping work, and noise problem. Steel plate bonding does not create any more section and weight but is expensive to carry out and requires anchor driving work and rustproof treatment. Moreover, on present highway bridges, load often exceeds the design value because of the increasing weight of motor vehicles and growing traffic volume, so that the strengthening of the superstructure has become necessary. (Another strengthening method, the steel plate bonding method, is considered complicated due to the anchor driving and resin filling.) Therefore, we reviewed strengthening with carbon fiber, which has high strength and elasticity. Tensile strength is 25,000kgf/cm^2, Young's modulus is $2.5 \times 10^6 kgf/cm^2$, weight only $175g/m^2$ and thickness $0.1mm$. Increases in section and weight can thus be kept very low. Carbon Fiber is produced in sheets and strands for easy processing and working. Only bonding work is needed; anchoring is not necessary. Thus reinforcement work will not damage the existing structure.

2. Use of Carbon Fiber Strengthening on the Substructure

In order to investigate the performance of carbon fiber strengthening of bridge piers and to establish design and work methods, we conducted loading tests on bridge pier models.

[1] Head, Bridge Section, Research Institute, Japan Highway Public Corporation
[2] Deputy Head, Bridge Section, Research Institute, Japan Highway Public Corporation
[3] Engineer, Bridge Section, Research Institute, Japan Highway Public Corporation

2.1 Shape and Sizes of Specimens

Dimensions of specimens are shown in Fig. 1 and Table 1. For the *No.*5 specimen only, we damaged the cut-off and base of column; the damaged portions were then repaired with mortar and the cracked portions filled with epoxy resin and bonded carbon fiber, to assess performance after an earthquake.

2.2 Test Method

In the loading method, horizontal cyclic loading was given at the top of column while applying an vertical loading ($6kgf/cm^2$) corresponding to the reaction to the dead load of superstructure. The loading pattern is shown in Fig. 2. δ_y in the Figure represents the horizontal displacement of the top of the pier column due to the yielding of the reinforcing bars at the base of column.

2.3 Test Results

Test results are shown in Fig. 3 and Table 2. Here, we defined cracking as when visually noticeable appear cracks, yielding as when the reinforcing bars in the longitudinal direction on the tensile side have yielded, and the ultimate state as when concrete fails or carbon fiber is ruptured.

The failure position of the *No.*1 specimen was at the cut-off portion of the reinforcing bars, while the failure position of the *No.*2 specimen shifted to the base of column. Thus it would appear that bending yield strength can be enhanced by bonding carbon fiber in the longitudinal direction.

The *No.*2 specimen suffered bending shear failure, but this changed to bending failure for the *No.*3 specimen, where the carbon fiber was wound in the direction of stirrups.

For the *No.*3 specimen, which had a amount of strand equivalent to one sheet wound around the base of column, failure was due to bending, and ultimate displacement was longer than the non-reinforced *No.*1 specimen. The *No.*4 specimen, which had two strengthning sheets in the lateral direction of the base of footing, did not fail under loading up to the maximum capacity of the loading device. Thus it was proven that deformation is improved by carbon fiber strengthening in the lateral direction.

The *No.*5 specimen was repaired after deliberately damaging it as stated above. The failure position shifted from the cut-off section to the base of column, failure itself was due to bending, and ductility was improved.

2.4 Discussion

2.4.1 Effect of Reinforcement

The experiment showed that the failure position shifted from the cut-off part to the base of column after bonding carbon fiber in the longitudinal direction, and that failure was due to bending when carbon fiber was bonded in the rateral direction, establishing its shear strengthening performance. Also, winding carbon fiber confines, the inner concrete and enhances the ductility of the bridge pier.

2.4.2 Energy Absorption

Generally, energy absorption improves as the area surrounded by the displacement of bridge pier and acting force increases, and the pier becomes more resistant to earthquake. Fig. 4 shows

energy absorption before and after repair. With respect to the same cumulative deformation, energy absorption is slightly greater before repair compared to after repair. However the tilts are almost parallel, and tilts do not change until $6\delta_y$ after repair, from which it can be said that energy absorption did not fall until the ultimate state. From this, the present method was confirmed to be an effective for strengthening against earthquake. Also, if parts damaged by earthquake are properly repaired, energy absorption recovers to the same level as before and yield strength also recovers. This method is therefore considered to be excellent for strengthening following earthquakes.

3. Use of Carbon Fiber Strengthening on the Superstructure

The superstructure of highway bridges are subject to repeated and continuously loading over long periods, lowering their durability against fatigue. We subjected a beam strengthened bonding with carbon fiber to 2 million cyclic loadings, and then performed static loading tests and reviewed the applicability of carbon fiber to beam members.

3.1 Shape and Dimensions of Specimens

Specimens were set up as shown in Table 3 for actual reinforced concrete and prestressed concrete bridges. Shapes and dimensions are shown in Fig. 5. Cracks were created in advance by applying a bending load, and strengthening carried out by bonding two layers of $20cm$-wide, $0.1mm$-thick carbon fiber. The design load was set such that the reinforcing bars would reach the allowable tensile stress ($= 1,800kgf/cm^2$). Strengthening was originally to be applied to the whole area of the bottom surface $10cm$ inwards from both supports. However carbon fiber began to peel off at the interface with the concrete of *No.*2 specimen during static loading; therefore for *Nos.*3 to 5 an overlapped carbon fiber portion was made at each end of bonding portion and the reinforcement area extended up to the end of the beam member.

3.2 Test Method

Fatigue loading: *Nos.*3 to 5 specimens in Fig. 6 were subjected to 2 million cyclic loadings at 3 to 4 *Hz*. Particular attention was given to the stress of reinforcing bars at the tensile side of the section of specimen. Upper and lower limit loads for load management were controlled as shown in Table 4.

Static test: Upon completion of fatigue loading test, we carried out static loading tests. Load, displacement and strain were measured

3.3 Test Results

The test results are listed in Table 5. Values were calculated from the results of material tests.

3.3.1 Situation of Failure

Fatigue tests: No anomaly such as peeling-off and rupture was found in *No.*3, for which the upper limit load was set to design load (load-creating tensile stress in reinforcing bars $= 1,800kgf/cm^2$), or *No.*5, for which 90% of yield for reinforcing bars was used. In *No.*4, where the upper limit load was set to yield load (load-creating tensile stress of reinforcing bars $= 3,900kgf/cm^2$), the carbon fiber peeled off and the load dropped after about 28,000 cycles. At this point repeated loading of *No.*4 was

terminated. For non-strengthened specimens. the open cracks were widest on the bottom surface, while cracks on the bottom surface of specimens were mostly closed. It appears that the occurrence of cracks on the bottom surface was restricted by the carbon fiber bonded to the entire bottom surface area.

Static tests: In the *No.*2 specimen, the bonded carbon fiber peeled off from the central part to the left side of the specimen during loading up to 18.7t, and the load decreased considerably. An examination of the peeled carbon fiber revealed chips of bottom concrete stuck on. We considered that deterioration, tensile strength and shear strength of concrete at the sticking interface are closely linked with the peeling off process. In *Nos.*3 to 5, the carbon fiber peeled off in the middle but remained fixed by supports at both the ends of member, so that the specimens resisted against load in an unbonded state until finally, the carbon fiber at the center ruptured and failure occurred. Fig. 7 shows the cracks after static loading in *Nos.*1 and 3. It can be seen that the cracks in *No.*3 are more scattered than in *No.*1(non-strengthening).

3.3.2 Displacement

Fatigue tests: Fig. 8 shows the displacement at the central part of the beam, periodically measured at each repeating cycle for the *No.*3 specimen. The displacement become larger as the repeating cycles increased in all state of upper limit loading, lower limit loading and non-loading(residual value). However, displacement tended to stabilize after about 10,000 cycles. This suggests a sufficient fatigue durability for 2 million repeats.

Static tests: Fig. 9 shows the relationship between the load of each specimen and the displacement at the center in static tests. In *No.*3 both strength and displacement are much larger than *No.*1(non-strengthening) even after fatigue loading. Compared to *No.*2 (without fatigue loading), displacement increased slightly from crack occurrence load (7tf) to near the design load (11tf) indicating the influence of fatigue. However, peeling-off of carbon fiber occurred at almost the same displacement and maximum load values are almost the same, so there will be no problems even against cyclic loading. In the case of *No.*5(reinforced concrete), the peeling-off of carbon fiber began just before reaching maximum load; however a sudden drop in load was not seen, the maximum load was almost the same as the analysis values, and the ultimate displacement was elongated.

3.3.3 Strain

Fig. 10 shows the strain distribution (during upper limit load) in the central section of the beam during repeated loading of the *No.*3 specimen. Even though the repeated loading cycles increased, the strain distribution on the section almost perfectly held a plane, thereby indicating that carbon fiber bears the load without being deteriorated by fatigue.

4. Conclusions

4.1 Use of Carbon Fiber Strengthening on the Substructures

We found that if carbon fiber is bonded in the longitudinal direction of a reinforced concrete bridge pier, then the bending strength can be improved, the failure position can be shifted from the cut-off position to base of column, and if bonded in the direction of the stirrups, the ductility can also be improved. In this report we calculated the number of sheets used for reinforcement such that all of the acting shearing forces would be borne by the carbon fiber. We are currently considering

the resistance to shearing forces by a conbination of concrete, stirrups and carbon fiber for greater economy. We are planning to carry out verification tests for this economic approach.

4.2 Use of Carbon Fiber Strengthening on the Superstructures

Carbon fiber is not damaged at the design load level, is a strong strengthening material, and provides strengthening even after repeated loading. The strength of members can be calculated using conventional methods (converted to reinforced concrete). In the future, additional studies will be required into the peeling observed during tests, as well as on effective fixing methods for end portions.

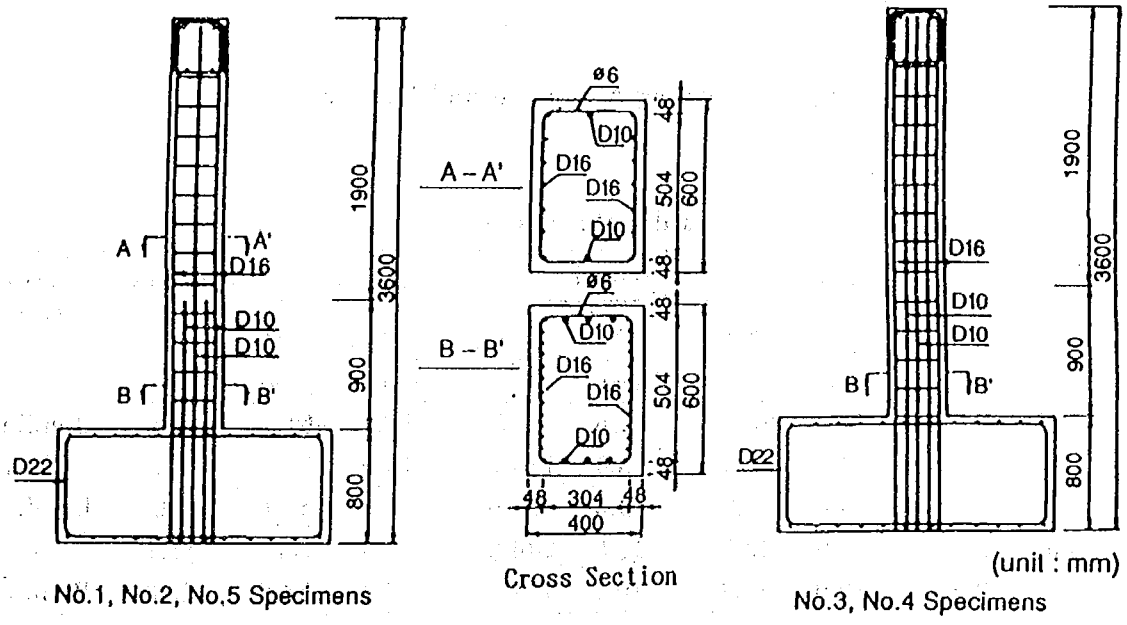


Fig. 1: Specimens of Pier Model Test

Table. 1: Specimens of Pier Model Test

No.	Height of Cut-off	Length of CF Strengthening				Sheets of CF		
		Length of Upper CF from Cut-off (mm)	Length of Lower CF from Cut-off (mm)	Total (mm)	Base of Column (mm)	Cut-off		Base of Column
						Longitudinal	Lateral	Lateral
1	900	-	-	-	-	-	-	-
2	900	450	450	900	-	2	2	-
3	-	-	-	-	600	-	-	1
4	-	-	-	-	600	-	-	2
5	900	530	400	930	500	2	2	2

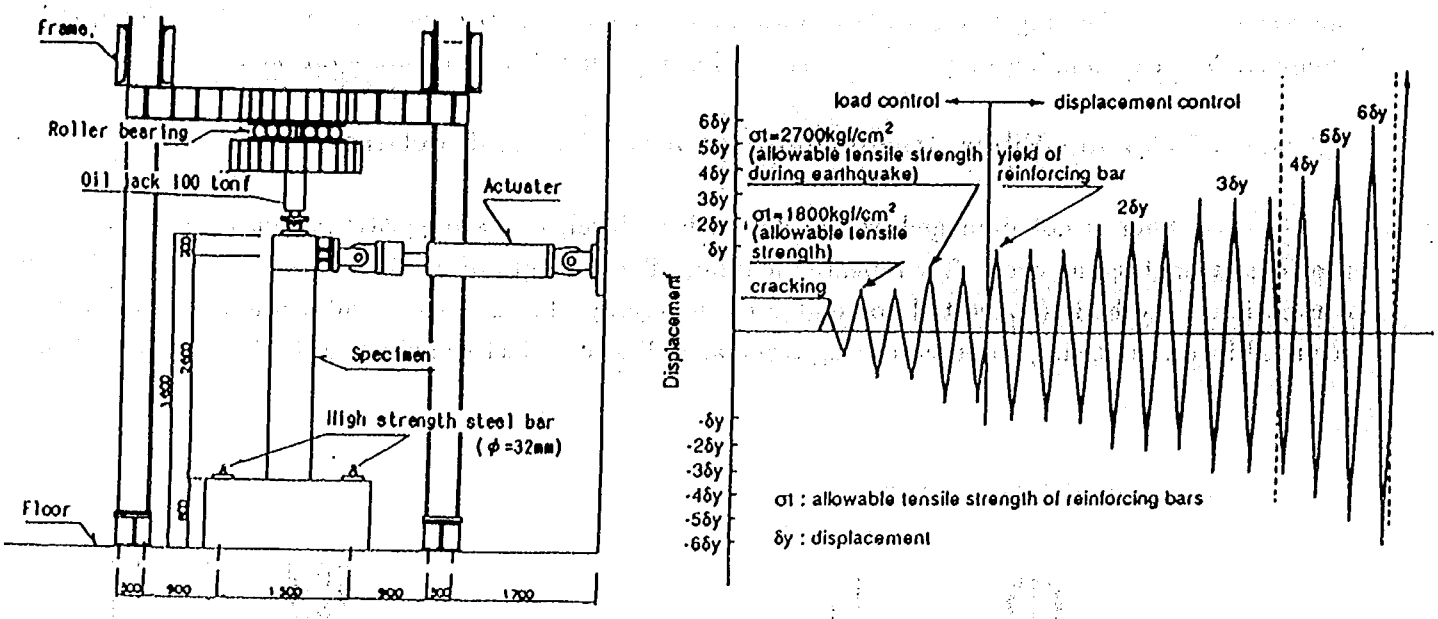


Fig. 2: Loading Apparatus and Pattern

Table. 2: Results

Spec. No.	Cracking		Yield		Ultimate		Max Load		Ductility Rate	Failure Type
	Load P_c (tonf)	Displ. δ_c (mm)	Load P_y (tonf)	Displ. δ_y (mm)	Load P_u (tonf)	Displ. δ_u (mm)	Load P_{max} (tonf)	Displ. δ_{max} (mm)	μ	
1	2.8	2.6	10.4	20.6	11.5	61.7	11.5	61.7	3.0	Bending
2	2.9	2.8	12.6	27.6	13.4	113.0	13.9	55.3	4.1	Shear
3	2.5	1.9	13.0	26.2	14.5	131.0	13.9	52.1	5.0	Bending
4	3.0	2.2	11.9	22.0	15.5	244.2	15.5	244.2	11.1	-
5	3.5	2.2	10.0	22.3	10.7	111.7	14.5	63.8	5.0	Bending

Table. 3: Specimen of Beam Model

Spec.No.	Strengthen with CF	Pre-Loading	Structural Type	Loading Type
1			PC	Static
2	○	○	PC	Static
3	○	○	PC	Cyclic (Allowable stress)
4	○	○	PC	Cyclic (Yield stress)
5	○	○	RC	Cyclic (Yield stress ×90%)

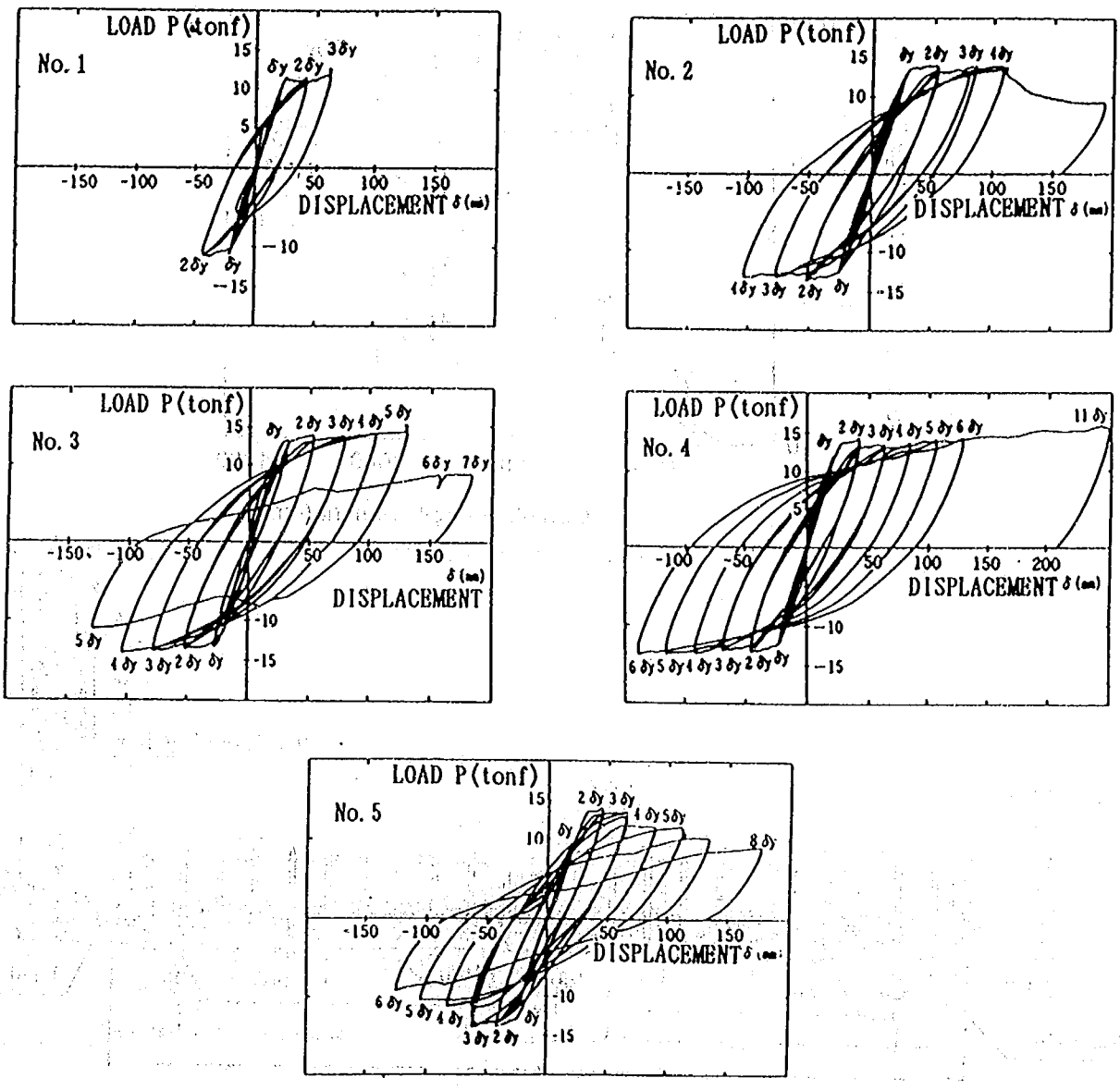


Fig. 3: Results

Table. 4: Conditions of Cyclic Load

Spec. No.	Upper level		Lower level	
	Load (tf)	Stress of tensile-steel bar (kgf/cm^2)	Load (tf)	Stress of tensile-steel bar (kgf/cm^2)
3	11.0	about 1800	3.0	about 0*
4	13.5	about 3900	3.0	about 0*
5	7.3	about 3400	3.0	about 600

* : Stress by prestressing was also taken into account.

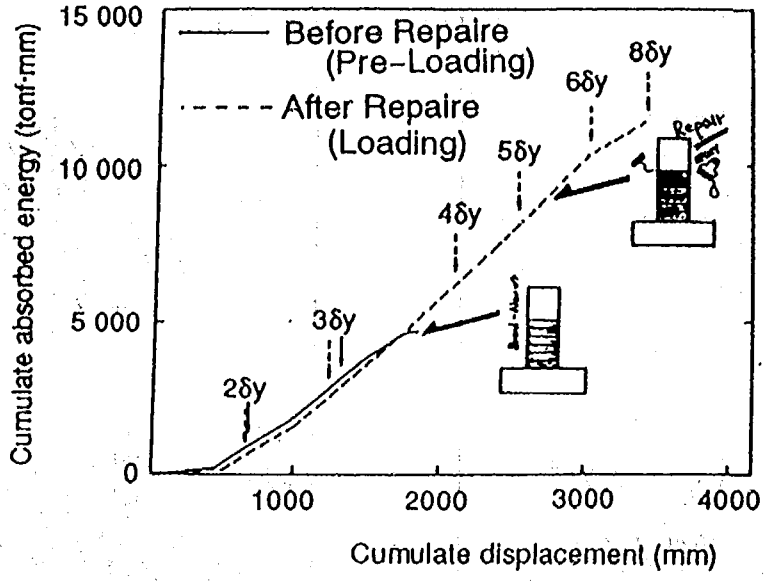


Fig. 4: Energy absorption

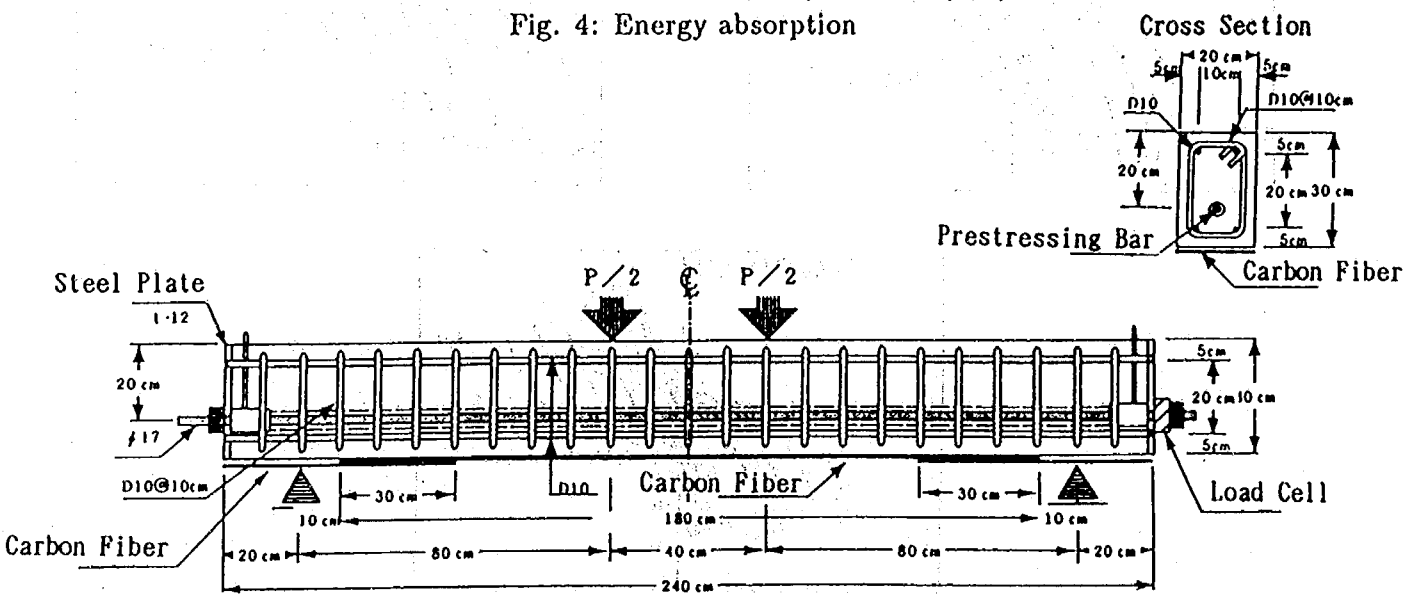


Fig. 5: Specimens of Beam Model Test

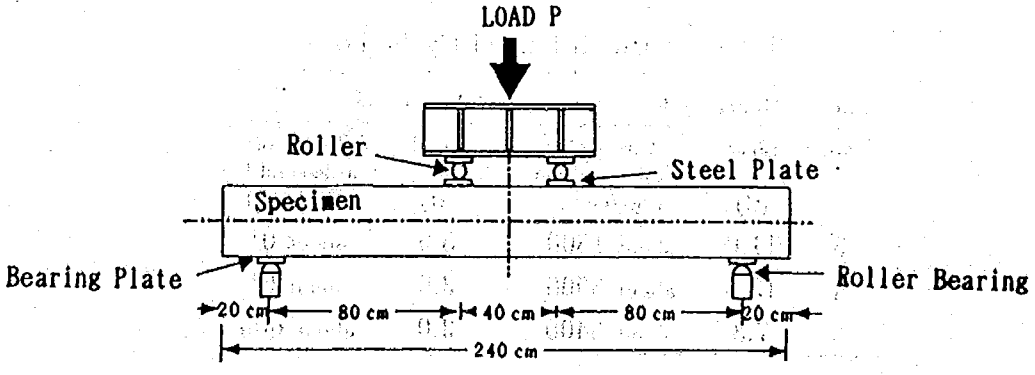


Fig. 6: Loading Apparatus

Table. 5: Results

Spec. No.	Fatigue Loading			Static Loading				Condition
	Upper Level (tf)		Condition	Yield stress		Max stress		
				expe.(tf) / culc.(tf)	Ratio	expe.(tf) / culc.(tf)	Ratio	
1	-	-	-	12.9 / 13.1	0.98	14.5 / 15.0	0.97	Bnding failuer
2	-	-	-	14.5 / 15.1	0.96	18.7 / 20.5	0.91	Peeling of CF (18.7tf)
3	11.0	Allowable	No problem	14.1 / 15.1	0.94	20.9 / 20.5	1.02	Peeling of CF (18.7tf) Braking of CF (17.9tf)
4	13.5	Yield	Peeling of CF (28,000 cycle)	– / 15.1	-	14.9 / 20.5	0.77	Braking of CF (14.9tf)
5	7.3	Yield ×90%	No problem	8.0 / 8.0	1.00	15.5 / 16.4	0.95	Peeling of CF (15.5tf) Braking of CF (15.4tf)

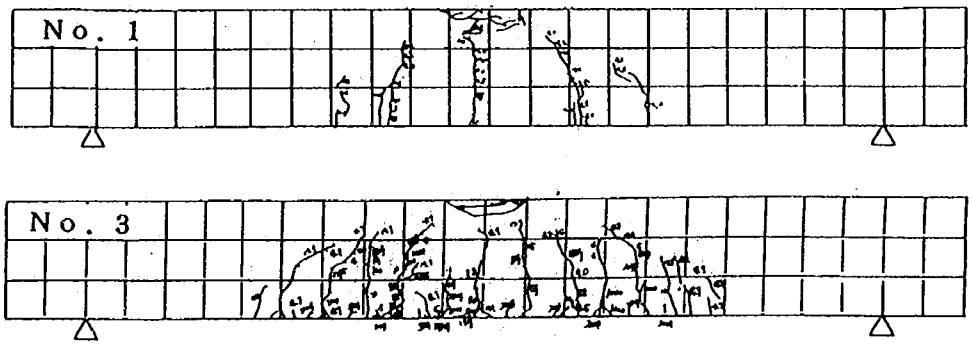


Fig. 7: Cracks after Static Loading

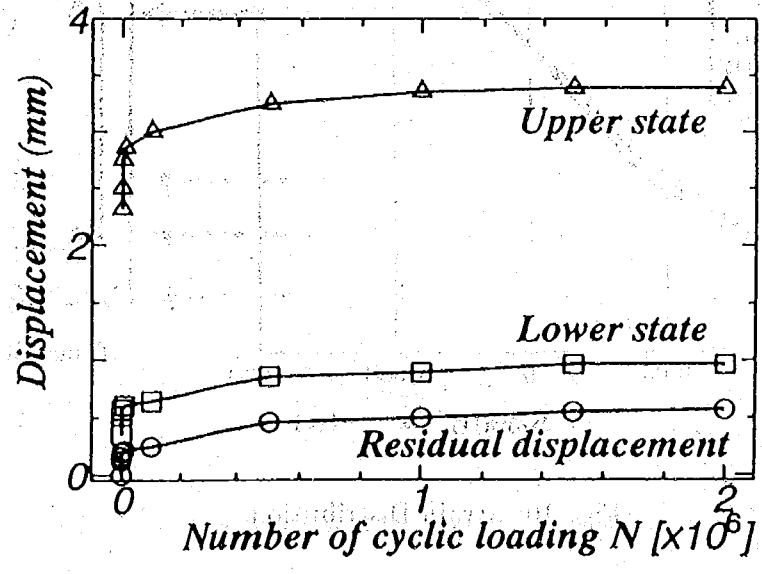


Fig. 8: Displacement during Fatigue Tests

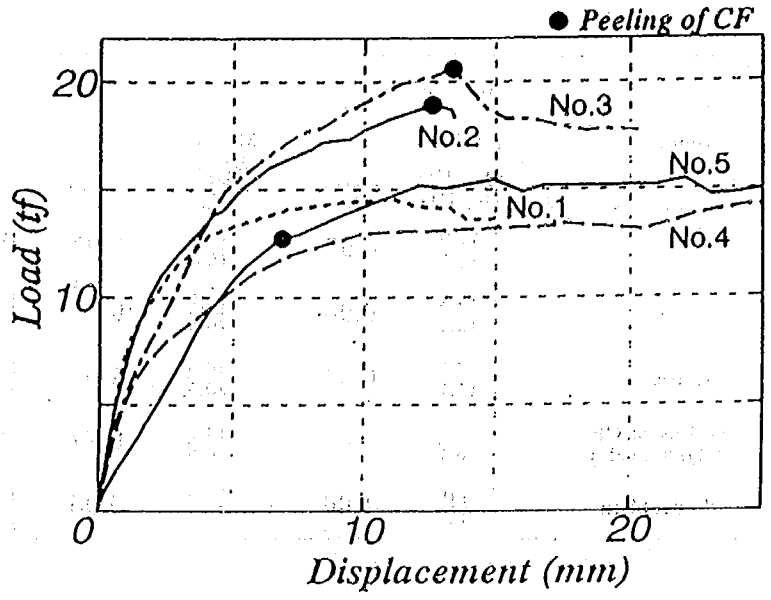


Fig. 9: Relationship between Load and Displacement

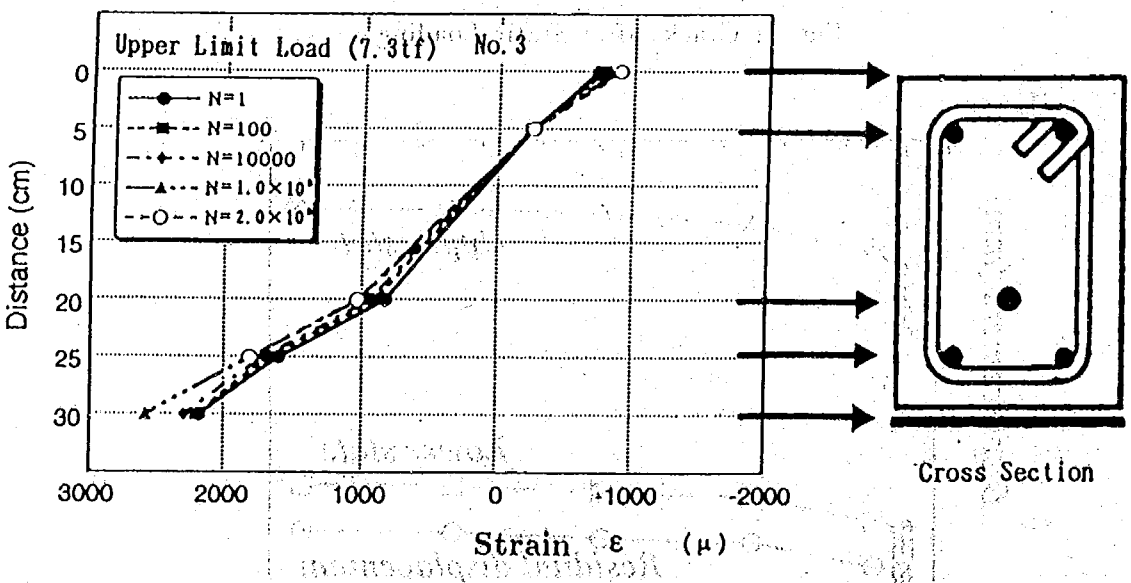


Fig. 10: Strain Distribution

RC Slabs Strengthened by Bonded Carbon FRP Plates : Part 1 – Laboratory Study

By H. Ichimasu, M. Maruyama, H. Watanabe and T. Hirose

Synopsis: RC slabs on steel girder bridges in the Tokyo Metropolitan Expressway are generally strengthened by installing additional stringers or attaching steel plates. But it is difficult to apply such methods to strengthening work in confined box girders or where there are obstructions. Carbon FRP plates (CFRP) have been selected as strengthening materials for their applicability to strengthening work in confined spaces, and because they can be bonded in lattice forms, allowing for bonding condition inspection on the lower faces of the slabs. The aim of CFRP strengthening is to reduce the reinforcing bar stress caused by excessive wheel loads. In part-1, investigations are conducted on CFRP applicability to strengthening work through static loading and work efficiency tests. Reinforcing bar tensile stress intensity was reduced by 38 to 56 % of the unstrengthened specimen. The loads at which the tensile stress intensity is 140 MPa (allowable reinforcing bar load) are around 1.3 times that of unstrengthened specimen. It can be concluded from the foregoing that reinforcing bar stress intensity can be reduced, confirming the possibility of strengthening.

Hisanobu ICHIMASU is a advisory manager at the Engineering Department, Metropolitan Expressway Public Corporation, Japan. He has been involved in many Planning and Design and Research projects on concrete structures. He is an assistant chairman of Committee of Specifications for Highway Bridges in Japan.
Masao MARUYAMA is a manager at the Tokyo maintenance Department, Metropolitan Expressway Public corporation, Japan. He has been involved in many Planning and Design and Research projects on concrete structures.
Hideo WATANABE is a manager at the Oriental Consultants Co., Japan. He has been involved in many Design and Research projects on concrete structures. He is a member of Committee of Specifications for Highway Bridges in Japan.
Tomoaki HIROSE is an engineer at the Oriental Consultants Co.,Japan. His current design interest is concrete structures .

INTRODUCTION

Small transverse reinforcing bars were built into RC slabs constructed before 1970 in Japan. The increase in traffic volume and the number of overweight vehicles has also resulted in frequent occurrence of cracks in the lower faces of RC slabs on plate girder bridges. As Tokyo Metropolitan Expressways carry an extremely high volume of traffic, strengthening work is to be conducted on the lower faces of RC slabs, thereby minimizing traffic disruptions. RC slabs are being strengthened at present by installing additional stringers and attaching steel plates from the lower faces. In the case of RC slabs inside steel box girders on plate girders with drainage pipes and other attachments (Fig. 1), however, the strengthening work is complicated by the narrow, confined space in which it must take place. Furthermore, when the slabs are strengthened with steel plates, the whole of the concrete surface is covered by the steel plates and this makes maintenance work difficult because of the difficulty of confirming the conditions of bonding between the steel plates and the slabs.

Studies were conducted with the aim of developing a strengthening method that would solve these problems and the use of Carbon FRP plates (CFRP) was suggested. CFRP can be bonded to the lower faces of the slabs in lattice forms, and are flexible, light weight, strong, and do not require any anti-corrosion measures. The concept of slab strengthening by CFRP is to reduce the reinforcing bar stress caused by excessive wheel loads and to prevent the development of bending cracks. Strengthening by CFRP is illustrated in Fig. 2.

The following are the results of tests to confirm work

efficiency and bending resistance of CFRP bonded to the lower faces of the slabs.

DETERIORATION OF STEEL BRIDGE RC SLABS

Studies on steel bridge RC slab fatigue damage stemming from repeated traffic loads began around 1975. The progression of such damage is illustrated in Fig. 3. : (a)In the initial stages, single-direction cracks occur due to drying shrinkage and transverse distribution strengthening. (b)These initial cracks result in a lowering of the transverse direction wheel load distribution capacity and this in turn results in the formation of cracks running parallel to the transverse reinforcing bars. (c)Repeated excessive wheel loads serve to develop and refine these cracks (leads to hexagonal cracks). These cracks eventually extend to the lower faces of slabs where their density stabilizes at about 8 m/m^2. The seepage of rain water also results in the flaking of limestone etc. (d)The slab loses its continuity, resulting in local collapse and fall-off. The RC slabs is damaged by causing the initial cracks in single-direction and repeated excessive wheel loads (shear stress) serve to develop.

The extent of decay [(Fig. 3 (a) or (b)] has increased on Tokyo Expressways and strengthening work is required. The concept of slab strengthening by CFRP is to prevent the development of the initial bending cracks. Strengthening by CFRP is not applicable, because shear stress must be reduced while hexagonal cracks still remain [Fig. 3 (c)]. The strengthening aim are as follows :

1. Prevention of the formation of the initial bending cracks which form into hexagonal cracks [Fig. 3 (a) or (b)].
2. Reduction of reinforcing bar tensile stress intensity (about 120 MPa). Done in consideration of the fact that are caused by excessive wheel loads.

CFRP MATERIALS

Studies are being conducted on application of continuous fiber materials, including carbon, aramid and glass fibers, to strengthening of concrete structures. As the main purpose of slab strengthening is to reduce the tensile stress intensity during service loads, the strengthening materials need to have high elasticity. This makes carbon fibers, with their excellent characteristics of light weight, high strength, high elasticity and high corrosion resistance(Fig. 4 and Table 1), a particularly suitable material for strengthening of concrete slabs.

Carbon fibers may be classified into the PAN type (polyacrylonitrile) and pitch type (petroleum or coal pitch). Of the

carbon fibers used on this occasion, "Cloth" was of the PAN type and "UD (unit-direction) Pre-Preg" was of the pitch type. When carbon fibers are used as slab strengthening materials, they are processed into CFRP plates the fibers are bonded together with epoxy resin to ensure effective action against tensile forces.

In employing carbon fibers as bending resistance of materials on lower faces of RC slabs, considerations need to be made on the states in which the carbon fibers are used. The following confirmation tests were carried out using the four types of strengthening materials given in Fig. 5 and by the bonding methods described below:

1. Ud pre-preg (pre-impregnated): Carbon fibers are laid out in one direction and impregnated with cold setting special epoxy resin [Fig. 6(a)]. The sheets thus prepared are coated with small amounts of special epoxy resin.
2. Cloth: Carbon fibers are woven in two directions as shown in [Fig. 6(b)] . The sheets thus prepared are impregnated with epoxy resin.
3. Cloth pre-preg : This product is manufactured by impregnating cloth in thermosetting resin. It is bonded to the slabs under the required thermosetting conditions (150°C for 30 minutes).
4. Hardened cloth plates: The required number of pre-preg sheets are bonded together in the factory to produce hard plates, which are bonded to the slabs with epoxy resin.

CFRP STATIC LOADING TESTS

Two types of static loading tests were carried out to confirm the bending resistance and the applicability of CFRP. The aims and the conditions of the tests were as follows:

1. Applicability Test: To assess the bonding ability of CFRP and its applicability as a strengthening material, CFRP was bonded to the RC beam specimens from above and a study was made on the relationship between the bonding method and the bending resistance.
2. Bending Resistance Test: To confirm the bending resistance under conditions close to the actual conditions of application. Bending cracks were made in full-size RC beams and RC slab specimens. CFRP was then bonded to the specimens from below. The bending resistance was then confirmed through loading tests.

APPLICABILITY TEST

Test Method and Test Factors

The CFRP was bonded from above using the methods described in the CFRP Materials section on the lower faces of RC beam specimens and were prepared to fit in with standard steel bridge RC slabs. The behavior under bending was studied through a cyclic loading test in which a gradually increasing load was applied to a single point at the center of the span.

Test factors studied included: (1)bonding ability of CFRP, (2)relationship between CFRP types and the bending resistance.

Test Cases

Specimens of the types shown in Fig. 7 and Table 2 were prepared. The specimens were given a span of 2.5 m, width of 330 mm and height of 180 mm in view of the scale (2.5 m span x 180 mm thickness) of the RC slabs to which they would be applied. The reinforcing bars used in the specimens were deformed (295 MPa design yield strength, 16 mm diameter bars). The concrete had a design strength of 28 MPa.

Test Results and Observations

The thermosetting cloth pre-preg (Series B) was bonded to the specimens by heating with a panel heater after application of epoxy resin. This method involves the work of heating the prepeg in addition to that of coating the concrete face with epoxy resin and is more troublesome than others. Furthermore, separation of CFRP at rupture point during the loading test underscored the impracticalities of this method indicated by the low level of bonding.

Because the bonding of cloth (Series C) involves repeated coating, bonding and squeezing out of the resin, there is high dependence on the workers and adequate care must be taken over quality control.

Bonding of hardened cloth plates (Series D) requires the least amount of work as this does not involve heating as in the case of pre-preg or layering as in the case of cloth. The bonding, however, will be made difficult by the air bubbles on large bonding faces and difficult by bonding at the slab haunches.

The bending resistance of CFRP is clear from the fact that

the strength cracking, yielding and maximum loads of the specimens strengthened by CFRP are larger (by approximately 1.6 times with two layers and by approximately two times with four layers) than those of the unstrengthened specimen (Series A), as shown in Table 2.

The allowable reinforcing bar load (the load at which the allowable stress intensity of 140 MPa is reached on the tensile reinforcing bars) of the specimens strengthened by CFRP is 1.6 to 2.3 times that of the unstrengthened specimen, while the reinforcing bar stress intensity was reduced to 38 to 56% of that of the unstrengthened specimen.

The increase in the allowable reinforcing bar load and maximum load are more or less proportional to the number of CFRP layers of cloth (Series C). With cloth pre-preg (Series B) the maximum load is reached at the bond rupturing point indicating the bonding strength in this series is smaller than cloth (Series C).

Notes
N/A=not applicable
CFRP tensile rigidity (MN) = CFRP sectional area x CFRP tensile strength
CFRP tensile proof stress (kN) = CFRP sectional area x CFRP tensile modulus of elastic
Strengthening area: L = beam span (2.5 m), l = bonding length (mm)
Allowable reinforcing bar load: load at which stress intensity in tensile reinforcing bars of 140 MPa is reached.
Reinforcing bar yield load: load at which stress intensity in tensile reinforcing bars of 350 MPa is reached.

BENDING RESISTANCE TEST

Applicability test results indicate that usage cloth pre-preg would involve extensive on site heating work. Cloth, hardened cloth plates, and ud pre-preg were selected and bonded to specimens from below. The bending resistance of these materials were then confirmed through loading tests.

RC Beam Test

Test method and test factors--So as to represent damaged slabs on the existing bridges, cracks were created on RC beam specimens by applying loads until the main reinforcing bar stress at the center of the span reached 180 MPa and CFRP plates were bonded to these specimens from below. Single-point loads were then applied to the span centers of the specimens to study the bending resistance of CFRP from the behavior under bending.

Test factors studied included: (1)types of CFRP (the number of fiber layers was two in all cases), (2)bonding area of CFRP, and (3)effect of CFRP orthogonal to the spans.

Test cases--Ten specimens as shown in Fig. 8 were prepared to examine the relationship between "the CFRP type, strengthening quantity, anchoring method, strengthening area and bonding method" and the "bending resistance."

The dimensions of the specimens and the materials used in them were the same as in the specimens of the Applicability Test.

Two layers of CFRP were bonded to all specimens, aiming to provide the amount of strengthening equivalent to the difference between the 1974 and the present requirements for reinforcing bar bending resistance values as listed in the "Specifications for Highways Bridges".

The bonding work was carried out as follows: (1) concrete surface preparation, (2)primer application, (3)epoxy resin application, and (4)bonding of CFRP strengthening materials from below.

Test results and observations--The test results are summarized in Table 3. No sagging or separation was observed in the CFRP bonded from below.

Fig. 9 shows load / strain (in the reinforcing bars at mid-

span) curve. The allowable reinforcing bar load of the specimens strengthened by CFRP is 1.3 times that of the unstrengthened specimen.

The y-axis in Fig. 10 indicates the load at which a 140 MPa tensile stress intensity (allowable reinforcing bar load) is reached within the reinforcing bars of the specimens strengthened by CFRP. The x-axis indicates CFRP tensile rigidity (CFRP elastic modulus x CFRP sectional area).

Allowable reinforcing bar load was around 1.3 times that of the unstrengthened specimen. The bending resistance was proportional to the tensile rigidity of the CFRP and a bending resistance similar to that during service loads was retained when the reinforcing bars yielded.

There was no lowering of the allowable load of the tensile reinforcing bars when additional CFRP was boded orthogonal to the specimen spans (Series B5 and B6), indicating that no adverse effects would result from bonding the CFRP in lattice forms on the slabs.

All specimens showed the behavior of the type shown in Fig. 11. After the yielding of the reinforcing bars, the CFRP began to separate (Fig. 12) and the maximum load was reached.

Because CFRP was bonded from above, the maximum load was determined by the rupture of CFRP in the Applicability Confirmation Test section. Here, however, the maximum load is determined by the separation of CFRP and this is thought to be due to the lower bonding strength resulting from the fact that CFRP was bonded from below.

The main aim in reinforcing the RC slabs is to reduce the tensile reinforcing bar stress intensity during service loads CFRP can be expected to provide adequate strengthening given that they fulfill their function adequately up to the point where the reinforcing bars yield.

Notes
N/A=not applicable
CFRP tensile rigidity (MN) = CFRP sectional area x CFRP tensile strength
CFRP tensile proof stress (kN) = CFRP sectional area x CFRP tensile modulus of elastic
Strengthening area: L = beam span (2.5 m), l = bonding length (mm)
Allowable reinforcing bar load: load at which stress intensity in tensile reinforcing bars of 140 MPa is reached.
Reinforcing bar yield load: load at which stress intensity in tensile reinforcing bars of 350 MPa is reached.

RC Slab Test

Test method and test factors--The RC slab test was conducted on full-size RC slabs to study the bending resistance of CFRP bonded to the slabs in lattice forms. The decayed slabs on existing bridges have hexagonal cracks [as shown in Fig.3 (b)]. To reproduce their effect, copper plates (thicknesses of 0.3 mm, height of 120 mm) in lattice forms 300 mm by 300 mm were embedded in the specimens during their preparation. CFRP was bonded from below on the lower faces of the slabs and a cyclic loading test was carried out under which gradually increasing loads were applied to the centers of the specimen spans.

Test factors studied included: (1) CFRP types of lattice-shaped bonding and (2) relationship between CFRP bonding positions and crack positions.

Test cases--Four specimens as shown in Fig. 13 and Table 4 were prepared to study the relationship between the strengthening quantity and bonding method and the bending resistance.

The specimens were given a span of 2.5 m, width of 2.5 m and thickness of 180 mm, to fit in with the RC beam specimens. The reinforcing bars and concrete were of the same specifications as in the RC beam test section.

Test results and observations--The test results are summarized in Table 6.

Fig. 14 shows the load / strain (in the reinforcing bar load at midspan) curve. The load at which the reinforcing bar stress intensity in the specimens reached 140 MPa (allowable reinforcing bar load) was around 1.4 to 1.8 times that of the unstrengthened specimen. The bending resistance was also proportional to the tensile rigidity of the CFRP up to the reinforcing bar yielding point (Fig. 15).

Because the allowable load on tensile reinforcing bars is more or less proportional to the tensile rigidity of CFRP, CFRP intervals and bonding positions are thought to be of little consequence.

Notes

N/A=not applicable

CFRP tensile rigidity (MN/m) = (All CFRP sectional area x CFRP tensile strength) / (All CFRP width)

CFRP tensile proof stress (kN/m) = (All CFRP sectional area x CFRP tensile modulus of elastic) / (All CFRP width)

Allowable reinforcing bar load: load at which stress intensity in tensile reinforcing bars of 140 MPa is reached.

Reinforcing bar yield load: load at which stress intensity in tensile reinforcing bars of 350 MPa is reached.

CONCLUSIONS

RC slabs on steel girder-plate bridges are generally strengthened today by attaching additional stringers steel plates. Such methods, however, are difficult to apply to strengthening work inside confined box girders or on girder-plate bridge RC slabs where there are obstructions. CFRP was chosen to allow strengthening work in confined spaces, and to allow attachment within lattice forms, thereby allowing bonding conditions on slab lower faces to be checked. Investigations were conducted on the applicability of CFRP through static loading and work efficiency tests. The following conclusions were drawn from these investigations:

1. CFRP could be used as strengthening materials on the lower faces of concrete slabs in the form of cloth, cloth pre-preg (with thermosetting resin), hardened cloth plates (plates made of cloth pre-preg thermally bonded together in factory) and ud pre-preg (unidirectional pre-impregnated fibers). Of these, application of cloth pre-preg involves difficult heating work on site, while it is difficult to bond hardened cloth plates on slab hunches, which leaves cloth and ud pre-preg as materials suited to practical application.
2. CFRP could be bonded to concrete slabs in lattice forms with epoxy resin from below without sagging or separation.
3. The results of loading tests on RC beams and slabs show that, while the bond strength is lower when the fibers are bonded from below than when bonded from above, attachment of CFRP contribute to the reduction of the reinforcing bar stress intensity during service loads since the separation of CFRP occurs after yielding of the tensile reinforcing bars.
4. The results of loading tests indicate that the reinforcing bar stress intensity during service loads and yielding load of the reinforcing bars are proportional to the tensile rigidity of CFRP.
5. When CFRP is bonded to lower faces of damaged RC slabs, the positional relationship between the cracks and CFRP bonds and the bonding intervals do not have any direct effects on the bending resistance so long as the bonding intervals are maintained below 200 mm.

It can be concluded from the foregoing that the reinforcing bar stress intensity during service loads can be reduced by bonding CFRP in lattice forms to the lower faces of the slabs, confirming the possibility of strengthening by CFRP. Future

tasks will include test strengthening work on existing bridges for confirmation of the bending resistance under vibration and measurement work for confirmation of the bending resistance.

Keywords: beams; bending resistance; bonding from above and below; Carbon FRP plates; epoxy resin; lattice forms; lower faces; RC slabs; reinforcing bars; strengthening work; tests.

RC Slabs Strengthened by Bonded Carbon FRP Plates : Part 2 - Application

By H. Ichimasu, M. Maruyama, H. Watanabe and T. Hirose

Synopsis: In part-1 it can be concluded that reinforcing bar stress intensity can be reduced. This confirms the possibility of strengthening. In part-2 CFRP is bonded by various methods from below on the lower faces of RC slabs. To determine of bonding methods in detail, CFRP will be studied the confirmation test and strengthening design methods. Strengthening design and measurement plan are then made for RC slabs on an existing bridge.

In the strengthening design the main reinforcing bars are strengthened by CFRP of two to three layers and the transverse reinforcing bars are strengthened with three to five layers. It was confirmed that the reinforcing bar tensile stress intensity is reduced around 120 to 130 MPa. CFRP may be used as a strengthening material for RC slabs. Measurements will be conducted in 1993. The bending resistance will be directly confirmed during the existing bridge strengthening operations.

Hisanobu ICHIMASU is a advisory manager at the Engineering Department, Metropolitan Expressway Public Corporation, Japan. He has been involved in many Planning and Design and Research projects on concrete structures. He is an assistant chairman of Committee of Specifications for Highway Bridges in Japan.
Masao MARUYAMA is a manager at the Tokyo maintenance Department, Metropolitan Expressway Public corporation, Japan. He has been involved in many Planning and Design and Research projects on concrete structures.
Hideo WATANABE is a manager at the Oriental Consultants Co., Japan. He has been involved in many Design and Research projects on concrete structures. He is a member of Committee of Specifications for Highway Bridges in Japan.
Tomoaki HIROSE is an engineer at the Oriental Consultants Co.,Japan. His current design interests is concrete structures.

INTRODUCTION

The damaged slabs are strengthened at present by attaching additional stringers or steel plates. Reinforced Concrete (RC) slabs inside steel box girders or on plate girders with drainage pipes and other attachments, however, present strengthening work problems due to the lack of work space. We conducted studies with the aim of developing a strengthening method to solve these problems. The use of Carbon FRP plates (CFRP) was suggested as a result of this.

The bending resistance of CFRP bonded to the lower faces of RC slabs (in Part-1) was confirmed. This paper presents: (1) CFRP bonding work test results on an existing bridge, (2) strengthening design methods, and (3)strengthening design results for RC slabs in steel box girders on an existing bridge.

CFRP BONDING WORK TEST

Outline

CFRP plates were bonded from below to the lower faces of RC slabs on a steel composite girder bridge used for maintenance work on the Metropolitan Expressways to examine bonding operations and performance.

Test factors studied included: (1) CFRP types and their bonding performances, (2) work efficiency (work time and quan-

tities of resin used).

The slabs used had spans of l = 2.5 m and thicknesses of t = 200 mm. The test cases and the bonding patterns of CFRP are given in Table 1 and Fig. 1 respectively.

There were eight test cases. The number of CFRP layers was two in all cases and they were bonded in the lattice forms. The widths of CFRP strips were either b = 250 mm or 500 mm. The bonding area was 2.2 m x 2.2 m on the lower faces of RC slab between stringer and stringer. It was ensured that the CFRP gaps would be less than 200 mm, the minimum distance between hexagonal cracks.

Test Results

Although CFRP was bonded adequately in each test cases, the high rigidity of the hardened cloth plates prevented bonding on slab hunches. It was also found that the 250 mm strips were easier to handle than the 500 mm strips, though bonding required many attempts.

The work time need for each CFRP type is summarized in Table 2. The figures total man-hours are relative to the work time for ud (unit-direction) pre-preg (strip width: 250 mm). As Table 2 indicates, there is little variation for the preparatory work, surface preparation, primer application and curing, but less time is required for the bonding and resin impregnation with ud pre-preg. This is because ud pre-preg has already been impregnated with resin, as can be seen from the work procedure in Fig. 2 and the quantities of resin used in Table 2, and bonding work on site can be carried out with greater ease than with cloth.

Notes
The figures above are relative to the work time for ud pre-preg (strip width: 250 mm) in terms of total man-hours. The bonding methods for CFRP are as follows:
(1) 2 layers along span --> 2 layers orthogonal to span,
(2) 1 layer along span --> 1 layer orthogonal to span --> 1 layer along span --> 1 layer orthogonal to span,
(3) 1 layer along span --> 1 layer orthogonal to span

STRENGTHENED RC SLABS ON EXISTING BRIDGE AND TEST CONSTRUCTION

Aim

The static bending resistance, strengthening work, and other items pertaining to the strengthening effect of bonded CFRP were confirmed in the tests discussed in Part-1. We will test the fatigue characteristics of the bond faces between the CFRP and concrete under cyclic loading . Such tests were carried out in bending fatigue studies by Okano et al.(1), who indicated that CFRP retains sufficient bending resistance even after two million fatigue cycles. Several examples of strengthening of existing bridge slabs are also indicated. The reinforcement of bonding glass fibers was carried out by Nakamura(2). Reinforcement through increasing the amount of lower face slab concrete with a special polymer cement mortar was carried out by Ishii et al.(3). Both parties indicated the methods improved the bending resistance. Our results for the bonding performance and bending resistance of CFRP are therefore similar. Strengthening work will be carried out on slabs on an existing bridge in 1993 to confirm the validity of the strengthening method under continuous vibration.

To strengthen the existing RC slabs inside box girder bridge in the Metropolitan Expressway. The following discussions on strengthening design method, design results and measurements made to confirm the bending resistance.

Design Method

The concept of strengthening--The slabs strengthened were constructed in 1962. The quantity of transverse reinforcing bars in these slabs is only around 25% of that required under the design standards in force at present, while the allowable stress intensity of the main reinforcing bars too is rather high, making the slabs susceptible to development of bending cracks.

The basic concept for the strengthening work, therefore, was "to restrain the development of bending cracks by bonding CFRP to the lower faces of the RC slabs, thus lowering the bending tensile stress intensity of the main and transverse reinforcing bars during service loads." The aim was to reduce the reinforcing bar tensile stress intensity to around 120 to 130 MPa in accordance with the allowable stress intensity given in the "Specifications for Highway Bridges"(4), values.

Calculation of bending stress intensity by RC theory--The specifications of RC slab designs used in Japanese highway bridges have been based on the allowable stress design method determined by the RC bending theory. The aim of strengthening by CFRP is to be reduce the intensity of the reinforcing bar tensile stress. We therefore used the expanding RC bending theory to calculate during service loads for RC rectangular beams (Fig. 3). CFRP is calculated as reinforcing steels which have different elastic modules. Table 3 confirms the validity of these equations when applied to RC beam Tests as shown in Part-1. We confirmed applicability of the equations, the results of comparison, the measurement values and the calculated values in equations (1) to (4) for specimens during service loads.

Neutral axis potion

$$x = \frac{1}{b}\left[-(n_s A_s + n_{cf} A_{cf}) + \sqrt{(n_s A_s + n_{cf} A_{cf})^2 - 2b(n_s A_s d_s + n_{cf} A_{cf} d_{cf})}\right] \quad (1)$$

Stress intensity

$$\sigma_c = \frac{2M}{bx(d - x/3)} \qquad where,\ d = \frac{n_s A_s d_s + n_{cf} A_{cf} d_{cf}}{n_s A_s + n_{cf} A_{cf}} \quad (2)$$

$$\sigma_s = \frac{\sigma_c}{x} n_s (d_s - x) \qquad where,\ n_s = \frac{E_s}{E_c} \quad (3)$$

$$\sigma_{cf} = \frac{\sigma_c}{x} n_{cf} (d_{cf} - x) \qquad where,\ n_{cf} = \frac{E_{cf}}{E_c} \quad (4)$$

Design constants--The design constants were determined as follows, on the basis of the results of material tests that were carried out in accordance with Japan Industrial Standards (JIS K 7073). Table 4 shows the design constants.

1. Tensile Strength: The characteristic values for the tensile strength (95% reliability value) are used to allow for the dispersion in the test results.

2. Allowable Stress Intensity: Because of the absence of yield points, values corresponding to 60 % of the tensile

strength are used, in line with the concept for determining the allowable stress intensity for prestressed concrete steel and carbon rods which have similar stress-strain curves.

3. Tensile Elasticity Ratio: The average values are used in the test results.

Strengthening Design on Existing Bridges

The bridge was constructed in November 1962. It was fewer transverse distribution reinforcing bars than the conventional bridges. The progress of decay has resulted in cracks in two directions on the lower faces but has not yet resulted hexagonal cracks. The results of the strengthening design for the RC slabs on this bridge are given below.

Structure--Fig. 4 shows RC slab structure. Superstructure Type is the two-box simple steel girder bridge, RC slabs.

1.Slab span : l = 2.0 m
2.Slab thickness : t = 170 mm
3.Main reinforcing bar volume : A_s = 1420 mm^2 / m
4.Transverse reinforcing bar volume : A_s = 570 mm^2 / m
5.Design strength of concrete : σ_{ck} = 24 MPa

Design conditions--Design bending moment [from the Specifications for Highway Bridges(4)] are resulted M = 26.0 kNm/m in the main reinforcing bars, and M = 18.5 kNm/m in the transverse reinforcing bars. Allowable tensile stress intensity of reinforcing bars are reduced 140 MPa or less.

Design results--For each CFRP, the number of strengthening layers required and the resulting reinforcing bar stress intensity with two types of CFRP are given in Table 5. Because the reinforcing bar tensile stress intensity is higher in the direction orthogonal to the bridge axis (transverse reinforcing bars) than parallel to it (main reinforcing bars), a greater number of layers are required along the orthogonal direction. The number of axial strengthening layers have been reduced in line with the orthogonal bending moment distribution.

In bonding CFRP, 250 mm wide strips were placed in lattice forms at 100 mm intervals. This was done in consideration of work efficiency (see Fig. 5). To ensure adequate anchorage, the orthogonal direction bonding area was extended to the ends of the slab hunches. In addition, bonding at the slab hunches was designed to fix the support materials and thus prevent the CFRP from sagging.

Cloth and ud pre-preg were used in the test strengthening

work for comparative study of the work efficiency and bonding performance of these two types of CFRP.

Measurement plan--Measurement will be made on the items listed in Table 6 during the strengthening work for confirmation of the bonding performance and strengthening effect of CFRP.

CONCLUSIONS

We bonded to the lower faces of RC slabs from below using a variety of methods. Confirmation tests were conducted for bonding work, strengthening design methods, and strengthening design results for RC slabs in steel box girders. The following conclusions were drawn from these investigations.

1. The bonding effectiveness of various types of CFRP were confirmed. Although CFRP bonded well in each test case, the high rigidity of the hardened cloth plates prevented bonding on slab hunches. It was also found that the 250 mm strips were easier to handle than the 500 mm strips even though satisfactory bonding required several attempts.
2. There was little variation in the preparatory work, surface preparation, primer application and curing, but less time was required for ud pre-preg bonding and resin impregnation. This was because ud pre-preg is already impregnated with resin. This can be seen in the installation operations and the quantities of resin used. On site, the material is easier to bond than cloth.
3. The reinforcing bars and CFRP stress intensities can be estimated with reasonable accuracy with RC bending theory which basis the tensile modulus of elastic for CFRP on the results.
4. We confirmed that CFRP applied in 2 to 5 layers reduces the reinforcing bar (the main reinforcing bars and the transverse reinforcing bars) tensile stress intensity to around 120 to 130 MPa

CFRP bonded by various methods from below to the lower faces of RC slabs reduced the reinforcing bar tensile stress intensity. CFRP plates are suitable strengthening materials for RC slabs.

Tests confirming the bending resistance of CFRP plates under vibration loading were not conducted in this study. Tests on existing bridges are scheduled for 1993.

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Keywords: bending resistance; Carbon FRP plates; epoxy resin; existing bridge; hunches; lattice forms; layer; lower faces; measurements; RC bending theory; strengthening design; transverse reinforcing bars.

RECENT APPLICATIONS OF ACM IN CIVIL ENGINEERING FIELD

Kiyoshi Katawaki, Itaru Nishizaki and Iwao Sasaki
Chemistry Division, Department of Materials and Construction Methods
Public Works Research Institute, Ministry of Construction

Summary

Since ACM including CFRP and AFRP, are produced in Japan, their applications has been developed with private sectors and governmental institutes. Within new materials, ACM cable is a fruitful success for applying civil engineering field
One large application area is for concrete structure of new construction and of re strengthen of existing structure. Another application is a ground anchor for improving soil structure. The advantage of ACM is light weight, corrosion free and reliable.
The applications of ACM are expected to be wider in civil engineering field from these superior characteristics.

Key word: ACM, CFRP, AFRP, their applications, cable, bridge, ground anchor, durability

INTRODUCTION

ACM, such as CFRP and AFRP, has advantages as corrosion free, high specific strength and light weight from this materials characteristics.
In Japan, ACM has wide variety of applications for civil engineering field since material scientists and civil engineers jointly have studied.
Among ACM, some applications of CFRP cable and AFRP cable are introduced in this paper.

CLASSIFICATION OF APPLICATIONS

The classifications of ACM is shown in Table1.

ACM will be applied for bridge, hanging cable, ground anchor and reinforcement in the shape of cable, FRP plate and rod.

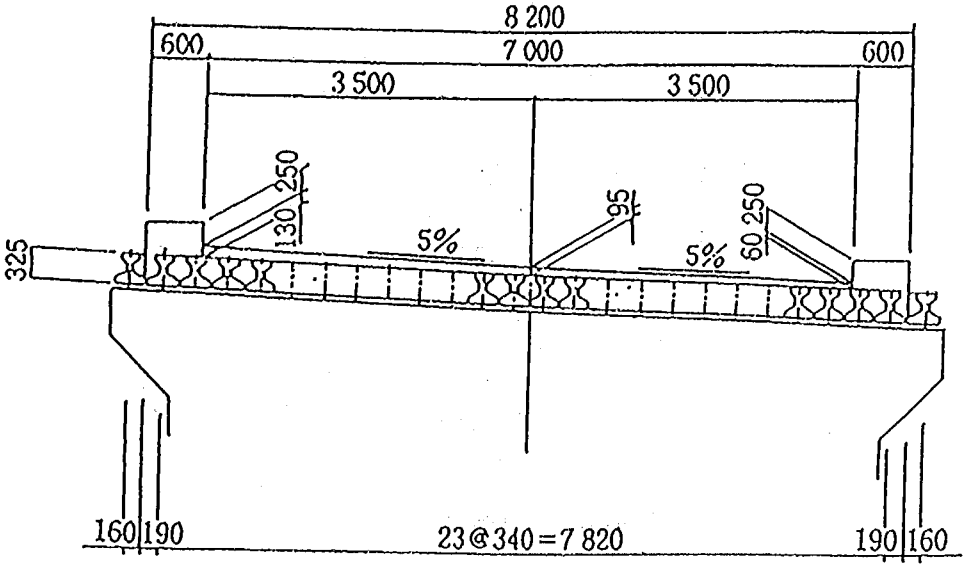
Table 1 Classification of ACM

type	structure	applications
cable	concrete bridge	pretension/posttension beam
	stayed bridge	hanging cable
	ground anchor	permanent anchor
	pilot cable	suspension bridge
FRP	plastic foot bridge	deck, stay cable
	inspection deck	deck
rod	plastic reinforcement	reinforced concrete

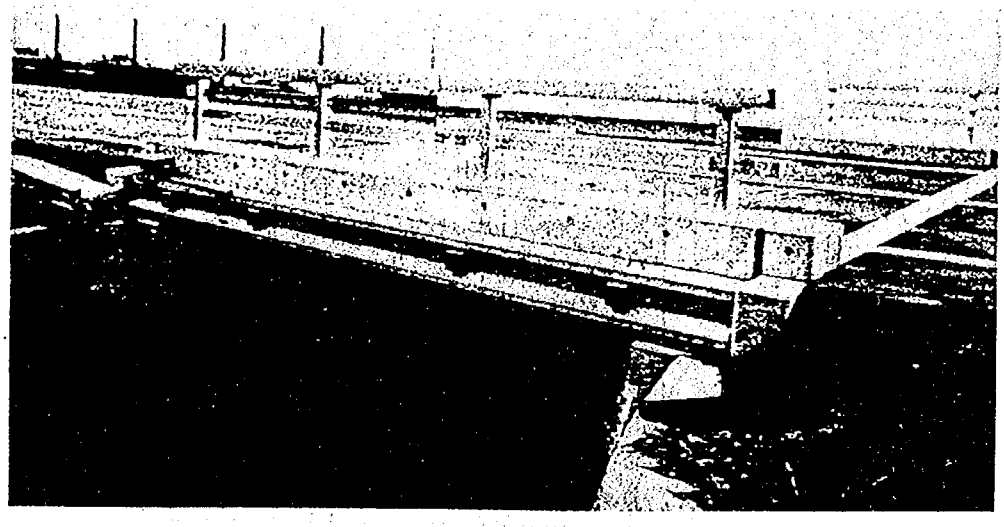
TYPICAL APPLICATIONS

Application for Concrete Bridge

Noto area of Ishikawa is one of the severest corrosion environment, being strongly affected by the winter sea wind. In old bridge, the PC steel wires in the concrete bridge are corroded and heavily damaged.
The Shinmiyabashi in Noto area has been constructed with CFRP cable and was completed until 1988..
CFRP cable was applied in Shinmiyabashi bridge for the first time in the world. The design and construction were advised with PWRI.
The bridge length is 6.1m and the width with pretension type PC slab bridge.

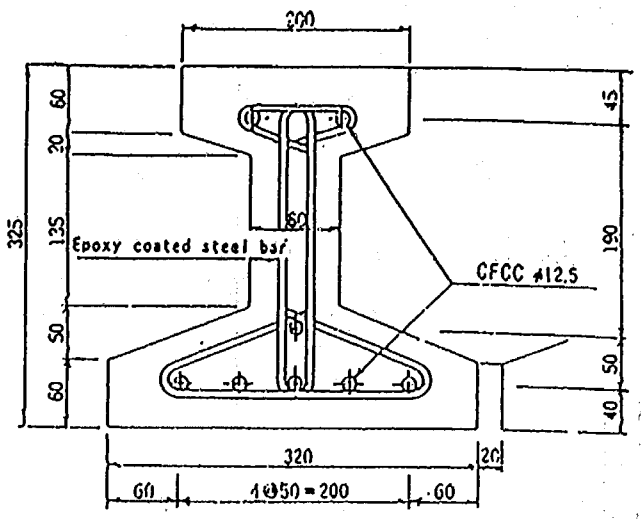


Cross section of Shinmiyabashi

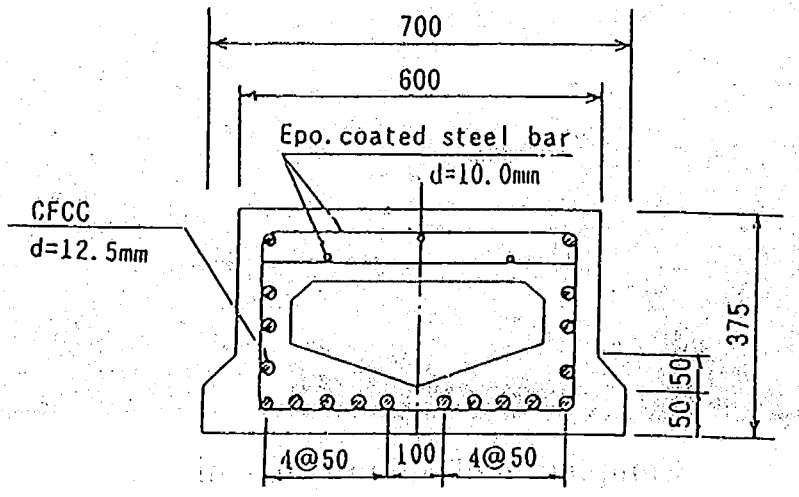


Completion of Shinmiyabashi

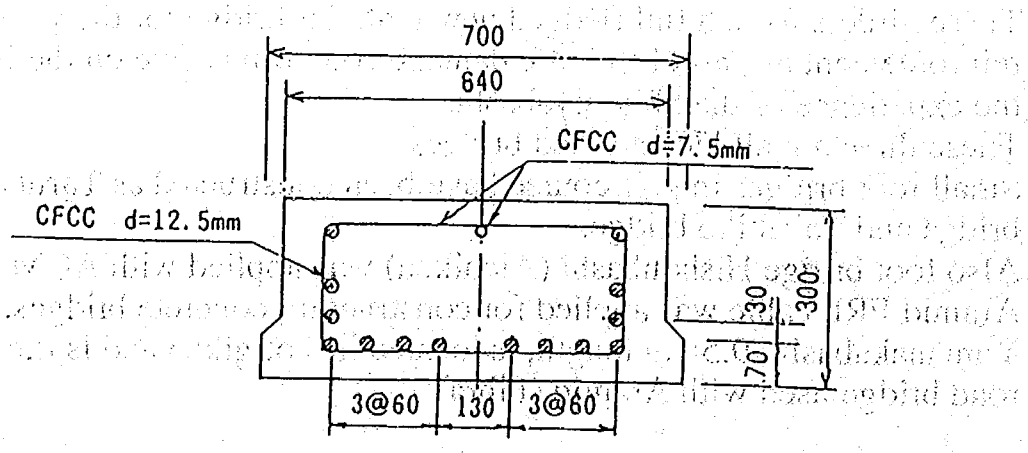
The other three bridges with CFRP cable in Noto area were constructed from 1992 to 1993.
These girders form a full fledged new material bridge for the wheel gird reinforcement as part of the safe damage countermeasure on the basis of the experience of the Shinmiyabashi.
These three are all bicycle road bridges.
Small foot bridges in golf course have been constructed as Tarubashi bridge and Takahiko bridge.
Also foot bridge Hishoubashi (Aichiken) was applied with ACM cable.
Aramid FRP cable was applied for constructing concrete bridges.
Yamanakabashi, 9.54 m length, is located in Totigiken and is the first PC road bridge used with Aramid (Fibra).



Cross section of the beam (Shinmiyabashi)



Cross section of the beam (improved)



Cross section of the beam (improved)

Bridge length:	6.1 m
Width:	7.0 m
Concrete strength of main beams:	49.0 MPa
Installation tensile strength:	
Tension during operation:	0.6 Pu (Pu: guaranteed breakage load)
Tensile strength immediately after installation:	0.55 Pu
Design tensile strength:	0.45 Pu
Reinforcement:	Epoxy coated steel bars (JIS G 3112 SD295)

Design of the beam (Shinmiyabashi)

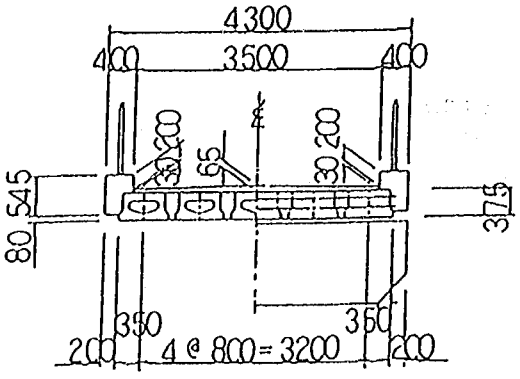
Bridge length:	10.5 m
Width:	4.3 m
Concrete strength of main beams:	49.0 MPa
Installation tensile strength:	
Tension during operation:	0.6 Pu
Tensile strength immediately after installation:	0.55 Pu
Design tensile strength:	0.45 Pu
Reinforcement:	CFCC and Epoxy coated steel bars

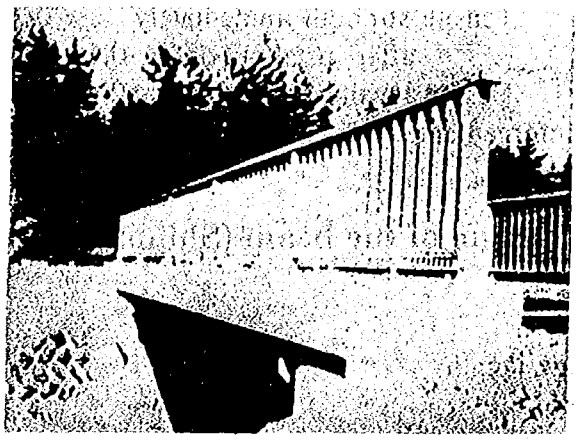
Design of the beam (improved)

Bridge length:	7.3 m
Width:	4.3 m
Concrete strength of main beams:	49.0 MPa
Installation tensile strength:	
Tension during operation:	0.8 Pu
Tensile strength immediately after installation:	0.7 Pu
Design tensile strength:	0.6 Pu
Reinforcement:	All CFCC

Design of the beam (improved)

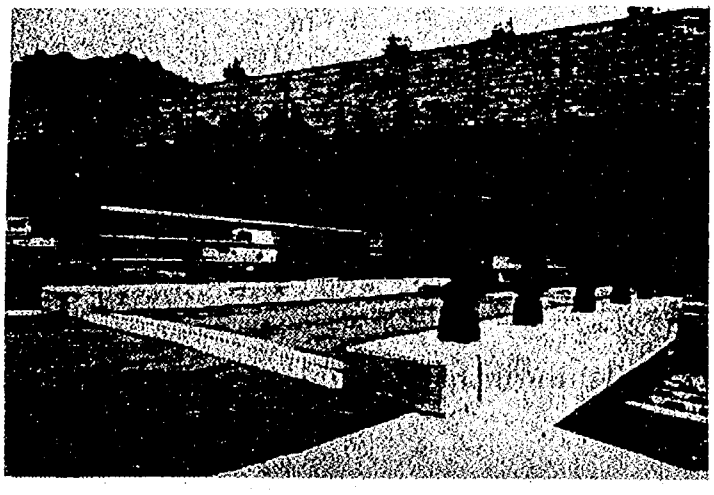
Nagatsu River Bridge is a prestressed bridge reinforced by non metallic materials adopting CFRP for reinforcing materials such as reinforcement, distributing bar and stirrup.





Bicycle road bridge

Multi strand post tension type bridge is adopted the inner cable/outer cable combination type PC structure.
This foot bridge has 111 m length and 3.6 m width with 1 span PC rigid frame. The inner cable is a post tension type CFRP and outer cable is applied with CFRP too.



Yamanakabashi

Research Project Sponsored by MOC Related to New Concrete Bridge

The research project of the use of new materials in the construction field has completed in March 1993.
In the project, many experiments in laboratories have been performed in

applying ACM for concrete bridge.
The guideline for designing concrete bridge applied with ACM was standardized by PWRI during this research project. This guideline deals how to design and construct pretension concrete bridges. This guideline will be testified in some bridges under coordinated with the pilot constructing program managed with MOC.

Application for Strengthening Concrete with ACM

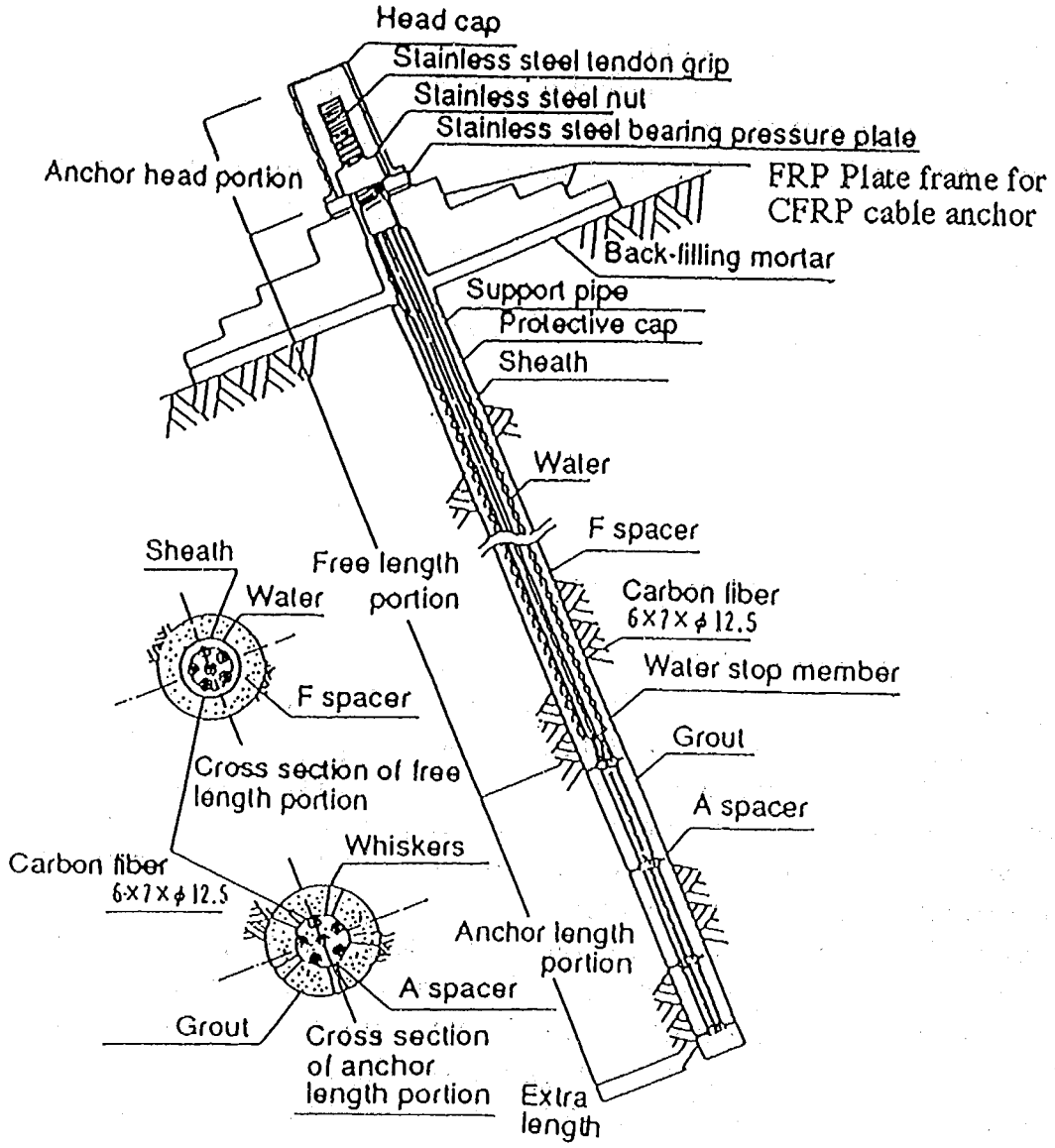
Some existing concrete structures have been strengthened with ACM. The details and some design systems are studied with the Japan Highway Cooperation and the Metropolitan Expressway Public Corporation.

Application for Ground Anchor

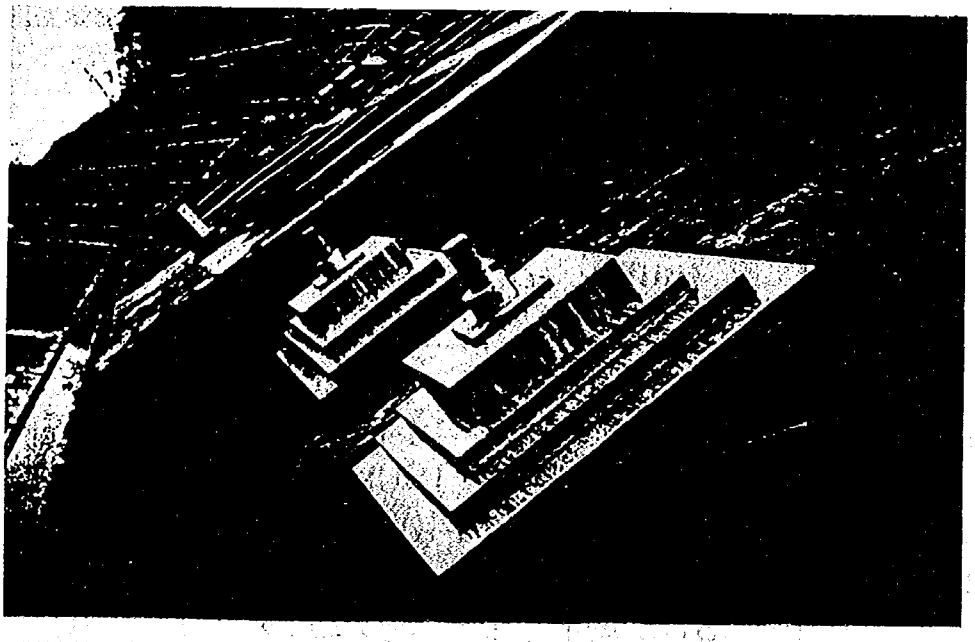
ACM cable has potential for usage in ground structure. Ground anchor is a typical case that ACM cable has been applied recently.
Ground anchor has a role of stabilizing soil slope and concrete wall, with using anchoring effect within ground soil. This has been widespread around Japan. However sometimes old anchor has been corroded in soil. ACM ground anchor has corrosion free advantage and high reliability even in corrosive soil or ground water.
3 type ACM ground anchor (Table 2) are developed and are evaluated under the technology evaluation code managed with PWRC.
The typical system consists anchor, cable and pressure receiving plate.
ACM ground anchor has light weight advantage.
Light weight means simplified construction and needs no heavy construction machines.
These light weight tension member and anchoring system are welcomed for the slope construction. Some test site shows cost effectiveness of ACM cable system.

Table 2 ACM for ground anchor

Type	AFRP	CFRP	CFRP
Material	Aramid	Carbon	Carbon
Shape	Rod	Strand	Rod
Diameter	7.4mmϕ	12.5mmϕ	8mm
Strength	8750kg 200kg/mm^2	14500kg 190kg/mm^2	9000kg 190kg/mm^2
Elastic modules	5400kg/mm^2	14000kg/mm^2	15000kg/mm^2
Unit weigth	62g/m	153g/m	80g/m
Grip	SUS304	SUS329	SUS304



Ground anchored with CFRP cable



FRP plate frame combined with CFRP cable anchor

FUTURE APPLICATIONS AND MATERIALS

Hanging cable in stayed bridge and suspension cable bridge is the one of promised fields applied with ACM in near future.
And out cable of concrete bridge will be applied too, as some studies related to this out cable system are going.
Since hanging cable and out cable will be exposed directly in sun shine, the weatherbility resistance of ACM materials must be essential.

For the construction field, the durability of composite materials is more important and the long term behavior of materials should be investigate. The chemical and physical behavior differ from steel or concrete. Japanese manufactures understand the importance of material design and make efforts to improving engineering quality, especially durability performance. We surveyed the deterioration process of composite materials in actual site of maritime environment in cooperation study with private companies. We have already started exposure test in tropical zone (Okinotorishima) and sub tropical zone (Okinawa).

Conclusion

Since ACM has superior characteristics, more applications in civil engineering field are expected.
ACM has environmental sensibility, so durability or deterioration resistance will be more important. However we have little information of the mechanical and long term chemical behavior not only in hot wet climates but in cold climates.
The durability test in atmospheric atmosphere and in corrosive soil ground will be performed for improving material characteristics of ACM.

Examples of Exposure Tests on FRP cables

Kiyoshi Katawaki, Itaru Nishizaki and Iwao Sasaki
Chemistry division, Public Works Research Institute,
Ministry of Construction, Japan

1. Introduction

Fiber reinforced plastics using high-tech fiber such as carbon fiber or aramid fiber have good performances; light weight and strong, therefore development of application techniques of these FRP for public structures are expected.
From these viewpoint, we are doing basic study on the durability of FRP cables.
In this report, we would like to introduce examples of our exposure tests, because exposure tests seems one of the main method of the investigation of durability.

2. Outline of the exposure tests of FRP cables

Our investigation on durability of FRP was started in 1988, so the longest specimens have been exposed for five years. The tests are classified into 3 cases as follow.

(1) CASE 1: Exposure test in order to study the durability of FRP under long term stressing condition.
- Exposed on shore and off shore
- Two types of CFRP and two types of AFRP have been tested
- Started in 1988 and now continue
- Some of specimens were recovered at the period of 1.5 years

(2) CASE 2: Exposure test in order to study the effect of the stress to the durability of FRP changing the tensile stress
- Two types of CFRP, two types of AFRP, Vinylon FRP and GFRP have been tested
- Started in 1990 and now continue
- Some of specimens were lost by typhoon and restarted in 1993

(3) CASE 3: Exposure test in order to study the effect of exposing environment to the durability of FRP
- Long FRP cables were set vertically from under water to the air, and the difference of the exposing environment was studied.
- Conducted since 1990 till 1992

3. The Exposure Sites

3.1 Maritime Technology Research Station in Suruga

Maritime Technology Research Station in Suruga (Shizuoka prefecture) is a platform located on shore in Suruga bay. It was made in 1983 in order to study the total maritime technologies such as the durability and the stability of maritime structures, the countermeasures for coastal disasters like erosion and so on.

The climate of Suruga is mild, but because of the location, It affected by sea salt strongly.
It was located in the approximately 250 meters point from coast, and the size is 15x15 meters. There are three decks, and the first deck is TP 13.9 meters, the second deck is TP 8.9 meters and the third deck is TP 1.9 meters. The bottom of the sea is TP -7.5 meters.
CASE 1 and CASE 2 were mainly tested at the third deck, but some of CASE 2 was tested at the second deck. CASE 3 was tested between TP -5.0 meters and the second deck.

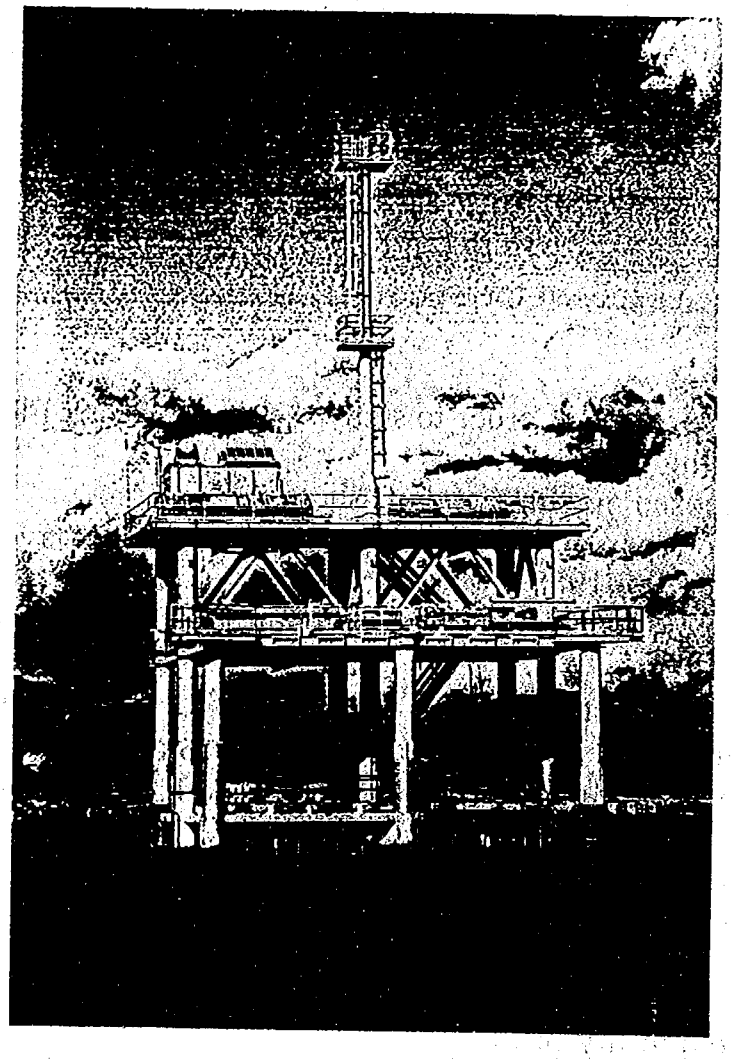


Figure-1 Maritime Technology Research Station in Suruga

3.2 Construction Materials Research Center in Tsukuba

This exposure site is located in PWRI. It was established in order to study the durability of materials for construction through exposure tests in 1990.
The total area is approximately 8000 square meters, and 5000 square meters are able to use for tests.
The climate of Tsukuba is temperature zone and it seems almost moderate and average in temperature and sunshine in Japan.
Average temperature is 13.3 degree, rainfall of a year is 1240 millimeters and total of sun light is 1960 hours.

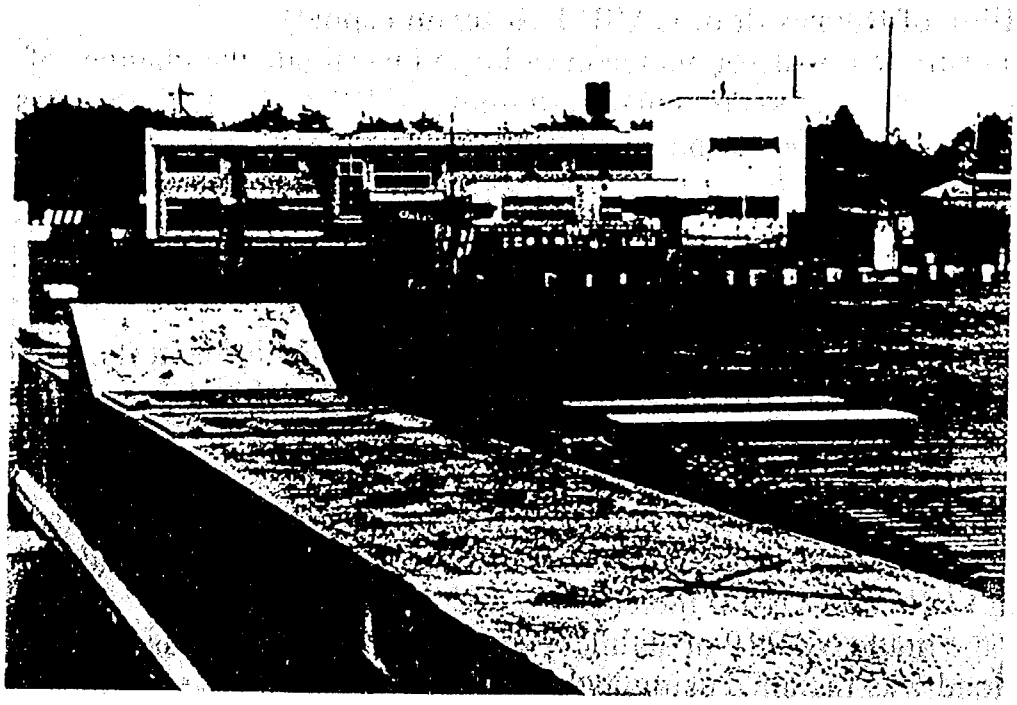


Figure-2 Construction Materials Research Center in Tsukuba

Table-1 Characteristics of FRP cables

	FRP types				Steels	
	AFRP1	AFRP2	CFRP1	CFRP2	Steel wire	Steel strand
Shape	Rod	Rod	Rod	Strand		
Fiber	Technola	Kevler	X24			
Matrix	Vinylester	Epoxy	Epoxy	Epoxy		
Fiber content (%)	65	65	65	65		
Diameter (mm)	8	8	8	12.4	7	12.4
Weight (g/m)	65.1	64.5	76.9	144	302.2	729
Density (g/cm^3)	1.28	1.35	1.57	1.53	7.85	7.85
Tensile strength (kgf/mm^2)	147	159	186	126	165	175
Breaking stress (kgf)	7,400	7,600	9,100	11,800	6,350	16,300
Elastic modulus (kgf/mm^2)	5,570	8,250	15,150	10,700	20,400	19,800
Breaking strain (%)	2.6	1.9	1.2	1.1	>4.5	6.5

4. Main Results the Exposure Tests

Many of the exposure tests are now undergoing. Main result of these are as follow.

4.1 Outline of the result of CASE 1 (interim report)

This exposure test was conducted in order to investigate the changes of the remaining tensile stress and tensile strength of FRP cables with the passage of time, because these performances seem very important as the application to the prestressed concrete tendons. In this interim report, the exposure length is 1.5 years.

4.1.1 Testing materials

Two types of CFRP and two types of AFRP were used in the tests as FRP cables. The characteristics of these FRP cables are shown in **table-1**.

4.1.2 Specimen

The shape of the specimen is shown in **figure-3**. Three cables using same type FRP are placed in a row, and exposed with keeping the tensile load. The length of the each FRP cables is 1.0 meter.

Anchorage made by FRP or stainless steel are set at each ends of the cables, and tensile load was installed using hydraulic jack and stainless steel plates on the aim of 5.0 tons for one cable.

The flame of the specimen were made by concrete, and ahead of the cables were recovered by concrete after tensile load install in order to keep safe if the cable brakes.

Four specimens are made for each kind of FRP, and two specimens are exposed for each exposure points.

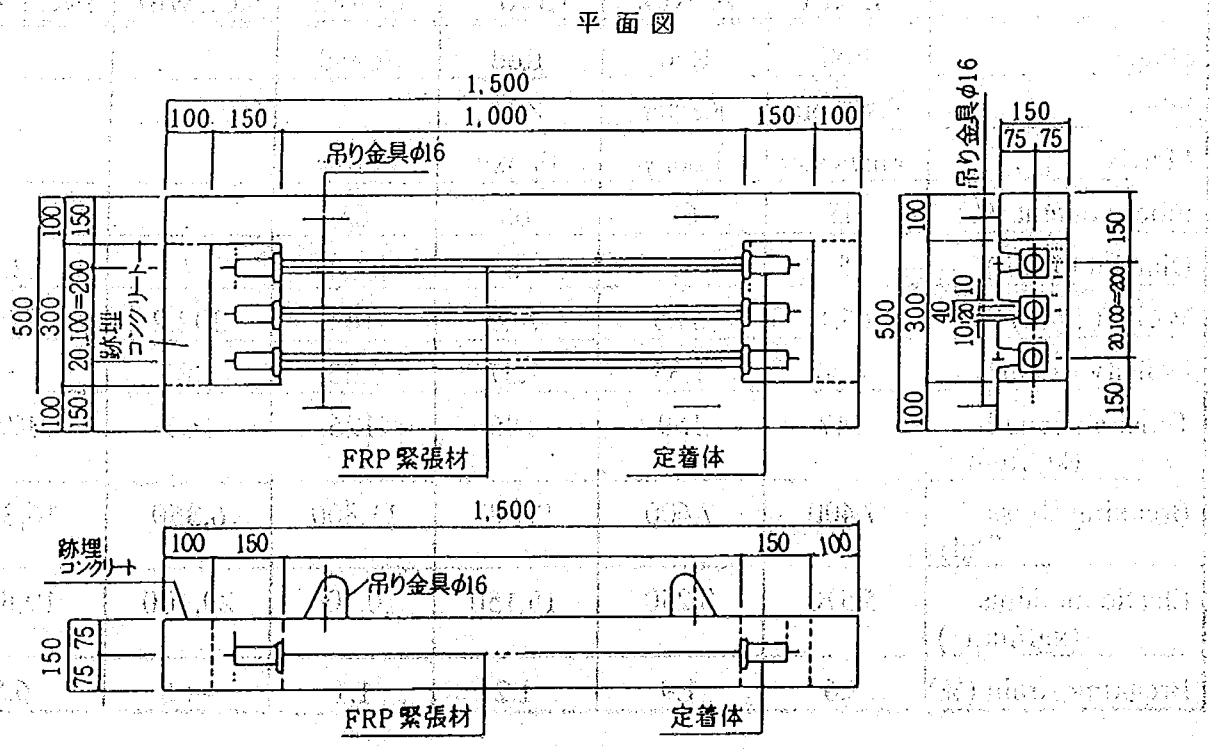
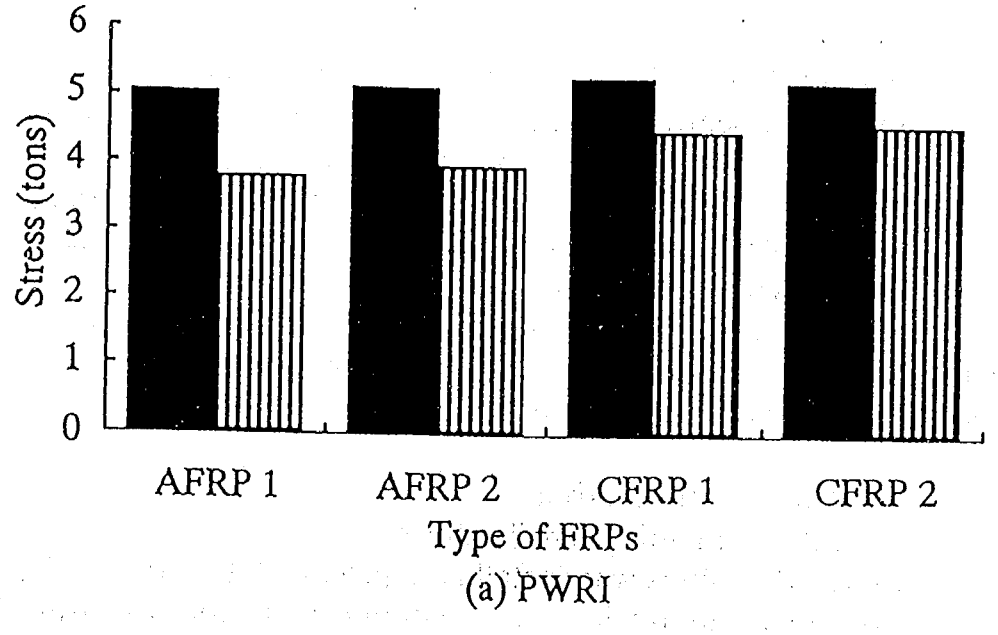
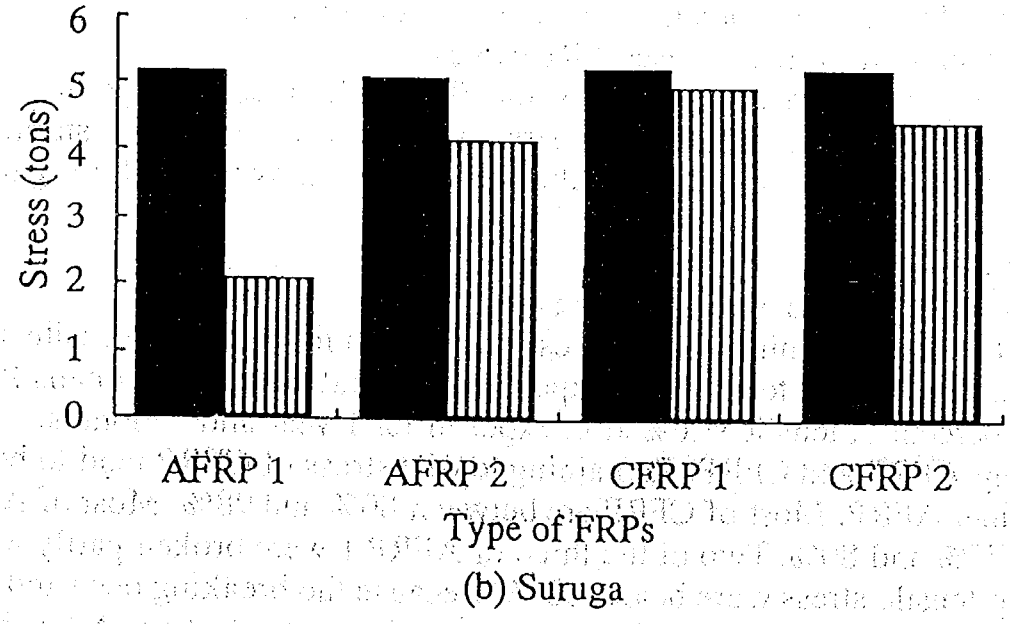


Figure-3 Specimen of CASE 1



(a) PWRI



(b) Suruga

Initial stress / Tensile strength		Remarks
AFRP 1	0.68	initial stress
AFRP 2	0.66	remaining stress
CFRP 1	0.55	
CFRP 2	0.42	

Figure-4 Remaining tensile stress

4.1.3 Exposure of specimens

Exposure tests were conducted in two different places. One is the Suruga Maritime Technology Research Station affected by sea salt splash, and the other is the exposure site of the Public Works Research Institute located in Tsukuba where is mild environment. Both place are able to be considered as in the air, but FRP cables considered hardly to be exposed to the direct sunlight because they are placed in each grooves of the flame.

The exposure tests were started in February 1987, and half of the specimens are recovered and investigated after 1 year and 7 months in September 1989. The other half specimens are exposed continuously.

4.1.4 Measurement items and method

(1) Measurement of the remaining tensile stress

The tensile stress of FRP cables was installed approximately 5.0 tons for one cable when the specimens are made. The remaining stress after exposure tests was measured in this test.

A hydraulic jack was set to the exposed tendon as shown in figure- and loaded, and measured the stress when the anchorage become loose.

(2) Tensile strength of the exposed FRP cables

Tensile strength and elastic modulus of the FRP cables recovered at the measurement of the remaining tensile stress were measured. Tensile strength was used breaking stress and elastic modulus was measured by using strain gauge.

4.1.5 Result

(1) Measurement of the remaining tensile stress

The result of the remaining tensile stress was shown in **figure-4**. Tensile stress was approximately 5.0 tons before exposure tests, but mostly specimens kept about 75 percent of tensile stress after exposed for 1 year and 7 months.

Comparing AFRP and CFRP, Remaining tensile stress of CFRP tend to be larger amount than AFRP. Most of CFRP are between 80% and 98%. Most of AFRP are between 75% and 80%. Two of the three of AFRP 1 were broken partly and its remaining tensile stress were below 30 %. Because the breaking occurred at the base, the reason of the breaking is suggested as the concentration of the stress. There are other possibilities of degradation of the matrix resin, but there aren't clear change in the elastic modulus as shown in next session, so it is necessary to be investigated by other analyzing method like chemical analysis.

It seems danger to think simply that CFRP is better than AFRP from this result, because initial stress was decided to 5 tons regardless of breaking stress, so initial stress was 0.42 and 0.55 of breaking stress for CFRP on the other hand 0.66 and 0.68 for AFRP.

(2) Measurement of tensile strength of the exposed FRP cables

From the main result, almost all specimens show no specific changes in tensile strength and elastic modulus.

4.2 Outline of the result of CASE 3

For the evaluation of durability of FRP materials under real maritime environment, This exposure test have been conducted from under water to the air for two years, and the durability has been evaluated through the observation of tensile strength and chemical property. In this section, the effect of exposing environment to the durability is reported as follows.

4.2.1 Materials

The FRP cables used in this study are shown in **Table-2**. In these cables, No.7 has surface coating by fluorine resin to protect from ultraviolet degradation.

Table-2 FRP cables used in this study

No.	1 2	5 6 7	10 11	14
Name	Carbon 1	Aramid 1	Glass	Vinylon
Fiber	Carbon	Aramid	E Glass	Vinylon
Matrix resin	Epoxy	Vinyl Ester	Vinyl Ester	Epoxy
Diameter	12.5	6.0	6.0	6.0
Vf (%)	64	65	65	65
Tensile strength	16.4	5.42	4.13	2.06

4.2.2 Condition of exposure test

Test materials(about 15m length) was set vertically as shown in **Figure-5.** The test specimen was continuously put between splash and submerged area with slight tension for which prevent from its swing.

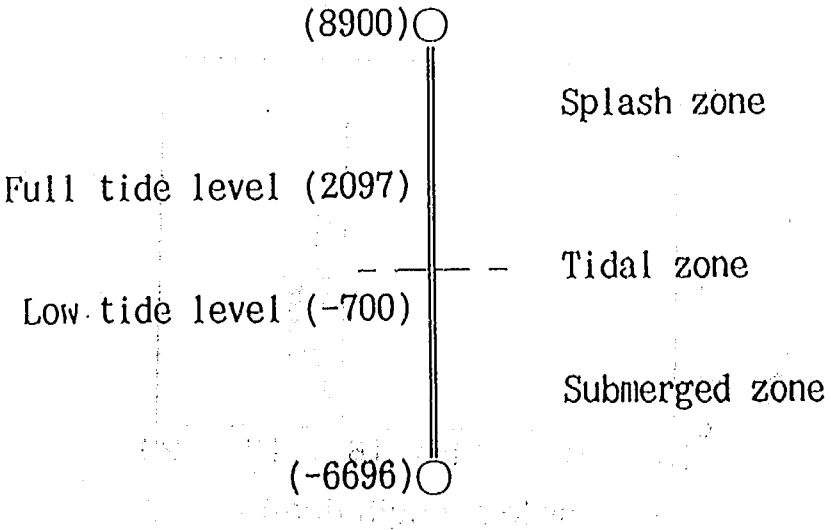


Figure-5 Condition of exposure test

4.2.3 Measurement items and method

For investigation of durability at each exposed environment, the specimens are divided off vertically environmental sections identified in **Figure-5** from the exposed long span FRP cables. The sectional specimens were carried out to determine the materials degradation by measurement shown in **Figure-6**, and the unit length of sections is decided to 2meters.

The tensile strength and elastic modulus was mainly used for determining of degradation, but infrared spectroscopy was also used for reference of chemical deterioration .

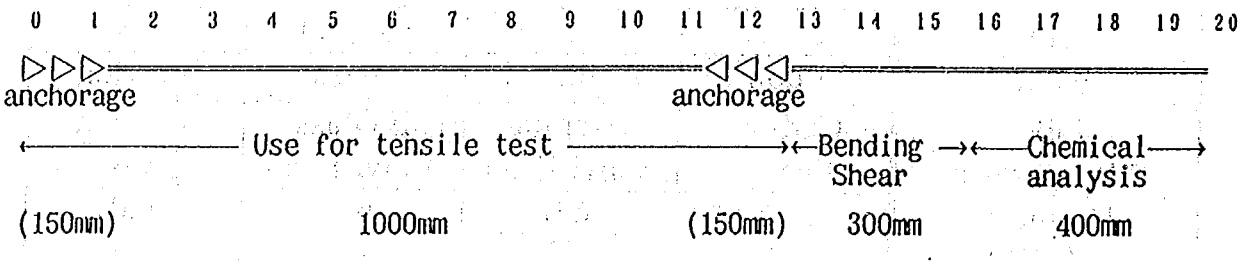


Figure-6 Specimens sectional division for measurement

4.2.4 Result

The result of tensile strength of exposed FRP cables is shown in **Figure-7 to 10** by plotting on vertical exposure level without unusual output measured with corroded anchorage for example.

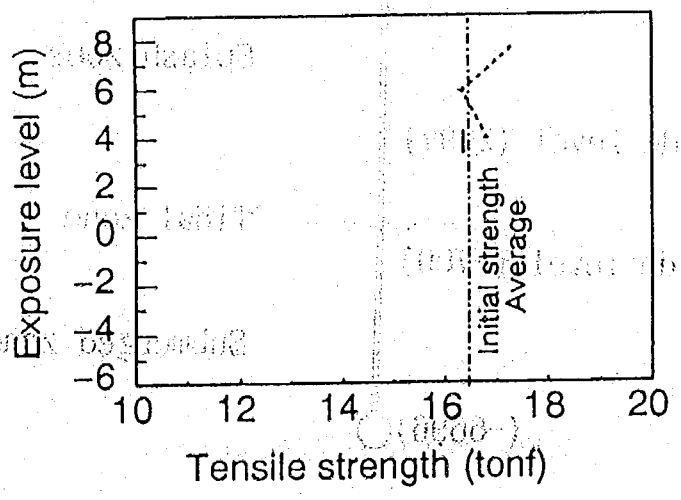


Figure-7 Relationship between remaining tensile strength and vertical exposure level (Carbon 1)

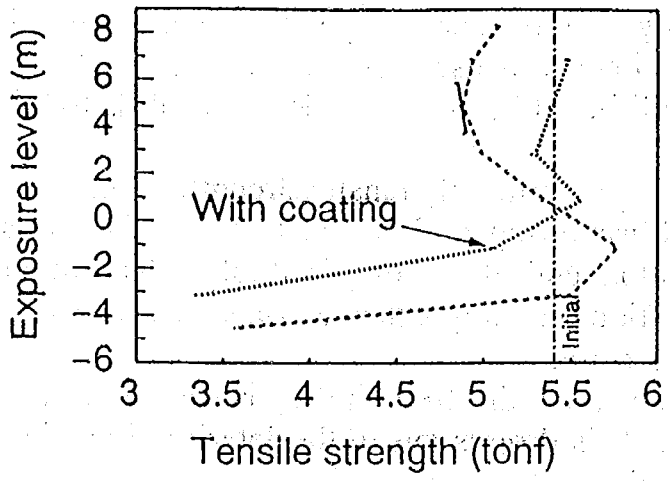


Figure-8 Relationship between remaining tensile strength and vertical exposure level (Aramid 1)

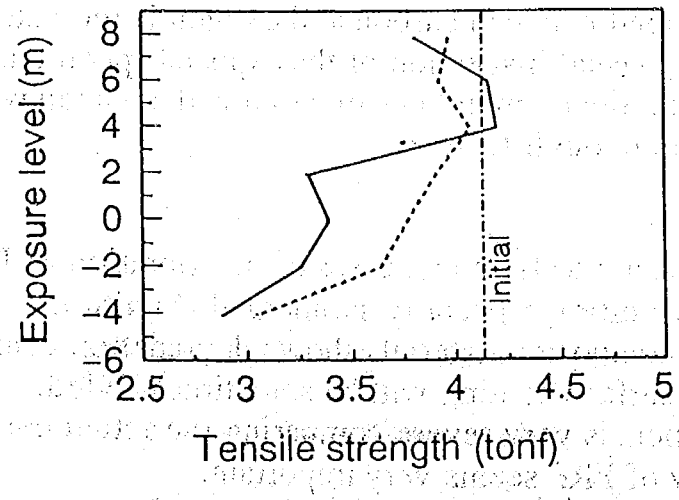


Figure-9 Relationship between remaining tensile strength and vertical exposure level (Grass)

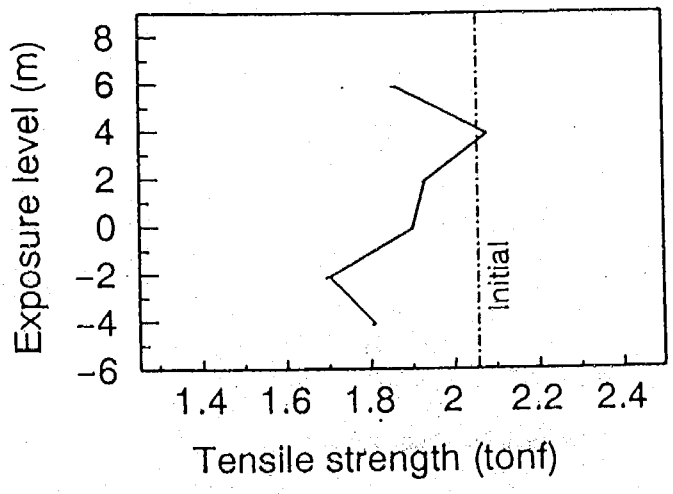


Figure-10 Relationship between remaining tensile strength and vertical exposure level (Vinylon)

Generally, there are many error of measuring in the tensile strength test for FRP cables, and only one specimen was used for every condition. Therefore, volumetric discussion will be difficult, but tendency result is found out as follows.

In submerged area, there are commonly tensile strength drop. There are two reasons why the strength has dropped. It seems that one of them is concentration of bending fatigue to bottom end of the long FRP cable. The other is hypothesis of performance deterioration on composite materials because of water penetration between fiber and matrix resin.

As for the result of Armada, certain strength drop is shown in the upper part of the surface of the water. This drop is due to the deterioration of polymer materials caused by the ultra violet ray.

Changing of the molecular structure was measured by infrared spectroscopy analysis using repeatedly reflection on the surface(horizontal ATR method). Main factor of the deterioration of epoxy resin is oxidation and decomposition, so increase of the double bond between carbon and oxygen is indicator. And rough texture was observed by visual inspection of the exposed specimens. The matrix resin broke down and the fiber content became rich is the reason why the specimens surface became rough texture.

5. Conclusion

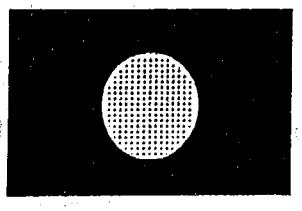
Through these two exposure tests, some cases of deterioration of FRP were observed under some condition especially submerged condition.

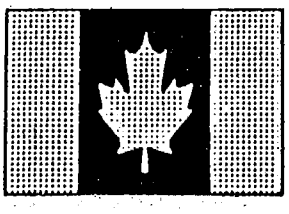
Some kind of polymer composite materials shows degradation caused by the ultra violet ray in the air, so surface coating will be sometime needed.

The exposing environment is very severe comparing the actual condition, but evaluation of durability of FRP seems very important.

LABORATORY EVALUATION AND FIELD EXPERIENCE WITH GFRP

PAR
DANIEL VEZINA ING.
HEAD OF CONCRETE DIVISION





presented to
ACM Workshop
Tokyo, december 6

T.1 INTRODUCTION TITLE

First of all, has you can see, I am mainly involved in concrete field and particularly bridge deterioration of all types. So, I am not an expert in composite material; but, since 1988 we begin to be interested by these new materials, GFRP. It was very attractive to use this new type of rebar because they prevent all domages caused by corrosion of steel.

In 1990, Quebec DOT, financed a first study to see if it could be possible to use GFRP in concrete.

The objective of my talk, this morning, is to present the results of the study and the field application with GFRP.

T.2 IDENTIFICATION

The name of the rod tested is "ISOROD" and it is manufactured by Pultrall inc. in Thetford Mines, Canada. This rod is a glass fibre type E with vinyl ester coating.

The tests have been performed by or Sherbrooke University and Polytechnic School in Montreal.

For the field test we selected a major bridge repair in Montreal area and we rebuilt the Median Barrier, New Jersey type with four differents reinforcement

- Normal steel
- Epoxy coated rebar
- Galvanised steel
- GFRP

The installation has been completed during Summer 1992 and inspection program is set up for the next years.

T.3 TEST PROGRAM

With this programm we wanted to see if GFRP rods can perform well in concrete exposed to freezing and thawing and also evaluated the bond to concrete.

Mechanical property of the GFRP was not the main objective of the project.

T.3 MECHANICAL PROPERTY

Evaluation of mechanical property has been limited to the main characteristic like:

- Tensile strength
- Modulus of Elasticity
- Poisson ration
- and thermal expansion

T.4 FLEXURAL TEST OF THE FREEZING AND THAWING

With this test we wanted to know the effect of the rapid cycle of freezing and thawing on flexural strength of concrete prism build with three differents types of rebar:

- Normal steel
- Epoxy coated rebar (ECR)
- GFRP

The test used was the flexural strenght determined by central loading (ASTM C293) and the freezing and thawing cycle meet the ASTM C666 requirement with 6 cycles/day.

T.5 ILLUSTRATION OF THE FLEXURAL TEST

T.6 REINFORCEMENT OF THE PRISM

Steel wire mesh 50 X 50 mm
Position of rods

T.7 TABLE OF RESULTS

This table gives the results the force (kN) at failure of the prisms at 0 and 600 cycles of F/T.

For the 3 bars evaluated, we note the same tendancy between 0 and 600 cycles but the level of resistance is not the same.

T.8 GRAPHICAL ILLUSTRATION OF FLEXURAL

We see about the same slope for the 3 rebars. Do not forget that the diameter of the GFRP is smaller than the two others.

Based on these results we can concluded that F/T has the same effect on GFRP than on the steel rod.

T.9 FLEXURAL TEST AT LOW TEMPERATURE

Again, we evaluate the flexural strenght of concrete prism reinforced with steel on GFRP.

This time we mesured the flexural strenght by the third point loading (ASTM C78).

The evaluation has been done on specimen conditioned at -30°C or 20°C before test.

T.10 TYPICAL RESULT

Steel at 20°C, charge vs deflection.

T.11 TYPICAL RESULT

Steel at -30°C

T.12 TYPICAL RESULT

Charge (kN vs deflection)
GFRP at 20°C

T.12 TYPICAL RESULT

GFRP at -30°C

Results illustrate clearly the difference of modulus between the rods (steel vs GFRP).

In both cases, low temperature did not seen to have some detrimental effect.

T.13 BOND WITH CONCRETE

This was one of the most important characteristic that we want to evaluate in this testing program.

The test has been realised in accordance with ASTM C234.91.

Basicaly the test is a measure of the force to pull off a rebar embedded in a concrete block (as illustrated).

Great difference is observed betwen GFRP and steel in term of bonding with concrete.

For the same bar diameter, GFRP is about 75% of steel bond.

Examination of the GFRB after test indicated the weakness of the ribs to improve bond with concrete.

T.14 ILLUSTRATION OF THE GFRP USED IN CONCRETE

Median barrier on Mederic Martin Bridge

T.15 FIELD APPLICATION

Actually the use of GFRP has been limited to non structural application

Province of New Brunswick use GFRP for slab on ground on a pier. Province of Quebec use GFRP for New Jersey Barrier. Hydro-Quebec and Aluminium Plant use GFRP for electromagnetic protection.

T.16 SITUATION IN CANADA

* Non structural application
* Most of the recent studies are realised by
  Sherbrooke University
  National Research Council (NRC)
* Specialist are working on a Canadian Code for ACM.

T.17 CONCLUSION

From this first field use in Quebec with this type of rod we can say that

- GFRP has a good performance in concrete submitted to freezing and thawing and at low temperature.
- Stability with time is still questionnable.
- Bond to concrete has to be improved.
- No problem with installation in field
- Cost is very high actually.

1993-11-26

ANNEX 1

IMPLEMENTING ARRANGEMENT BETWEEN THE PUBLIC WORKS RESEARCH INSTITUTE OF THE MINISTRY OF CONSTRUCTION OF JAPAN AND THE RESEARCH AND DEVELOPMENT DIRECTORATE OF THE DEPARTMENT OF TRANSPORT OF CANADA CONCERNING COOPERATION IN HIGHWAY SCIENCE AND TECHNOLOGY

The Public Works Research Institute (PWRI) of the Ministry of Construction of Japan and the Research and Development Directorate (R&DD) of the Department of Transport of Canada, hereinafter referred to as "the Parties",

Desiring to promote and enhance the development and transfer of technology with respect to highway transportation between Japan and Canada; and

Desiring to proceed with cooperative activities pursuant to and governed by all the provisions of the Agreement between the Government of Japan and the Government of Canada on cooperation in Science and Technology (the Agreement) signed in Tokyo on May 7, 1986;

Have decided on the following Implementing Arrangement (the Arrangement) in accordance with Article III of the Agreement:

Article I
Scope and Objectives

The purpose of this Arrangement is to provide for a program of mutually beneficial cooperative activities to be undertaken by both the Parties in the field of highway transportation research and technology including, but not limited to, the following topics:

1. Paving in Cold Areas (PICA)
2. Intelligent Vehicle Highway Systems (IVHS)
3. Wind Resistant and Seismic Structures
4. Road Environment
5. Advanced Composite Materials (ACM)

Article II
Cooperative Activities

Cooperation may be pursued through several means, including but not limited to:

1. Exchange of technical information, reports,

data bases and publications;
2. Exchange visits by technical experts on short term assignments;
3. Joint workshops and symposia on topics of mutual interest; and
4. Joint research.

Article III
Participating Agencies

Both the Parties, as appropriate in the cooperative activities, may allow the participation of other agencies, outside their own organizations. Such agencies, to be referred to as the Participating Agencies, may be drawn from all sectors of research establishment, including other levels of governments, universities, national laboratories, and the private sector. The Parties will act as coordinating bodies for all the cooperative activities including those of the Participating Agencies.

Article IV
Program Coordination

The Parties designate their following officers as overall Program Coordinators for implementing this Arrangement:

PWRI: Assistant Director–General

R&DD: Chief, Planning and Coordination

The Program Coordinators will be responsible for:

1. Designating a Contact Person for each individual topic under this Arrangement;
2. Selecting cooperative activities;
3. Preparing periodic status and progress reports;
4. Arranging meetings, workshops and exchange visits;
5. Meeting periodically to review the cooperation and resolve any difficulties.

Article V
Implementation

The cooperative activities will be implemented in accordance with the following terms and conditions:

1. Funding arrangements, wherever required, will be agreed upon on a case–by–case basis;
2. In connection with the exchange of reports, data and other material, each Party will respect any conditions or limitations on further dissemination as may be

proposed by the other;

3. The Party transmitting information, while making every effort to ensure its accuracy, will not be held liable for the content or use of such information;
4. In case of joint projects, both the Parties will decide in advance on the tasks to be performed by each and the dissemination of results.

Article VI
Intellectual Property

Scientific and technical information of a non-proprietary nature resulting from the cooperative activities under this Arrangement may be made available to the public through customary channels and in accordance with the normal procedures of the Participating Agencies.

The intellectual property created or any proprietary information furnished in the course of cooperative activities under this Arrangement will be protected and managed by both the Parties in accordance with prior decision in each individual case and both the Parties will consult with each other for this purpose as necessary.

Article VII
Duration

This Arrangement will come into effect upon signature and will remain in force for five years. Either Party may terminate this Arrangement at any time upon six months' written notice to the other. The Arrangement may be extended and amended at any time by written confirmation by both the Parties as long as it is in force. The termination of this Arrangement will not affect the carrying out of any cooperation activities undertaken under this Arrangement and not fully executed at the time of the termination of this Arrangement.

DONE in Tsukuba, this 7th day of December, 1993,

For the Public Works Research Institute of the Ministry of Construction of Japan

Yukihiko Sumiyoshi
Director-General
Public Works Research Institute

For the Research and Development Directorate of the Department of Transport of Canada

A. E. Pokotylo
Director General
Research and Development

ANNEX 2

Schedule of the Workshop

Dec. 4(Sat) Arrival at Narita from Canada

5(Sun) Arrival at Narita from Canada

6(Mon) Task Committee Meeting
- A : Paving in Cold Area (PICA)
- B : Intelligent Vehicle Highway Systems (IVHS)
- C : Wind Resistant and Seismic Structures
- D : Road Environment
- E : Advanced Composite Materials (ACM)

7(Tue) Visit to PWRI Laboratories
Signing Ceremony
Opening Ceremony
Keynote Topics
"The Road Administration System in Japan"(Road Bureau, MOC)
"The Road Administration System in Canada"(Transport Canada)

8(Wed) Presentation on Road Research
"Road Research in Japan"(PWRI)
"Road Research in Canada"(Transport Canada)
Reports of Task Committee
Discussion on the Workshop Summary
Program Coordination Meeting
Closing Ceremony

9(Thur) Study Tour (Tsukuba --> Kobe)
Akashi Bridge, Maiko Tunnel

10(Fri) Study Tour (Kobe --> Osaka --> Kyoto)
Kansai International Airport,
Traffic control center of Hanshin Expressway Public Corporation,
Meishin Expressway

11(Sat) Trip (Kyoto --> Tokyo)

12(Sun) Departure to Canada from Narita

Session Program of the Workshop

Monday, December 6

9:30 - 10:00 Registration (Meeting Room 8F)

10:00 - 12:00 Task Committee Meeting

A:PICA (Meeting Room 526)

10:00～10:30 Presentation
"Pavements in Japan"
Toshiyuki Nakamura / Head, Pavement Division, Road Department, PWRI

10:30～10:50 Discussion

10:50～11:10 Break

11:10～11:40 Presentation
"Pavements in Canada"
Gerhard J. Kennepohl / Manager, Pavements & Roadway Office, Research & Development Branch, Ontario Ministry of Transportation

11:40～12:00 Discussion

B:IVHS (Meeting Room 627)

10:00～10:30 Presentation
"Present State of IVHS in Japan"
Makoto Nakamura / Head, Traffic Engineering Division, Road Department, PWRI

10:30～11:00 Presentation
"Present State of IVHS in Canada"
Milton D. Harmelink / Director, Transportation Technology and Energy Branch, Ontario Ministry of Transportation

11:00～11:15 Break

11:15～11:45 Presentation
"Vehicle Information & Communication System (VICS)"
Yositaro Masuda / Technical Counselor, Highway Industry Development Organization

11:45～12:00 Discussion

C:WIND·SEISMIC (International Conference Room 8F)

10:00～10:45 Presentation
"Seismic Design of Road Bridges in Japan "
Kazuhiko Kawashima / Head,
Earthquake Engineering Division, PWRI

10:45～11:30 Presentation
Donald L. Anderson / Professor, Department of Civil Engineering, University of British Columbia

11:30～12:00 Discussion

D:ROAD ENVIRONMENT (Meeting Room 532)

10:00～10:40 Presentation
"The Present Status on Road Environment in Japan"
"The Road Environment Policy in Japan"
Jun Ando / Assistant Director, Road Environment Research Section,Planning Division, Road Bureau, MOC
"The Technology Related to the Road Environment"
Minoru Ishida / Head, Traffic Environment Division, Environment Department, PWRI

10:40～11:20 Presentation
"Environmental Impact Assessment Process Followed in Canada"
"Detailed Examples of Studies, Designs and Construction of Highway Environmental Projects"
"Experiences Related to Noise Mitigation, Soil Erosion Techniques and Road Surface Drainage Issues"
Michael Kent / Director, Highway Environment, B.C. Transportation and Highway

11:20～11:30 Break

11:30～12:00 Discussion on R&D Activities of Both Countries

E:ACM (Meeting Room 534)

10:00～10:50 Presentation
"First Experience with FRP in Quebec"
Daniel Vezina / Chef de la section des Betons de ciment Division des produits industriels
Transports Quebec

"Advanced Composite Materials in Bridge and Structures in Canada - An Overview"
Ken W. Neale / Professor, Department of Civil Engineering, Faculty of Applied Science, University of Sherbrooke

10:50～11:00 Break

11:00～12:00 Presentation

"A Study on the Strengthening with Carbon Fiber of Existing Structure"
Hirofumi Ando / Bridge Section, Research Institute, Japan Highway Public Corporation

"RC Slabs Strengthened by Bonded Carbon FRP - Laboratory Study and Application -"
Masao Maruyama / Manager, Design Division, Tokyo Maintenance Department, Metropolitan Expressway Public Corporation

"Recent Applications of ACM in Civil Engineering Field in Japan"
Kiyoshi Katawaki / Head, Chemistry Division, PWRI

"Examples of Exposure Tests on Fiber Reinforced Plastics Cables"
Itaru Nishizaki / Researcher, Chemistry Division, PWRI

12:00～13:30 Lunch (Outside of the Institute)

13:30～17:00 Task Committee Meeting

A:PICA (Meeting Room 526)

13:30～14:00 Report on PICA-5 and Direction of PICA-6
Gerhard J. Kennepohl / Manager, Pavements & Roadway Office, Research & Development Branch, Ontario Ministry of Transportation

14:00～14:45 Discussion

14:45～15:00 Conclusion
Toshiyuki Nakamura / Head, Pavement Division, Road Department, PWRI

15:00～15:30 Break

15:30～16:00 Report on the Direction of Cooperative Activities
Toshiyuki Nakamura / Head, Pavement Division, Road Department, PWRI

16:00～16:30 Discussion

16:30～17:00 Conclusion
Toshiyuki Nakamura / Head, Pavement Division, Road Department, PWRI

B:IVHS (Meeting Room 627)

13:30~14:00 Presentation
"Towards a Universal Low-Cost Multi-Application IVHS Infrastructure"
Lewis Sabounghi / Senior Development Officer, Transportation Development Center

14:00~14:30 Presentation
"Preparation and Application of Digital Road Map in Japan"
Masao Shibata / Executive Managing Director, Japan Digital Road Map Association

14:30~15:00 Discussion
15:00~15:15 Break
15:15~17:00 Discussion on the Direction of Cooperative Activities

C:WIND·SEISMIC (International Conference Room 8F)

13:30~14:30 Visit to Laboratory
14:30~17:00 Discussion on the Direction of Cooperative Activities

D:ROAD ENVIRONMENT (Meeting Room 532)

13:30~14:45 Discussion on the Direction of Cooperative Activities
14:45~15:00 Break
15:00~16:00 Drawing up the Task Committee Report
16:00~17:00 Tour through the Facilities for Road Environment R&D in PWRI

E:ACM (Meeting Room 534)

13:30~15:00 Discussion on the Direction of Cooperative Activities
15:00~15:15 Break
15:15~17:00 Preparation of the Report of Task Committee

Tuesday, December 7

9:30~12:00 Visit to Research Laboratories in PWRI
(Pavement Test Field, Guide Light System, Test Track, Boundary Layer Wind Tunnel Laboratory, Vibration Laboratory, Air Pollution Laboratory, Material and Structural Engineering Laboratory Complex)
12:00~13:30 Lunch (Meeting Room 1F)
13:30~14:00 Signing Ceremony (Meeting Room 8F)
14:00~14:30 Opening Ceremony for the Workshop (Meeting Room 8F)
14:30~14:45 Group Photograph
14:45~15:00 Break

Keynote Topics (Meeting Room 8F)
(Chairman : Toshinori Mizutani, Director, Environment Department, PWRI)
15:00～16:00 "Road Administration System in Japan"
Nobuhiko Sato, Director, Planning Division,
Road Bureau, MOC
16:00～17:00 "Road Administration System in Canada"
August E. Pokotylo, Director General,
Research & Development Directorate, Policy and
Coordination Group, Transport Canada

Reception
18:00～20:00 (Hosted by Yukihiko Sumiyoshi, Director-General, PWRI)
(Hotel Sunroute Tsukuba)

○11:30～13:30 Registration (Meeting Room 8F)

Wednesday, December 8

Presentation on Road Research (Meeting Room 8F)
(Chairman : Masashi Ikemura, Director,
Material and Construction Method Department, PWRI)
9:00～ 9:45 "Road Research in Japan"
Yutaka Anzaki, Research Coordinator for Road Traffic,
Road Department, PWRI
9:45～10:30 "Road Research in Canada"
Shyam Khubchandani, Chief, Planning and Coordination,
Research & Development Directorate, Policy and
Coordination Group, Transport Canada

10:30～10:45 Break
10:45～11:45 Reports of Task Committee (Meeting Room 8F)
11:45～13:00 Lunch
13:00～15:30 Discussion on the Workshop Summary (Meeting Room 8F)
15:30～15:45 Break
15:45～16:30 Program Coordination Meeting (Meeting Room 8F)
16:30～16:40 Break
16:40～17:10 Closing Ceremony (Meeting Room 8F)

Reception
18:00～20:00 (Hosted by Canada)
(Tuskuba Center for Institutes)

Signing Ceremony

1. Time
   Tuesday, December 7, 1993 (13:30 - 14:00)

2. Place
   Meeting Room (8th Floor), Public Works Research Institute

3. Program
   Call to order by Mr. Masahide Tamura, Director of Planning and Research Administration Department, Public Works Research Institute

   Signing Japan Side : Yukihiko Sumiyoshi, Director-General, Public Works Research Institute, Ministry of Construction
   Canada Side : August E.Pokotylo, Director-General, Research and Development Directorate, Policy and Coordination Group, Transport Canada

   Remarks by Mr.Yukihiko Sumiyoshi, Director-General, Public Works Research Institute, Ministry of Construction

   Remarks by Mr. August E.Pokotylo, Director-General, Research and Development Directorate, Policy and Coordination Group, Transport Canada

   Closure by Mr. Masahide Tamura

Opening Ceremony

1. Time
   Tuesday, December 7, 1993 (14:00 - 14:30)

2. Place
   Meeting Room (8th Floor), Public Works Research Institute

3. Program
   Call to order by Dr. Takashi Iijima, Assistant Director-General, Public Works Research Institute

   Remarks by Mr. Hiroyuki Fujikawa, Director-General, Road Bureau, Ministry of Construction

   Remarks by Mr. Donald Wilfred Campbell, Ambassador, Embassy of Canada

   Remarks by Mr. Shinichiro Ogura, Director, International Affairs Division, Science and Technology Promotion Bureau, Science and Technology Agency

   Introduction of Participants

   Closure by Dr. Takashi Iijima

   Adjourn

4. Group Photograph 14:30 - 14:45
   Place : in front of the main entrance(1F)
   (in case of rain : 1F lobby)

Closing Ceremony

1. Time
   Wednesday, December 8, 1993 (16:40 - 17:10)

2. Place
   Meeting Room (8th floor), Public Works Research Institute

3. Program
   Call to order by Mr. Masashi Taguchi, Director, General Affairs Department, Public Works Research Institute

   Closing Remarks by Mr.Shyam Khubchandani, Chief, Planning and Coordination, Research and Development Directorate, Policy and Coordination Group, Transport Canada

   Give Presents

   Closing Remarks by Dr. Takashi Iijima, Assistant Director-General, Public Works Research Institute, Ministry of Construction

   Closure by Mr. Masashi Taguchi

Schedule of the Study Tour

December 9 (Thur)	7:30	Leave Sky Hotel(TEL:0298-51-0008)
	13:20	Arrive at Kobe
		Akashi Bridge(Under Construction ; U.C)
		Maiko Tunnel(U.C)
	17:30	Arrive at Green Hill Hotel II (TEL:078-222-0909)
10 (Fri)	7:30	Leave Hotel
		Kansai International Airport(U.C)
		Traffic Control Center of Hanshin Expressway Public Corporation
		Meishin Expressway
	17:00	Arrive at Kyoto Royal Hotel(TEL:075-223-1234)
11 (Sat)		Move from Kyoto to Tokyo
	18:00	Arrive at Hotel Yaesu-Fujiya(TEL:03-3273-2111)
12 (Sun)		Departure to Canada