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TECHNICAL MEMORANDUM
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PWRI**

**The Progress of Civil Engineering and Its Contribution
to Economic and Social Development in Modern Japan**
-----PWRI's 70 Years and Perspective-----

May, 1993
PUBLIC WORKS RESEARCH INSTITUTE
MINISTRY OF CONSTRUCTION, JAPAN

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FOREWORD

The first step in the modernization of Japan was taken with the Meiji Restoration in 1968. The new government was urged to strengthen national power. It can be considered that infrastructure improvement played an important role as the basis for national construction. The government introduced advanced foreign technology, educated engineers in the field of civil engineering, promoted R&D applicable to the natural, socio-economic conditions in Japan, and carried out the development of original technology, in order to realize effective infrastructure improvement.

It is recognized that the utilization of natural and human resources, and the reformation of introduced technology to fit the natural and social conditions of the country is important. Therefore, uniquely Japanese R&D is required.

PWRI was established in 1922 as the Civil Engineering Laboratory of the Ministry of Interior, and attained its 70th year in 1992. Initial activities focused on experiments for road material. Many departments such as earthquake, river, erosion control, bridge, road, machinery, construction methods, and sewage were established one after another in accordance with the continuously changing socio-economic demands. PWRI has achieved much through R&D.

This paper describes the role of infrastructure investment in the economic growth of Japan, the history of PWRI's research and development activities concerning effective infrastructure improvement, the tendency of the economy and society in Japan, and the perspectives of PWRI's research in the near future.

Yukihiko SUMIYOSHI

Director-General

PWRI, Ministry Of Construction, Japan

Kenji SUZUKI

Planning and Administration Dept.

and

Katsura HIRABAYASHI

Planning and Administration Dept.

1 ECONOMIC GROWTH IN JAPAN AND INFRASTRUCTURE INVESTMENT

Since the Meiji Restoration (1968), the Japanese economy has been developing rapidly, especially since the end of World War 2. This is a remarkable fact in World economic history. This economic growth was often called a "Miracle recovery". Many economists have analyzed the reason for this economic growth as the success of economic policy, aggressive investment by private company, diligent Japanese character, advance of technology, and low-military spending. However, although Japanese military budgets have been smaller than those of the other advanced countries, it would be difficult to achieve such rapid growth without proper public investment. This chapter describes the role of infrastructure investment in Japanese economic growth.

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1-1 ECONOMIC GROWTH IN JAPAN AND INFRASTRUCTURE INVESTMENT

The new government of the Meiji Restoration tried to prevent invasion by Western countries through the concentration of national power in the government and by the modernization of industry. The government therefore gave first priority to railroad construction and river improvement for transportation. However, there was little technological background concerning these in Japan, therefore, engineers of western countries were invited to complete the construction. In 1873, the first railway from Shinbashi, Tokyo to Yokohama was built under the guidance of foreign engineers.

For the industrialization of Japan the government imported western technologies, for example, steel plants, machines, and steam engines. Japan has been fortunated concerning national industrialization. The Japanese government promoted the production and export of silk to prevent a species crisis through excessive imports. At that time it was usual for the Japanese economy to be in a trade deficit because of unfair customs treaties with western countries.

This industrialization necessitated a sufficient supply of energy resources. As coal mines developed in mountain areas, building of railways urged transportation of large amount of coal. It is said that the construction of a national rail network facilitated Japanese industrialization. From 1840 to 1870 the silk industry in Europe was heavily damaged by disease of silkworm. Therefore, Japan faced a boom in silk exports. A low price for silver in the period from 1885 to 1895 raised the imported goods price, and it protected domestic industries and promoted exports to the foreign countries under gold specie system. As a whole, it seem the policy for industrialization was a success.

In Japan, before the Meiji restoration, the economic center was in Osaka and the political center was in Tokyo. Therefore, the line from Tokyo to Osaka necessarily became the major traffic and communication system. In addition, because the largest coal mine was found out in northern Kyushu Island and the first steel plant was built there (1901), so the line of Tokyo-Nagoya-Osaka-Kyushu became the first land axis. The land axis had an advantage in that the pacific ocean could be used as large sea lane that connected Japan to foreign countries through its many natural harbors on Japan's pacific coast. Figure 1-1-1 shows the national land axis of industry. Expansion and development of industry concentrated along the land axis. Figure 1-1-2 shows the total distance of the railway network. In 1907 (late Meiji era) the length of railway reached up to 7,884 km, showing rapid development of Japan's railway network.

On the other hand, low water improvement for rivers to obtain river transportation did not contribute enough to flood prevention. This resulted in frequent flood disasters in agricultural areas. Therefore, the government changed the policy to high water improvement to prevent floods after realizing railway transportation has a much larger capacity than river transportation. Figure 1-1-3 shows the budget of infrastructure investments in laps of time. A victory in the Sino-Japanese War (1894-1895) generated enough money for infrastructure investment, however, the Russo-Japanese War (1902-1903) reduced the budget for infrastructure investment sharply. This is a typical example of the disadvantage of excessive military spending.

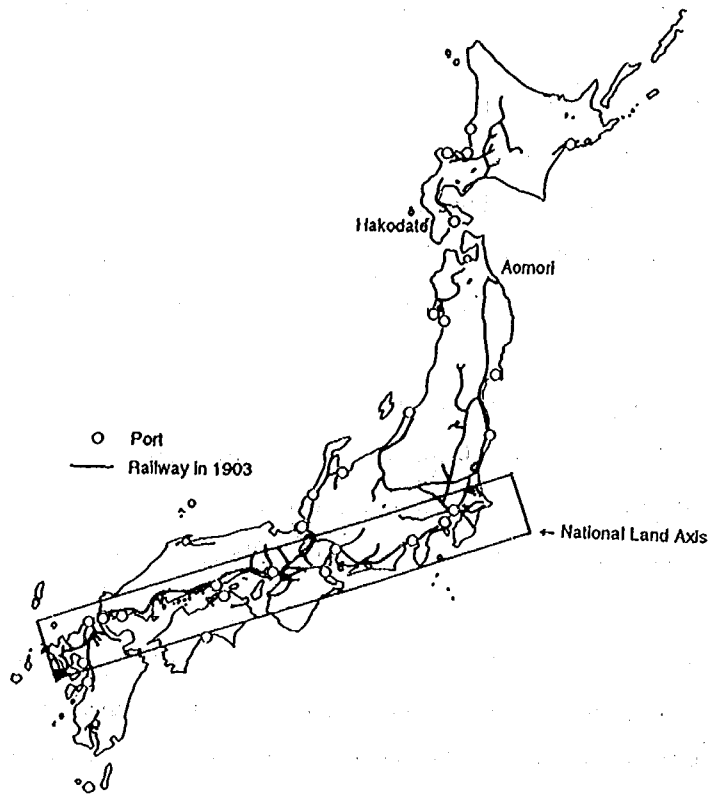


Fig. 1-1-1 Port, Railway and National Land Axis in Meiji Era.

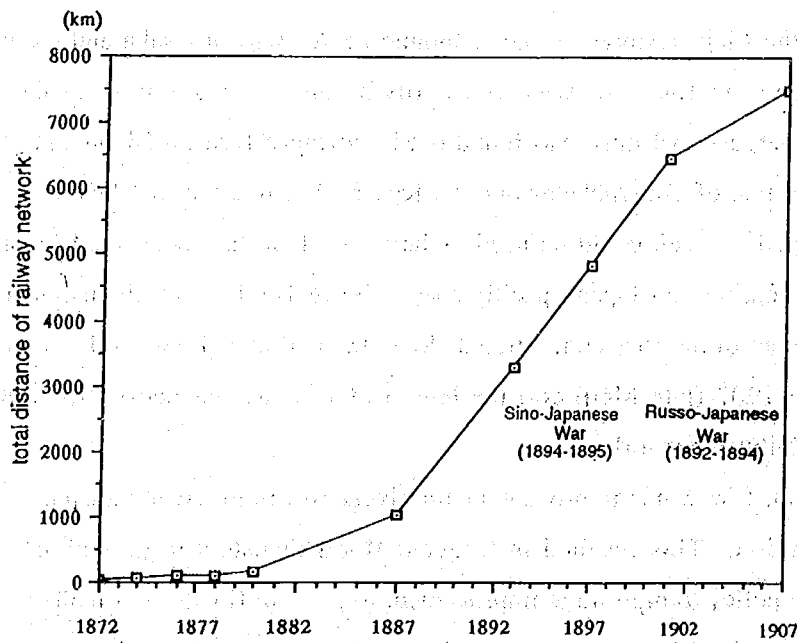


Fig. 1-1-2 Total Distance of Railway Network.

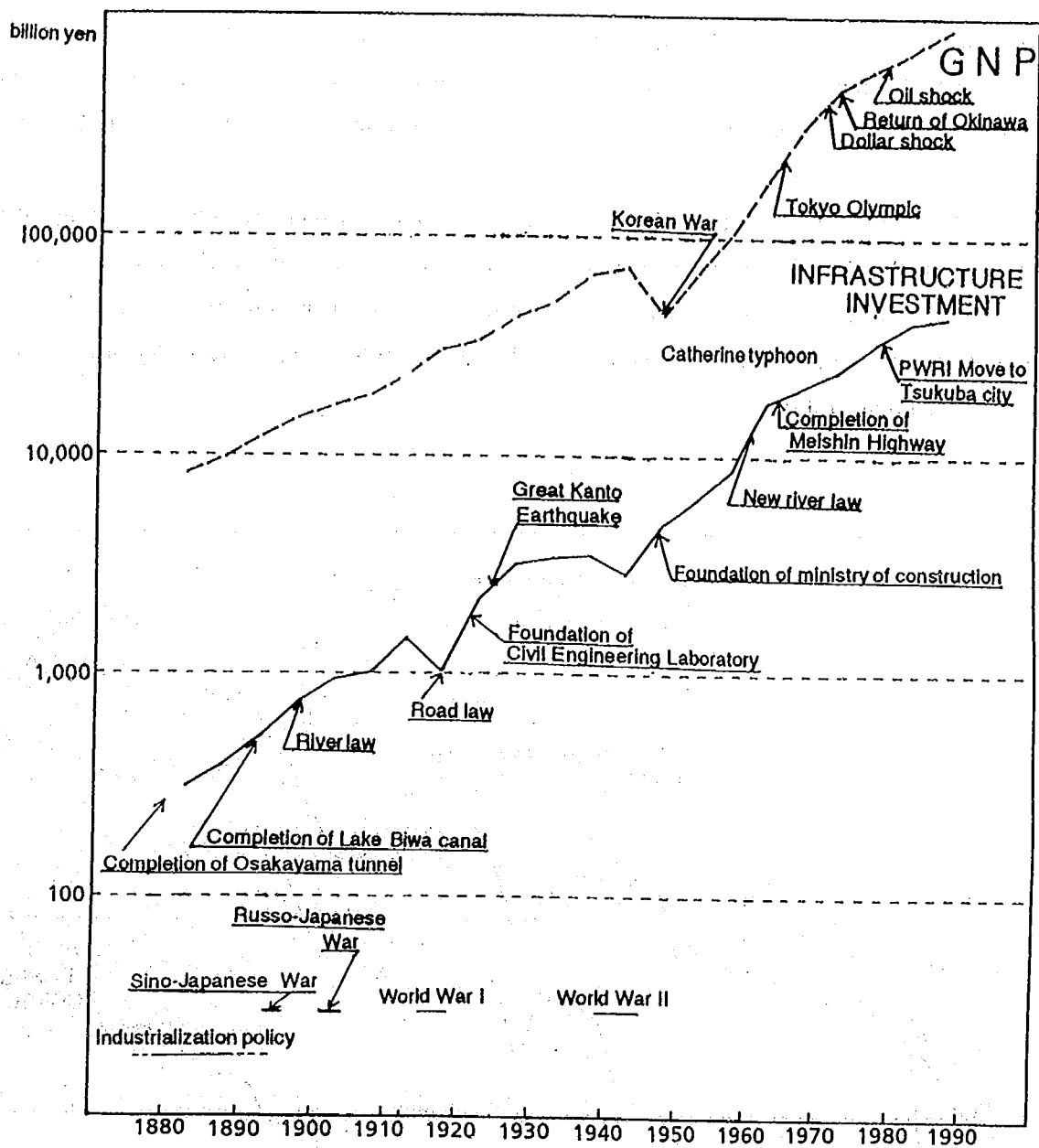


Fig. 1-1-3 Growth of GNP and Infrastructure Investment.

Another war influence on infrastructure investment can be seen in Figure 1-1-3. During World War I, the Japanese economy was thriving because of large export of war goods to western countries, however, after the war ended in 1918, a reactionary recession hit the Japanese economy for a short time.

The first Road Law of Japan was formulated in 1920. Before World War I major traffic investment of Japan had been concentrated in railway development, however, the usefulness of car traffic became apparent during the recovery from the Great Kanto Earthquake and World War I. This led to an increase in road investment and the formulation of a Road Law. Investment for road development became larger than that of railways by the 1930s.

The world economy crisis (1932) hit the Japanese economy especially in the country side where the major industry was agriculture. The national government created a countermeasure to high unemployment by applying a

large amount of investment to road and river improvement. The first Road Law, second and third Flood Control Programs formulated at that time were remarkable policies in Japanese history. However, because those programs were without any financial guarantee, they were reduced or discontinued when Japan faced the Manchurian Incident and the China Incident.

During World War II the first priority was given to the military budget. The productivity of industry became sharply smaller than that of the prewar period. Japan was often victim to flood disasters by typhoons after the end of war. The emphasis on military investment was one of the reason for the disasters. Investments on river improvement were temporarily increased just after World War II to aid in the recovery of areas affected by these disasters (see Figure 1-1-4).

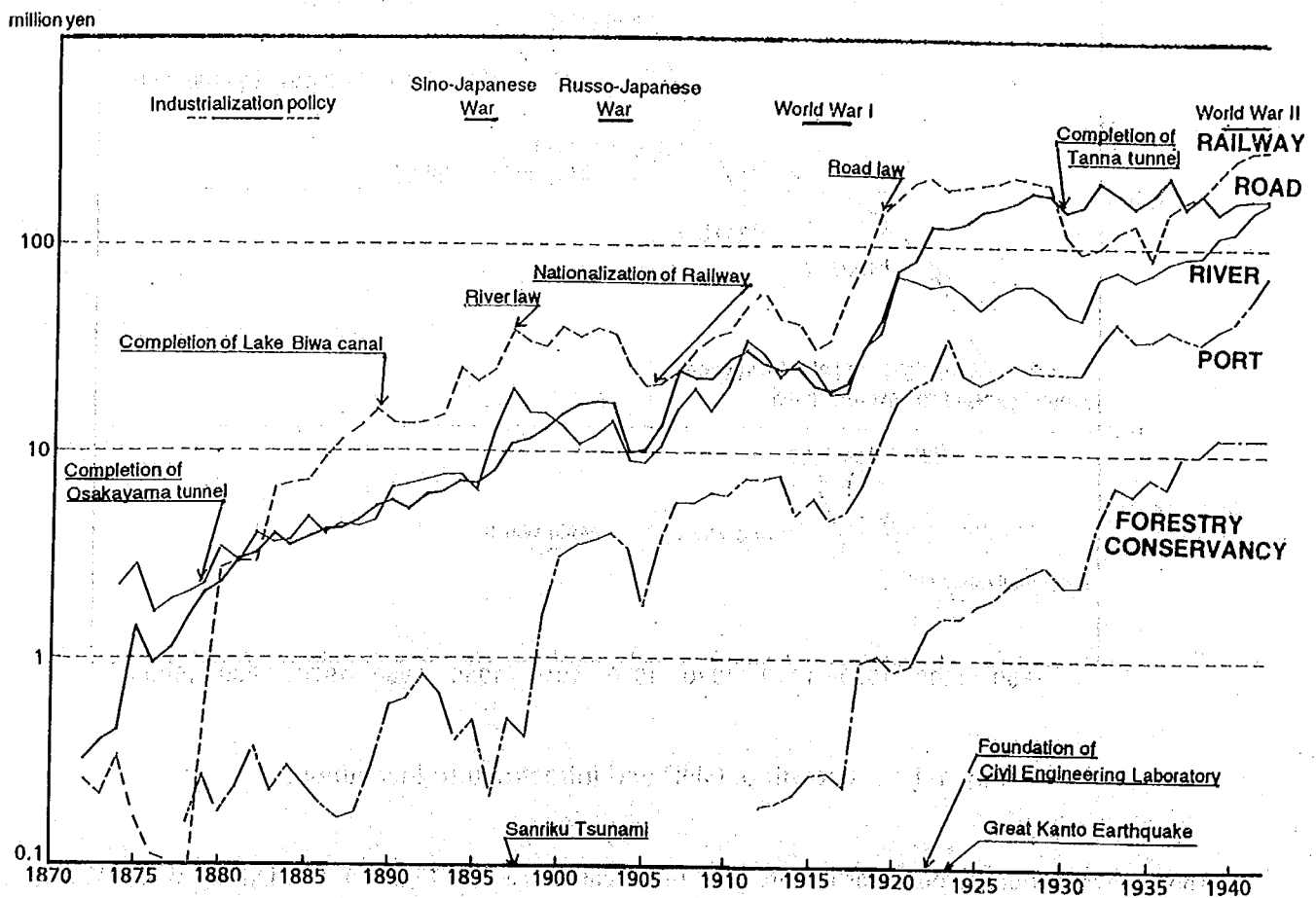


Fig. 1-1-4(a) Growth of Infrastructure Investment (before World War II).

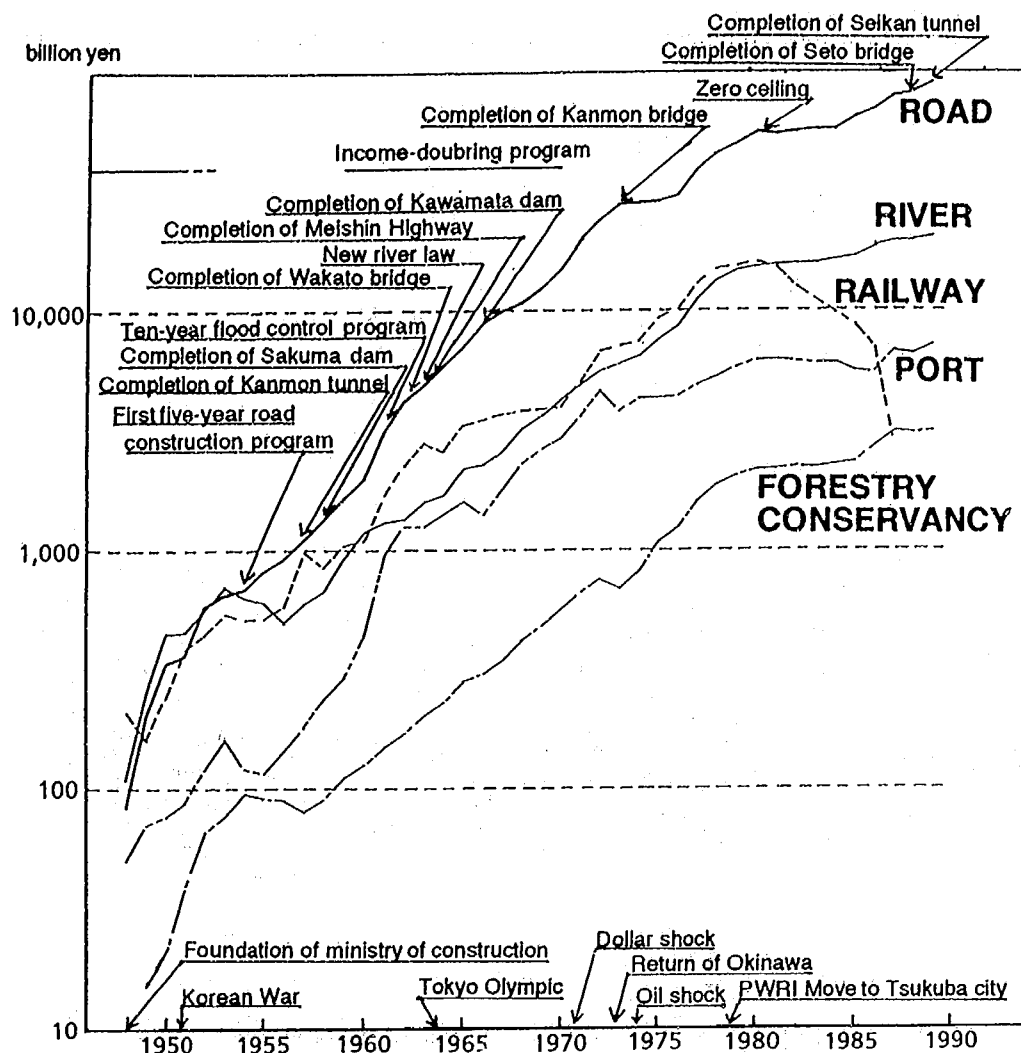


Fig. 1-1-4(b) Growth of Infrastructure Investment. (after World War II)

The turning point for the post war Japanese economy was the Korean War boom. Stimulated by the war, demand for strategic goods soared sharply in the major countries of the world, lifting the Japanese economy out of a recession into a boom. For meeting the demands created by the boom the newest type industrial facility was imported. The boom necessitated a supply of electricity to industries through the construction of a large size dam such as Sakuma Dam.

In 1954 Japan had fully recovered from the damage of the war because the GNP had reached the same level as that before the war.

The next turning point for the Japanese economy was the "Income-Doubling Program" formulated in 1960. The government developed five-year programs in infrastructure investment supported by financial laws and economic policies. These policies resulted in an average GNP growth rate of 10% in the term of 1960-1970.

It should be noted that included in this program were construction of highways and Shinkansen railway. The first five-year plan for road construction was developed in 1954, and the second was developed in 1958. The construction of expressways started in the third five-year program. Today it is planned that 14,000 km of high

graded expressway network will be completed in 2010 in the eleventh five-year plan as shown in Figure 1-1-5.

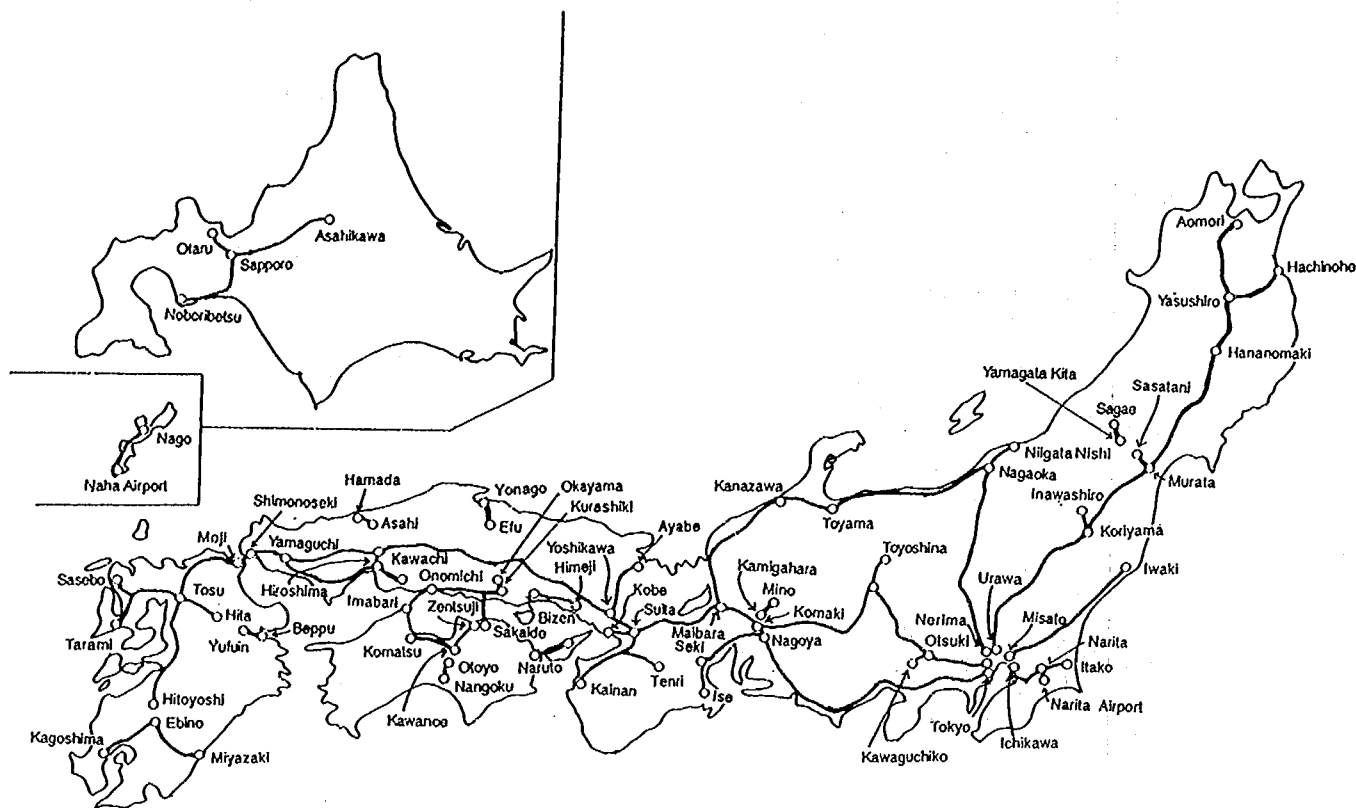


Fig. 1-1-5 High-Graded Trunk Road Network.

Before World War II, Japan developed a plan for a bullet train which would run at the speed of 200 km/h from Tokyo to Manchuria by way of the Korean peninsula. However, the project was discontinued when World War II began. This project reappeared after the war, because unexpected rapid economic growth seemed to test the capacity of the Tokaido Railway connecting Tokyo with Osaka. The Tokaido Shinkansen was completed in 1964 as the next important axis. It is recognized that this led to a trend toward fast transportation. After that, the shinkansen network reached Sanyo, Joetsu, and Tohoku district. Figure 1-1-6 shows the present shinkansen network. In addition, the reason for a sharp decrease in investment for railways, is the movement toward reconstruction of national railway organization. In 1987 Japan National Railway divided among private companies.

In 1972 Japan had the second largest GNP in the world, created by this rapid economic growth. However, a Dollar-Shock (1971) and an Oil-Shock (1973) stopped this rapid economic growth. The Japanese economics system was forced to change its structure, and the high-rise in oil prices led to a rise in market prices. The Japanese economy shifted to "stable economic growth".

Some distortion caused by this rapid economic growth was observed in the 1970s. Itai-Itai disease and Minamata disease were caused by factory waste. Opt-chemical smog was caused by air pollution in the Tokyo

area. Also urban problems were observed in this period such as an imbalance between urban areas and rural ones, traffic jams and noise excessive. After that, environmental and urban problems began to be emphasized in new project planning. For example, during the period of rapid economic growth, major river improvement projects were centered on the construction of large scale gravity concrete dam or arch dams. But these projects changed, because of a new environmental priority, to a focus on the prevention of urban river water pollution and the securing of an adequate water supply by constructing medium size dams. Today, the total length of river banks, as set by the national government is 17,094.8 km, and the total length of low depth bank protection is 3,411.9 km. Today, 81 dams are under directed administration of the national government.

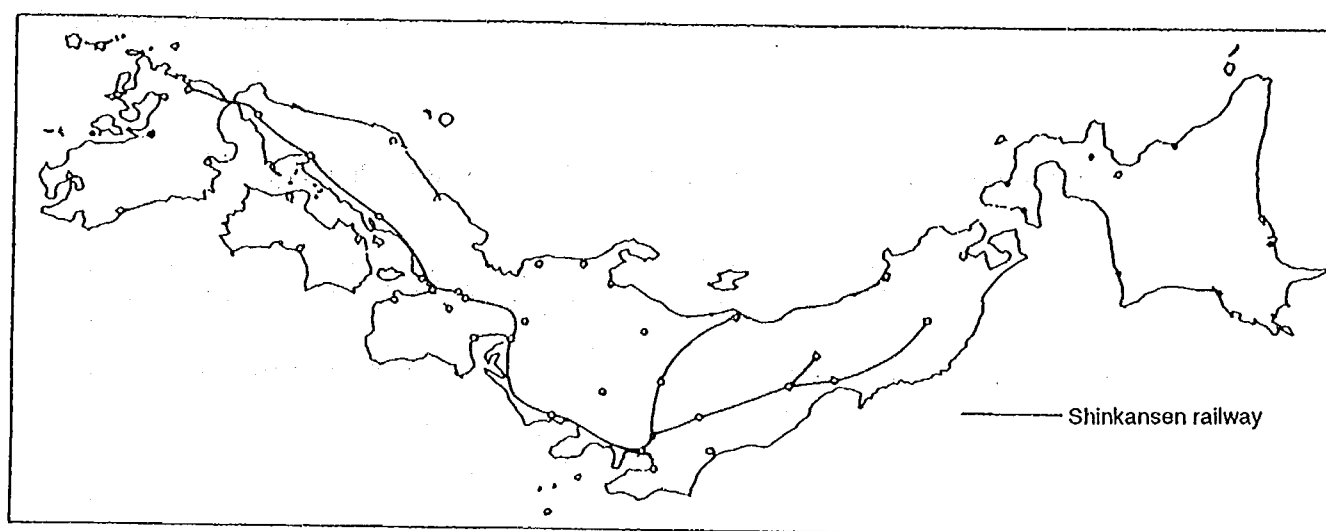


Fig. 1-1-6 Today's Shinkansen Network.

As a result of higher incomes for citizens, a demand for more comfortable living forced the government to formulate comprehensive national development projects. The first project (1961-1969) aimed to balance development on Tokyo area with development in other areas in Japan and sought to deconcentrate industry, income, population, house space, and education. The second project (1965-1980) focused on the creation of a comfortable environment. The third one (1975-1985) aimed at making a total environment for comfortable living. Forth one aimed at the creation of multi-polar national land. Table 1-1-1 shows the summary of the 4 comprehensive national development programs.

Big projects such as The Seikan Tunnel, The Honshu-Shikoku Bridges, The New Kansai Airport, The Tokyo Bay Loop Highway, shinkansen and highway networks that were planned in the period of high economic growth, are now being completed during this period of stable economic growth. Some are still under construction. Table 1-1-2 shows the outline of these projects.

During the period between 1982 to 1988 the general budget for infrastructure improvement was reduced every year, placing the task for the reconstruction of the economy under the inspection of a Temporary Administrative Committee. Only road investment was increased by an activation of a Financial Investments and

Loans System and the generation of private funds under the Toll Road System. The average ratio of increase in infrastructure investment was 1.4% in comparison with a 3.7% increase in GNP. This suggests that infrastructure improvement has not been kept up with the economical or social needs of society.

The Japanese economy during the period of 1987 to 1991 was called a "Bubble Economy" in which a low-interest financial policy caused high land values and a soaring stock market. The high land values disturbed prosperity in the market, and an increase in employment opportunity through infrastructure investment because of a high cost incurred by the location of construction sites especially in the metropolitan area. The government increased the official interest and placed controls on the trade of real estate. This policy caused a recession and discontinued many projects planned by private companies. The recession Japan is now facing is the result of these policies. This result suggests that an excessive boom or "Bubble Economy" did not present any advantages to the national economy.

Table 1-1-1(a) Comprehensive National Development Program.

	Comprehensive National Land Development Program	New Comprehensive National Land Development Program
1. Date of Formulation	Oct. 5, 1962 Cabinet Decision	May 30, 1969 Cabinet Decision
2. Project Term and Final Fiscal Year	1960 - 1970 1970	1965 - 1985 1985
3. Background	1. From Post War Reconstruction to High Economic Growth 2. Disclosure of Regional Problem 1) Problem of Megalopolis 2) Earning Differential Among Prefectures 3. Income-Doubling Program, Pacific Belt Plan	1. High Economic Growth 2. Concentration of Population and Industry in Large City 3. Earning Differential Among Prefectures 4. Effective Utilization of Resources
4. Goal	< Balanced Development > 1. Prevention of Enlargement of City and Reduction of Regional Differences 2. Effective Utilization of Natural Resources 3. Proper Regional Distribution of Capital, Labor, Technology and Resources	< Creation of Amenity > 1. Reservation of Nature 2. Expansion and Balance of Development Possibilities in Whole National Land 3. Development Considering Regional Characteristics and Utilization of National Land 4. Securing Amenity
5. Development Method	< Priority Development > 1. Deconcentration on Industry 2. Priority Development of Regional Area Connecting to Tokyo Area	< Large Projects > 1. Balancing Utility of National Land by Constructing Shinkansen and Highway Network
6. Emphasis	1. Control of Building Factories in Over Populated Area 2. Promotion of Deconcentration of Industries in Middle Size Rural Cities	1. Construction of Traffic and Communication Networks 2. Realizing the Large Project Using the Communication Network

Table 1-1-1(b) Comprehensive National Development Program.

	3rd Comprehensive National Land Development Program	4th Comprehensive National Land Development Program
1. Date of Formulation	Nov. 4, 1977 Cabinet Decision	Jun. 30, 1987 Cabinet Decision
2. Project Term and Final Fiscal Year	Expected Final Year is 1985	Expected Final Year is 2000
3. Background	1. Aiming at Stable Economic Growth 2. Promotion of Dwelling in Rural Area and Move of Industries to Rural Area 3. Regional Differential 4. Saving Energy and Resources 5. Change of People's Interest	1. Concentration of High Performance Cities and Deconcentration of Population 2. Unemployment in Regional Area 3. Technology Revolution 4. Change of Industrial Structure 5. Real Internationalization 6. Society of Aged People
4. Goal	< Amenity > 1. Presupposition of Limited Domestic Resources 2. Respect for Regionalism and Tradition 3. Accordance of Human with Nature	< Balanced National Land Development > 1. Activation of Regional Area 2. Internationalization of Cities 3. Securing Safety and High Quality Environment
5. Development Method	< Plan for Dwelling in Region > 1. Prevention of Overpopulation and Depopulation	< Plan of Communication Network > 2. Multipolarized National Land Made by Communication Network
6. Emphasis	1. Conservation of Natural Environment and Historic Monuments 2. Securing Stable People's Living 3. Creation of Amenity 4. Equal Opportunity of Education, Culture and Medical Treatment	1. Safety and Comfortable National Land 2. Regional Area with Vitality 3. Realizing Comfortable Living by Industry Development and Infrastructure Investment

In 1990, the Japan-U.S.A. Structure Impediment Initiative (S.I.I.) declared that Japanese infrastructure investment during the period of 1991 to 2000 should be 3.3 trillion dollars. That is 1.6 times that of the previous ten year period. The focus of this investment is on raising the standard of living by construction of sewerage systems, city parks, road and river improvement projects.

At present the Japanese economy is in a recovery from the "Burst Bubble". The new policy of the national economy is the enhancement of public and citizen comfort.

Table 1-1-2 Big Projects.

BIG PROJECT	OUTLINE	EXPECTING EFFECTS
Tokyo Bay Ring Highway	Seashore highways and Trans-Tokyo Bay Highway	Disappear of traffic jam in Tokyo Direct connection from Chiba pref. to Kanagawa Pref.
Kansai International Airport	24 hours international airport off Senshu in Osaka Bay	Internal connection
Honshu-Shikoku Bridges	3 routes of Kojima-Sakaide Kobe-Naruto, and Onomichi-Imabari	Birth of A Inland Sea Culture and Economic Zone
Selkan Tunnel	Undersea Tunnel from Tsugaru to Oshima Shinkansen will run through.	Activation of Selkan Area
Tohoku Shinkansen	From Tokyo to Aomori. This will be connected to Selkan Tunnel.	Promotion of the industrialization in Tohoku Region
Joetsu Shinkansen	From Tokyo to Japan Sea coasts	Promotion of the economic growth in Japan Sea Area
Kan-Etsu Expressway	From Tokyo to Japan Sea coasts	Promotion of the economic growth in Japan Sea Area /Secure of the transportation in the heavy snow belt in Japan Sea coasts
Tohoku Expressway	From Tokyo to Aomori	Promotion of the economic growth in Tohoku Region

1-2 THE ROLE OF INFRASTRUCTURE INVESTMENT

Infrastructure investment stimulates the growth of the economy directly and indirectly. This section describes the effects of infrastructure investment such as the economic effects, disaster prevention, the triggering of economic growth, and energy consumption.

1-2-1 The Relation between GNP and Infrastructure Investment

Figure 1-1-3 shows the relation between GNP and infrastructure investment. The average growth rate was 3.5 % before World War II(1880-1944) and the ratio of infrastructure investment to GNP was 2,8 %. On the other hand, these indices after the war(1945-1989) were 7.7% and 5.2% respectively. These indices suggest that infrastructure investment has a strong correlation with GNP.

1-2-2 Economic Effect of Infrastructure Investment

1)ROAD IMPROVEMENT

As an example, the effect of road construction on the economy is examined in this section. Direct economic effects of road construction are as follows;

- High mileage for car
- Shortened travel time
- Rationalization of transportation, and an advance in productive efficiency
- Increase of GNP
- Increase of tax and employment opportunities, and lower prices for goods

Figure 1-2-1 shows a simulation of the economic effects of the 10th Five-year Road Improvement Program.

The simulated model shows the expectancy of a stock effect of 48 trillion yen (436 billion dollars, $\text{\$/¥}=110$) and flow effect of 111 trillion yen (1.0 trillion dollars) as created by 51.7 trillion yen (470 billion dollars) in investment.

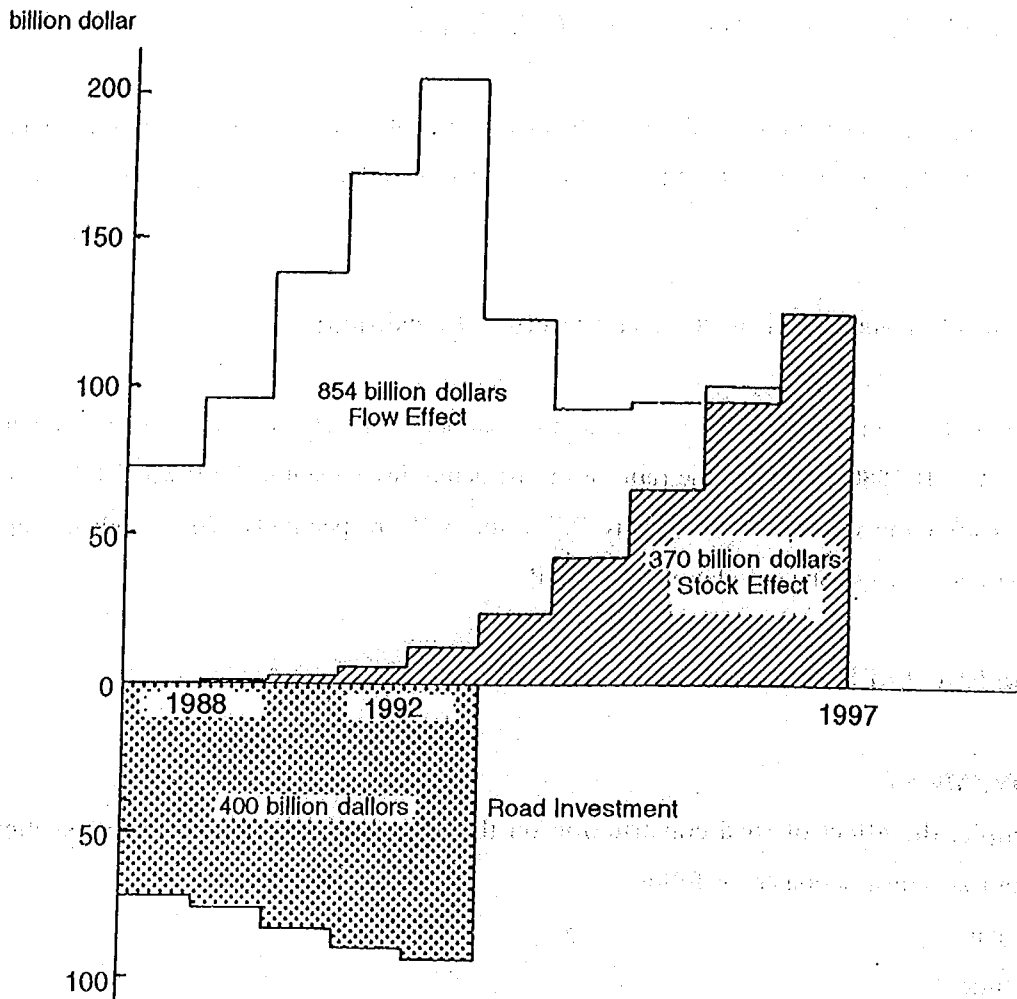


Fig. 1-2-1 Growth of GNP through 10th Five-Year Road Improvement Program.

2) INFRASTRUCTURE INVESTMENT AND DISASTER PREVENTION

Reducing losses incurred by floods in order to protect a loss of economic activity is one of the most important purposes of river improvement. Figure 1-2-2 shows the ratio between the cost of damage due to a disaster and the GNP in the period between the end of war to the present. It is clear that the losses due to disaster have been reduced by infrastructure investment. It is definite that a 10 % disaster rate just after the war was reduced to less than 1.0 % after 1965 by construction of large size dam and river improvement projects as shown in Figure 1-2-2.

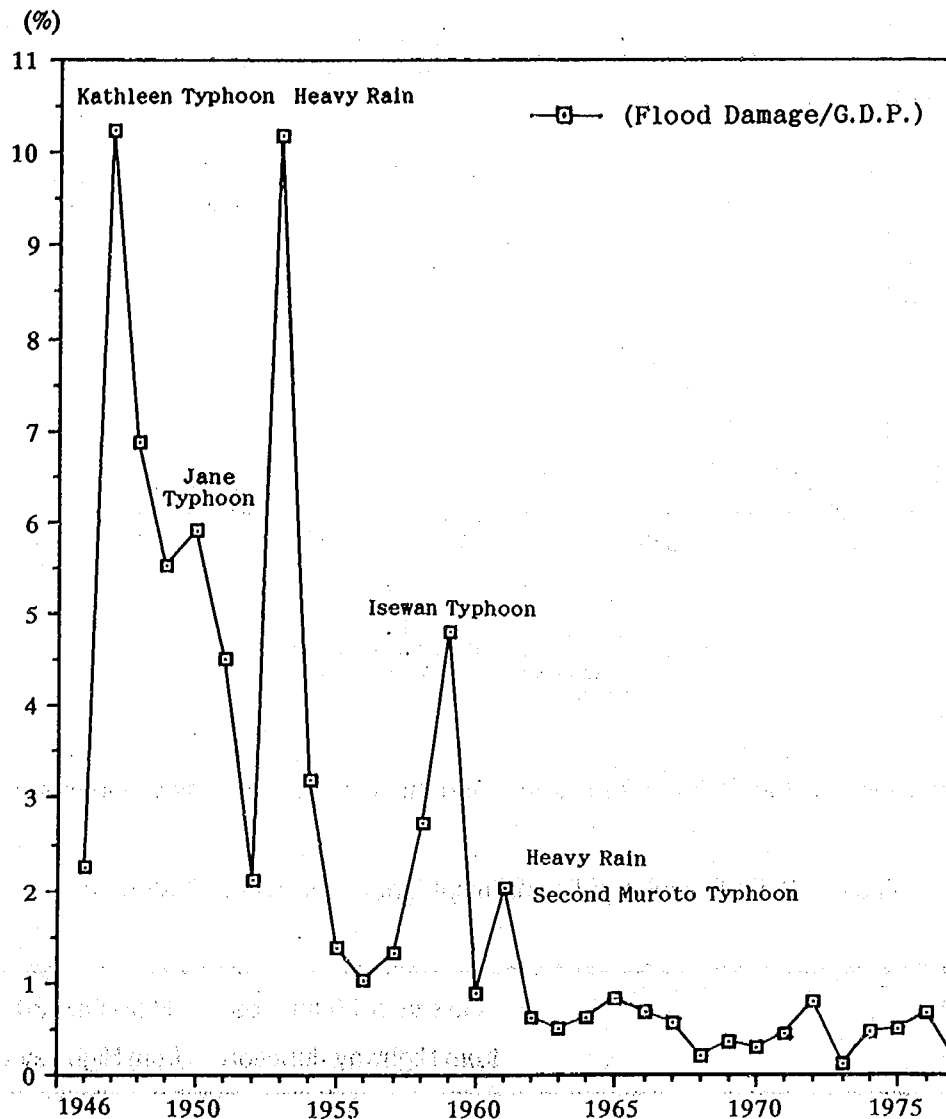


Fig. 1-2-2 Fluctuation of Damage/G.D.P.

3) TRIGGERING OF ECONOMIC GROWTH

A trigger effect for economic growth is caused by infrastructure investment. This is explained the population change, and production change on the area adjacent to the Tohoku Expressway.

Iwate prefecture was one of the most underdeveloped prefectures in Japan. A low labour price led to the movement of industry into this area after the construction of the expressway in the district. Figure 1-2-3 shows the population growth in Iwate prefecture's cities along the expressway. The population growth rate in this area reached up to 21 % during the last twenty years which is larger than that of the Japanese average rate of 18 %.

Table 1-2-1 shows the comparison of income, manufacturing production and sales volume between remote areas (more than 30 min.) and adjacent areas (within 30 min.) of an expressway interchange. It indicates that the completion of the highway contributed to increase in these economic indices.

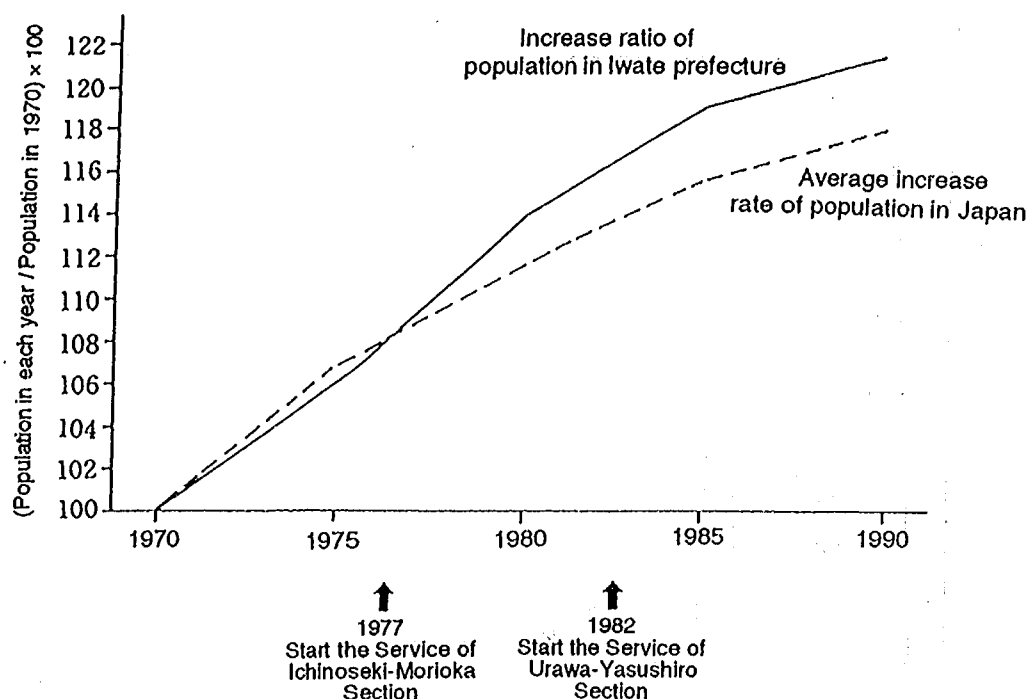


Fig. 1-2-3 Increase in Population in the Area along the Tohoku Expressway in Iwate Prefecture.

Table 1-2-1 Social and Economical Indexes in Iwate Prefecture.

		Less than 30 minites from Highway Junction	More than 30 minites from Highway Junction
Increase of Population	(1985/1980)	3.7 %	0.9 %
Increase of Income	(1984/1979)	44.6 %	37.8 %
Manufacturing Production	(1985/1980)	38.5 %	31.0 %
Sales Volume	(1985/1980)	48.4 %	42.1 %

4) INFRASTRUCTURE INVESTMENT AND ENERGY CONSUMPTION

It is likely that energy consumption is proportional to the growth rate of GNP. Japan's rate of energy consumption is the most efficient among advanced countries in the world.

Figure 1-2-4 shows the relation between the growth of GNP and energy consumption in Japan. The vertical axis shows the ratio between energy consumption of each year and that of 1970, and shows the ratio between the GNP of each year and that of 1970. This figure shows that energy consumption of Japan did not increase after 1975. The following are considered to be the causes of the decline or stabilization shown in Figure 1-2-4;

(1) Efficiency of plant power sources and therefore, increased production has raised the GNP.

- (2) Growth of the information and communication industry reduced energy consumption. Those industries can raise the GNP without increasing energy consumption.
- (3) The construction of highways and shinkansen railways reduced energy consumption.

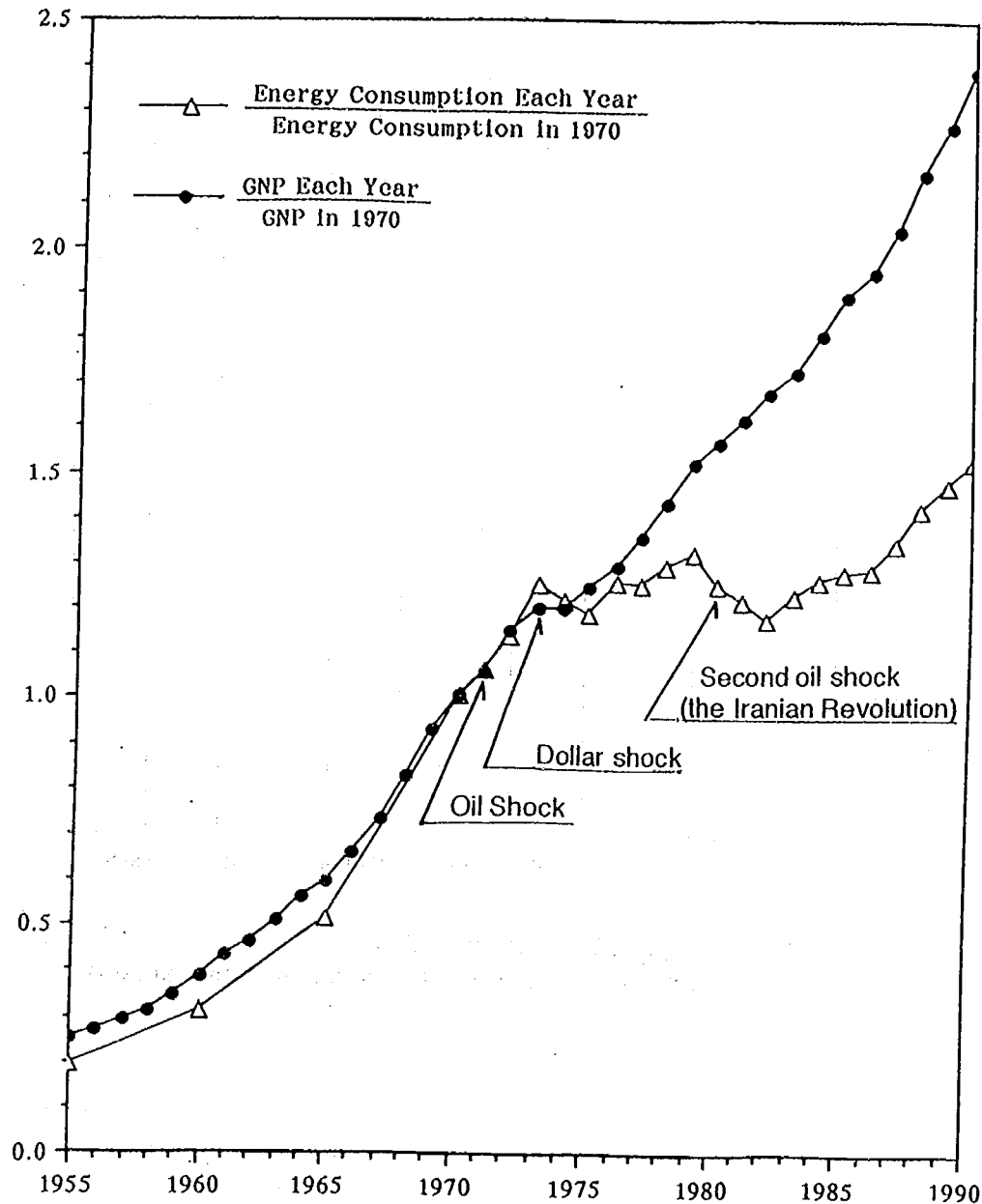


Fig. 1-2-4 Increase in Energy Consumption and GNP.

Typical examples can be shown in Table 1-2-2 and Figure 1-2-5. Table 1-2-2 shows the effects of such a bypass on mileage and emission of CO₂. Figure 1-2-5 shows the mileage improvement resulting from the reform of intersection. It can be seen that road improvement reduces not only the energy consumption but also environmental problems. In addition, the problem that energy consumption has been increasing with the growth of GNP after 1982, must be analyzed carefully.

Table 1-2-2 Suppositive Data on Mileage before and after Complation of a Bypass Improvement.

	Fuel saving by bypass construction (ml/km)	Cut weight of CO ₂ emission (g/km)	Cut rate of CO ₂ emission (%)
Passenger car	19	45	18
Small truck	36	85	24

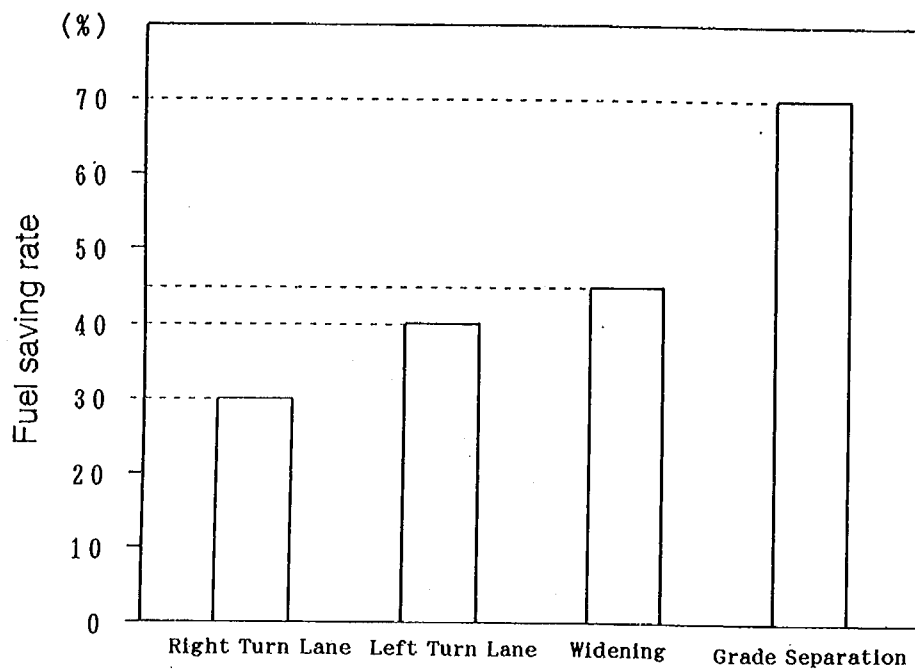


Fig. 1-2-5 Suppositive Data on Mileage.
(using 16 examples of intersection improvement)

2 ADVANCES IN CIVIL ENGINEERING TECHNOLOGY

It is thought that there are three factors in the development of civil engineering technology. They are research and development, technological education and the financial aspects supporting the investment. Each factor as it has developed in Japan is presented in this chapter.

2-1 ADVANCES IN CIVIL ENGINEERING TECHNOLOGY

The advancement of civil engineering technology can be divided into the following five stages.

- 1) Introduction of foreign technology by invited foreign engineers (1868-1887).
- 2) Reform of the imported technology by Japanese engineers educated in foreign countries (1888-1911).
- 3) Technological stagnation (1912-1945)
- 4) Introduction of Foreign Technology (1946-1964)
- 5) Development of original technology (1965-Present)

2-1-1 Introduction of Foreign Technology by Invited Foreign Engineers

Before the Meiji era Japan already possessed technology related to tunnel, bridge, and dam construction and bank protection work. However, Japanese technology was not designed for large size structures but only for small size structures meant for traffic or travel on foot or by horses. Therefore, building infrastructure necessitated the import of foreign technology by means of inviting foreign engineers with exceptional salary.

In railway areas, E. Morell for the national railway, J. Crowford of the U.S.A. for the Hokkaido railway, H. Rumuschöttel of German for the Kyushu railway were invited. These engineers did everything concerned with railway construction such as surveying, design and supervising of construction work. In river, lake and offshore improvement areas C.J. Van Doorn, I.A. Lindow, G.A. Escher, A.H. Thissen, J. De Rijke, of Holland and H.S. Palmer of England were invited. Table 2-1-1 shows the foreign engineers and their construction work.

Table 2-1-1 Invited Engineer and Main Work

FIELD	INVITED ENGINEER	MAIN WORK
RAILWAY	E. Morell (U.K.)	Shinbashi-Yokohama Railway
	E. J. England (U.K.)	Osaka-Kobe Railway
	R. V. Boyle (U.K.)	Nakasendo Railway
	J. Crowford (U.S.A.)	Sapporo Railway network
	H. Rumschoettel (Germany)	Kyusyu Railway network
BRIDGE	Vogel (Holland)	Kurogane Bridge
	Branton (U.K.)	Yoshida Bridge
	N. W. Hilt (U.S.A.)	Toyohira Bridge
	Paul, White (U.K.)	Mukogawa Bridge
	C. A. W. Pownall (U.K.)	Tone and Ara River Bridges
DAM	W. K. Burton (U.K.)	Nunobiki Dam
TUNNEL	E. J. England (U.K.)	Ishiyagawa Tunnel
	J. Diack (U.K.)	Sumiyoshigawa Tunnel
	T. Gray (U.K.)	Ashiyagawa Tunnel
RIVER & HARBOUR	C. J. V. Doorn (Holland)	Tone River, Yodo River Asaka Irrigation
	Doorn	
	J. De Rijke (Holland)	Osaka Harbour, Yodo River
	Tuischen (Holland)	
	De Rijke	Kiso 3 Rivers
	G. A. Escher (Holland)	Yodo River
WATER WORKS	H. L. R. Mulder (Holland)	Tone Canal
	I. A. Lindow (Holland)	Shinano River
	H. S. Palmer (U.K.)	Yokohama Water Works

2-1-2 Reform of the Imported Technology by Japanese Engineer Educated in Foreign Countries.

In the 1880s, Japanese engineers who were educated by foreign engineers or in foreign countries began to design and direct construction. Table 2-1-2 shows invited foreign engineers and the Japanese engineers educated by them.

Table 2-1-2 Foreign Engineer, Japanese Engineer, and Their Pupils

MASTER	PUPIL	MAIN WORK
J.De Rijke(Holland)	T.Okino(studied in France)	Improvement of Yodo River, Osaka Port
J.De Rijke(Holland)	H.Saeki(studied at College of Engineering)	Improvement of Kiso River lower reach
G.A.Escher / J.De Rijke (Holland)	K.Furuichi(studied in France)	construction of Sakaide Port
V.Doorn(Holland)	I.Minami	Asaka Canal
H.S.Palmer(U.K.)	Y.Mikuni(studied in the U.K.)	construction of Yokohama Port
T.R.Sharbrington/E.Holsam (U.K.)	24 graduates of the College of Training Engineer	construction of railways
M.Inoue(studied in the U.K.)	Y.Kunisawa(a graduate of the College of Training Engineer	Osakayama Tunnel

Construction projects, in which the Japanese method of implementation and the European method of survey and planning were combined, triggered the reformation of introduced techniques from foreign countries. Example construction exercises were conducted at the Osakayama Tunnel and at Lake Biwa Canal.

1)OSAKAYAMA TUNNEL

Osakayama Tunnel was the first one built by Japanese engineers (l=664.8m). Figure 2-1-1 shows the entrance of the Osakayama Tunnel. The director for this construction was N. Kunisawa who graduated from the College of Training Engineer, established by M. Inoue, in Osaka. He used a Japanese original construction method, which utilized man power by using only a chisel, and a mandril. The reason was why there were many skilled workers in gold mines at that time. Kunisawa was able to use them for the construction at a low labor cost. A Western style was used for the floor. The tunnel floor was made of blocks and powder was used to destroy hard rocks. So it is said that the tunnel was completed only in 20 months by a combination of a Japanese traditional method and some Western technology.

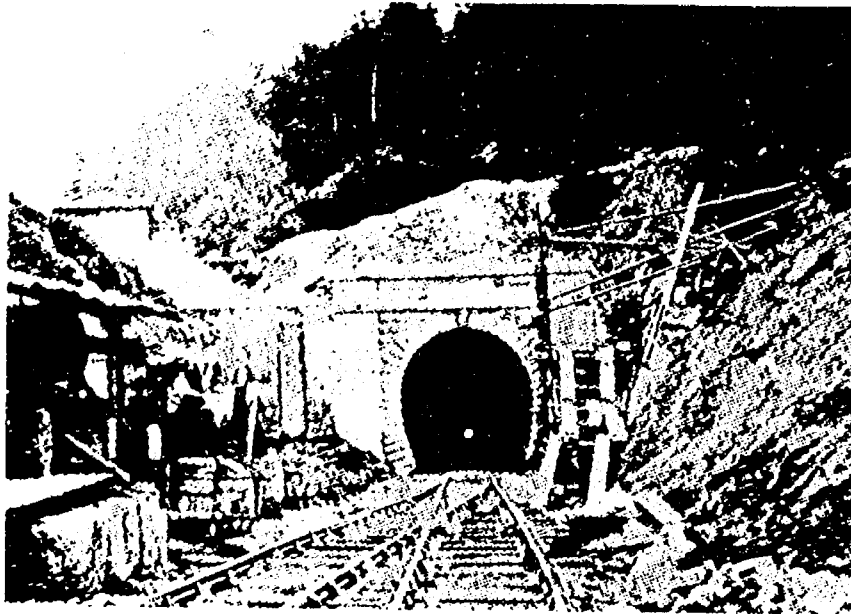


Fig. 2-1-1 Osakayama Tunnel.

2) LAKE BIWA CANAL

Lake Biwa Canal was the first big, multi-purposed project in Japan. The general purpose of the Lake Biwa Canal was the modernization of Kyoto City as one of the most historic cities in Japan. This modernization policy was to be achieved by the first generation of electricity, and a water supply and boat transportation link from Osaka City to Lake Biwa by construction of a water channel from Lake Biwa to Kyoto City with a distance of 20km. S. Tanabe, who graduated from the College of Engineering(now Eng. Dept. Tokyo Univ.), conducted the work. One-third of the total length of the channel was tunnel work. He used the newest technology such as a dynamite with detonator, a ventilation system and a water pump powered by a steam engine. Also the introduction of the shaft method should be noted. Figure 2-1-2 shows the entrance of No.1 tunnel.

The first hydraulic power generator developed by this project supported the first street car network in Kyoto City. In addition, it triggered a labor market for light industry in Kyoto City. It should be noted that the power plant built at that time is still in use.

The Development project for Lake Biwa is currently under construction. The newest project is the Lake Biwa Comprehensive Development Project which started and has continued since 1972. This project reflected the following indices.

- (1) environmental protection: improvement of the sewage systems, parks, port, roads, and construction of facilities for livestock, and for garbage disposal
- (2) flood protection: improvement of rivers emptying into Lake Biwa, construction of a dam, and sabo work
- (3) water supply: improvement of water supply systems for drinking water and for industry, improvement of facilities for fisheries and agriculture



Fig. 2-1-2 Lake Biwa Canal.

2-1-3 Technology Stagnation

The largest project in the period between the late Meiji Era and World War II was Kanmon Tunnel. Many methods to connect Honshu with Kyushu were examined before the tunnel was constructed. Technology in both road and railway development was investigated. The tunnel method was finally selected because a bridge would obstruct the passage of battleships and become a bombing target.

The government supported and accelerated the construction of the Kanmon Railway Tunnels (a upline and a downline), because the government considered that the railway was better for military transportation than road ways. Development plans for the Kanmon Railway Tunnels started in 1936 and was completed in 1944. The total length of the upline is 3604m, including 1322m undersea, and the total length of the downline is 3614m, including 1322m undersea.

Construction of the Kanmon Road Tunnel started in 1939, but budget restraints and a shortage of construction materials in World War II period obstructed the completion. After World War II the construction continued slowly with little prospect of completion because of objection to the plan from government side. But a Toll Road System, which was established in 1952, changed the situation. Regulation of the appropriation of toll fees for construction gave the financial guarantee to the project. The construction work began again in 1952 and finished in 1958. The tunnel has a length of 3461m, including 780m undersea (see figure 2-1-3).

In the period from the Taisho Era to the early Showa Era there was a technology stagnation. The reason for this stagnation was seen to be the priority given to military spending in the budget and a recession forced concerns away from new technology in civil engineering.

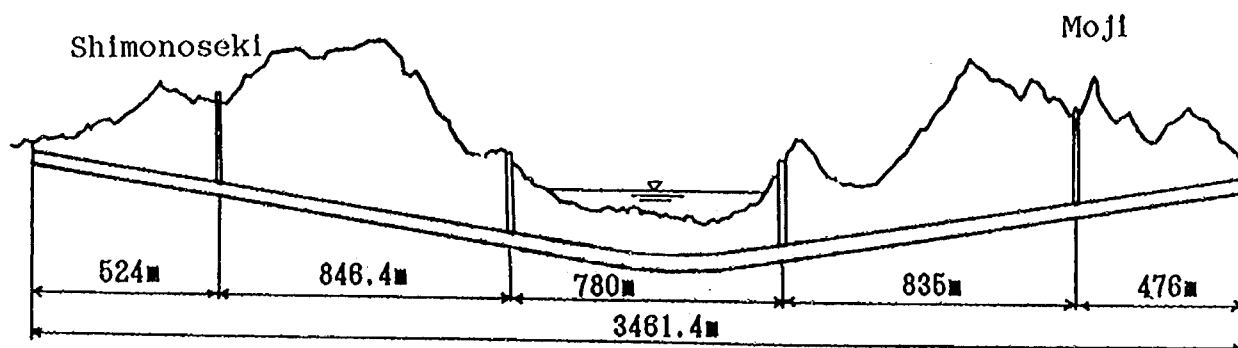


Fig. 2-1-3 Vertical Section of Kanmon Tunnel

2-1-4 Introduction of Foreign Technology

Japan's technology has made rapid progress after World War II. The rapid economic growth in the 1950s necessitated large scale constructions of tunnel, dam and bridges. Imported foreign technologies influenced to these large constructions after World War II. The rapid economic growth presented chance of the adjust of imported technology to Japanese conditions of nature, economy and society. These adjustment has led Japan to be one of the most advanced nation of the world in civil engineering technology. Sakuma Dam and Wakato Bridge are remarkable projects.

1)SAKUMA DAM

American technology for construction machines surprisingly changed the Japanese construction process. Sakuma Dam 150 m in height, was completed in only 28 months. Figure 2-1-4 shows the view of Sakuma Dam. The shortening of construction time was enormous given that the term was almost half compared with past experience. Power shovels, damp trucks and bulldozers reduced the required period of time. Construction of Sakuma Dam is recognized as the beginning of the use of construction machine in Japan.

2)WAKATO BRIDGE

Wakato Bridge completed in 1958 is the first long suspension bridge in Japan with a span of 367 meters (see figure 2-1-5). Therefore, there were many obstacles during the preparation for construction. Basic suspension bridge technology was imported from western countries, but the ideas of measures against typhoons and earthquakes were not in use there. In order to overcome these difficulties all the brain power in Japan was mobilized for field surveys in weather and geology, the development of steel cable, rust proofing, wind tunnel simulation and durability for earthquake. The surveys spent long time of two and half year. All materials used for this bridge were made in Japan. The completion of this project provided confidence to Japanese engineers and researchers. Design and construction of this bridge formed the technological basis for long span suspension bridges of Japan.

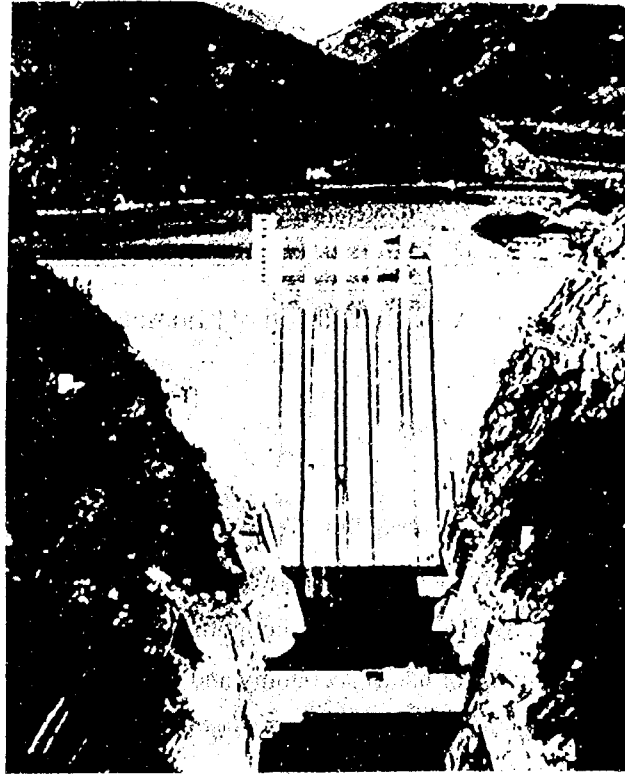


Fig. 2-1-4 Sakuma Dam.

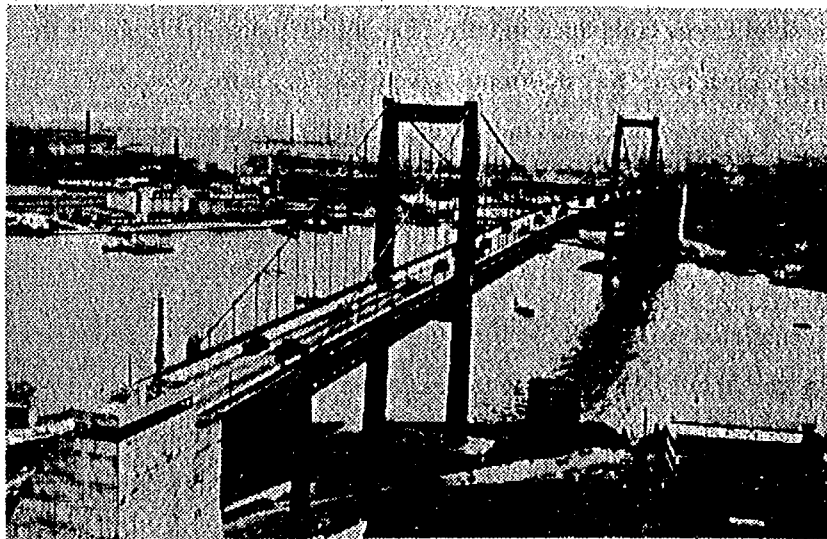


Fig. 2-1-5 Wakato Bridge.

2-1-5 Original Technology

Japanese original technology for large size structures developed in the late 1970s. This original technology concerning survey, planning, and construction were supported not only by R&D activities in the construction industry but also by other basic industries such as steel, machines and computers. Kawamata Dam, Kanmon Narrow Bridge, Shimajigawa Dam, Seikan Tunnel and Honshu-Shikoku Bridges utilized this original technology.

1) KAWAMATA DAM

The Kawamata Dam was built at the Seto Gorge of Kinu River in 1966, for the purpose of flood control, irrigation, and electric generation. This dam was 117 meter height, 130 meter long with flat arching shape (see figure 2-1-6). Collapse of the Malpasset Dam focused attention on the disposal of base rock at that time. Therefore, On planning the Kawamata Dam, the curvature of the arch was made smaller in order to reduce stress on the base rock plate. From this experience flat arch dam method exported to foreign countries. It was recognized that the dam construction technique in Japan become one of the best in the world by the time the Kawamata Dam was constructed.

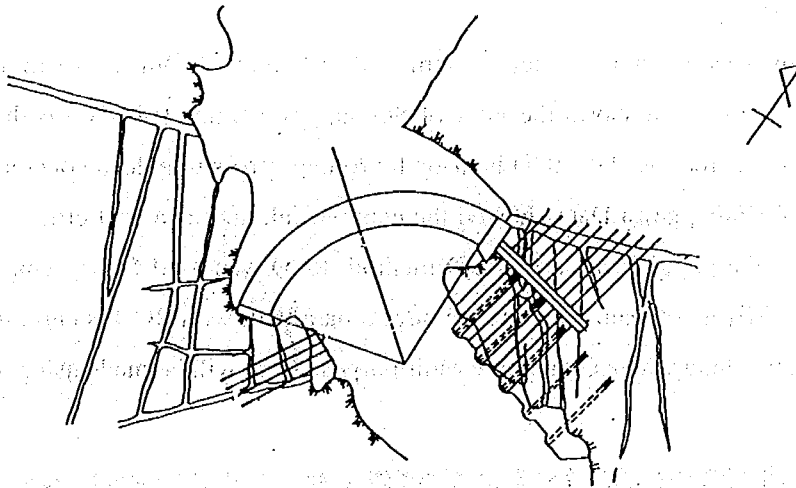


Fig. 2-1-6 Plan of Kawamata Dam

2) KANMON NARROW BRIDGE

The Kanmon Narrow Bridge connecting Shimonoseki City on Honshu Island to Moji City on Kyushu Island was completed in 1973 with a span of 712 meters in length. A expressway with 6 trucks is on it. The construction methods for the substructure was the spread foundation method for Shimonoseki side and the pneumatic caisson method for Moji side. Technological basis for the Kanmon Bridge had been perfected during the construction of the Wakato Bridge (1958). In addition to the basic technology, a pre-fabric parallel wire strand and a special connecting method for girder erection, developed for the Honshu-Shikoku Bridges were applied to this bridge construction. Figure 2-1-7 shows the view of a strand erection.

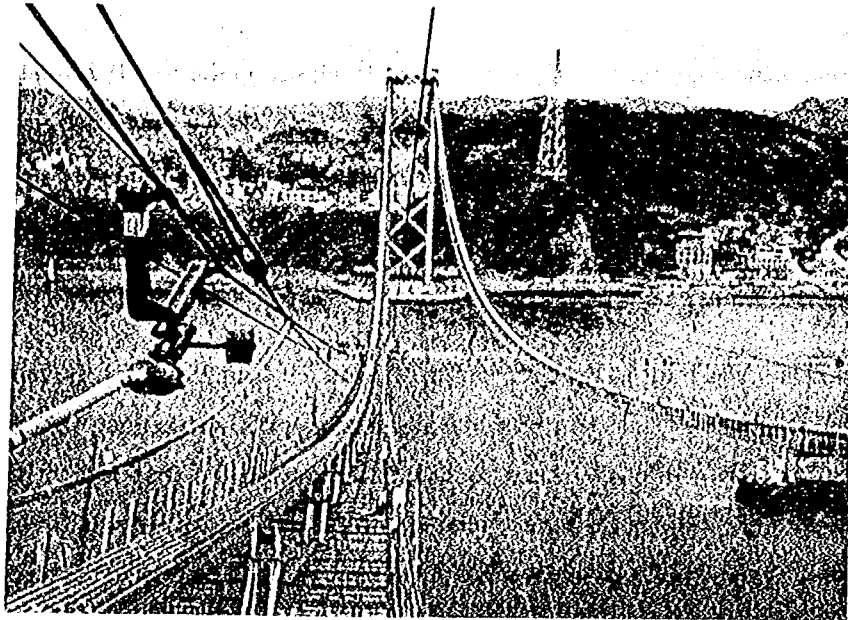


Fig. 2-1-7 Settlement of Cable Strand (Kanmon Bridge).

3)SHIMAJIGAWA DAM

Shimajigawa Dam was a gravity concrete dam with a height of 89m at a tributary of Saba River in Yamaguchi Prefecture. Figure 2-1-8 shows the view of Shimajigawa Dam. This dam is the first dam built using Roller Compacted Dams concrete (RCD). RCD is made by rolling zero-slump lean concrete into the construction site. The construction of Shimajigawa Dam showed the economical, and technical efficiency of RCD method. It became the beginning of the popularization of RCD method. RCD was used for the construction of Tamagawa Dam and Nunome Dam. Miyagase Dam which is the largest dam built with RCD is currently under construction. RCD has been exported to China where Guanyinge Multipurpose Dam will be made using the RCD method.

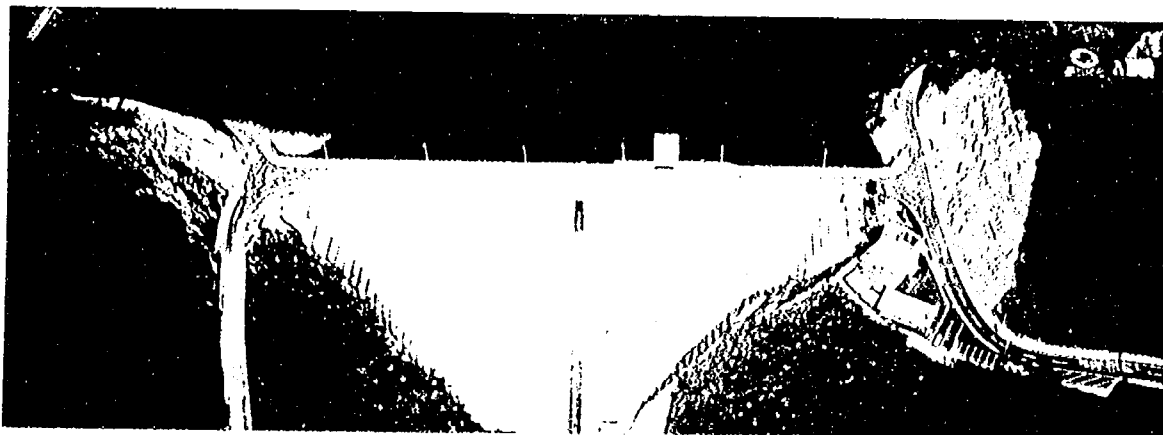


Fig. 2-1-8 Shimajigawa Dam

4)SEIAN TUNNEL

The Seikan Tunnel is the longest undersea tunnel in the world. This tunnel was first planned before World War II. The construction started in 1964, and was completed in 1985. It has a length of 54km, including a 23.3km undersea part. The track was regulated for a shinkansen railway for future construction of such a railway. The implementation faced difficulties mainly with seawater seepage at the maximum depth of 140m from sea surface, and 100m from the sea bed. New technology developed during the construction of the Seikan Tunnel included methods for measurements on the sea surface, long distance horizontal boring, hardening of soft rock plates by injection of cement milk, concrete blasting and tunnel boring machines. Some of these new technologies were applied to the Dover Strait Tunnel. Figure 2-1-9 shows the longitudinal cross section of the Seikan Tunnel.

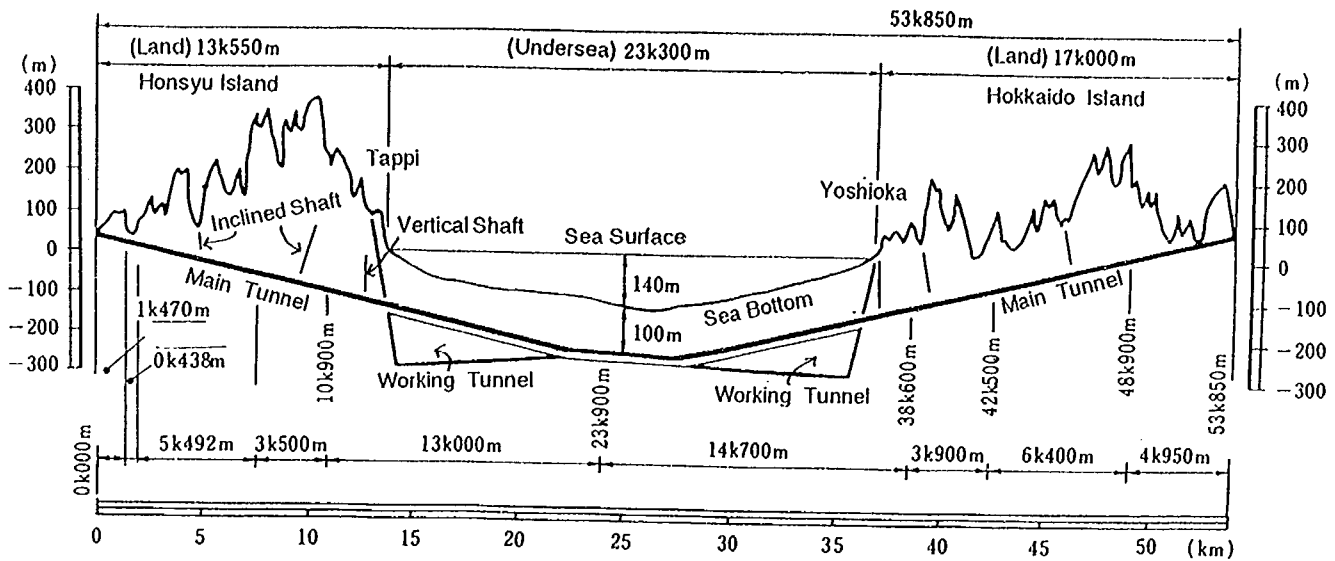


Fig. 2-1-9 Vertical Section and Plan View of Seikan Tunnel.

5)HONSHU-SHIKOKU BRIDGES

Honshu-Shikoku Bridge Project aims to connect Honshu Island and Shikoku Island by way of many bridges. The Honshu-Shikoku Bridges have three routes. Among the three routes the Kojima-Sakaide route was completed in 1988(see figure 2-1-10). Designs for these bridges are made by field surveys and analyses of earthquakes, typhoons and tides. Many new technology were applied in the bridge. Pre-fabric caissons shortened the construction time. Multi-column foundations were invented as the countermeasure to a high ocean current. Long block realized the collective erection by uniting technology of base ships and cranes. Parallel strand cable method and air suspension cable method increased the strength and shorten the construction time.

The Akashi Narow Bridge which will be completed in 1998 has span length of 1990m, and is the longest suspension bridge in the world.

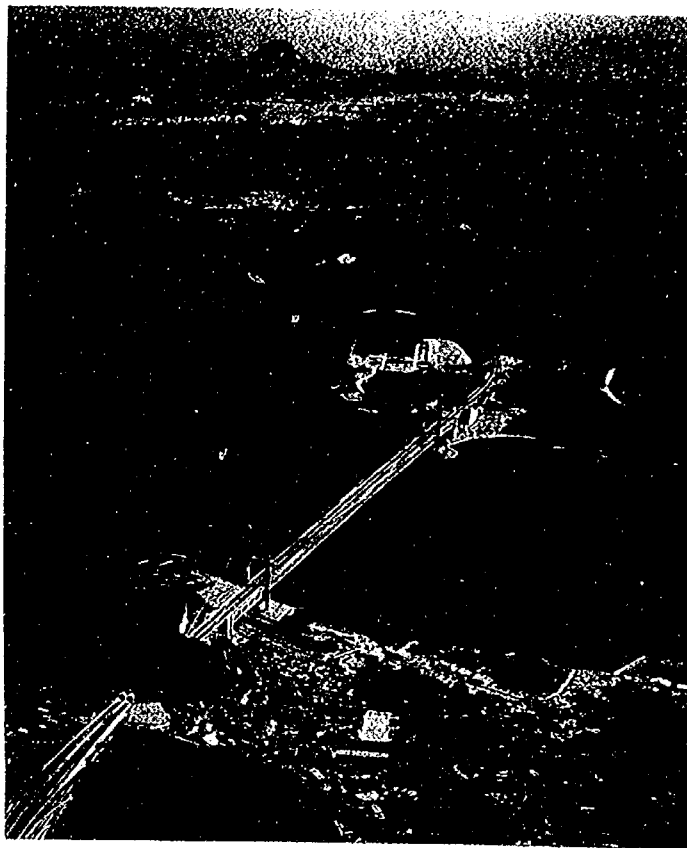


Fig. 2-1-10 Honshu-Shikoku Bridge.

2-1-6 Advancements on Technology for Enlargement of Structures

Enlargement of structures can be used as an index for measuring the advancement of technology. The length of tunnel, the length of span of bridge and the height of dam are discussed in this section. Figure 2-1-11, 12, 13 show the enlargement of these structures.

Adoption of a steel support arch, first used in the construction of the Ohara Tunnel in 1953, expanded the length of tunnels. This expansion made it possible to obtain wider working space for the mechanization of construction. In addition, the introduction of H-beam and an advanced method for rolled steel contributed to the popularization of the steel support arch.

Mechanization is a factor in the enlargement of structures. First, machinery construction in Japan was used in the Sakuma Dam, which shortened the construction time. Construction of the Seikan Tunnel is one of the results of this mechanization. The Tunnel Boring Machine introduced in the 1960s, was used in the construction of Seikan Tunnel where reform was required to fit the field condition there.

The NATM (New Austrian Tunneling Method) was adopted first in the construction of the Nakayama Tunnel on Joetsu Shinkansen line in 1975. This method developed with the advancement of computer technology as the design of NATM depends on numerical processing of its design. The Shield Method, introduced for the construction of tunnels under river and in weak ground, was another factor in the enlargement of tunnels. From the 1960s, this is mainly used for the construction of subways in urban areas.

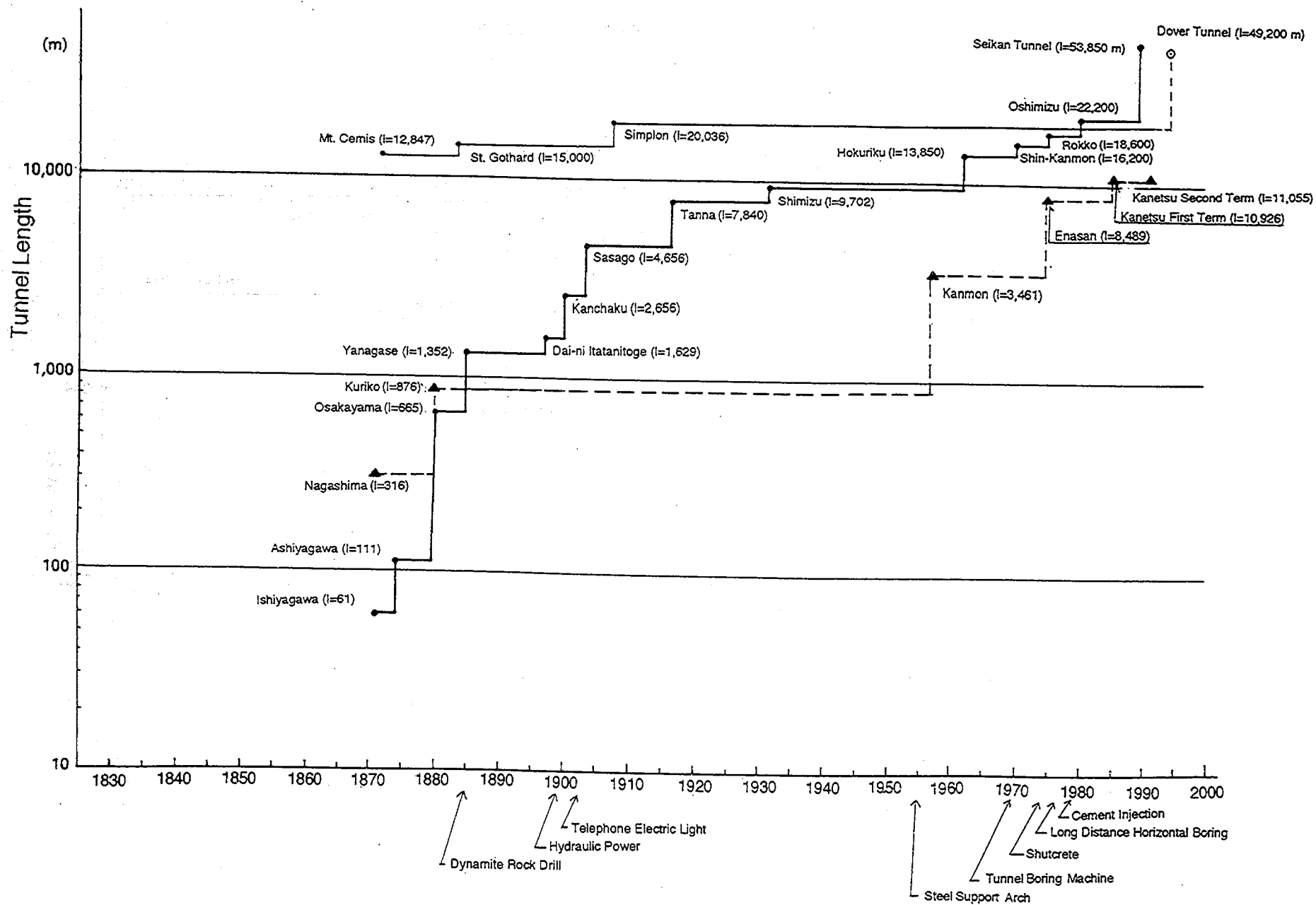


Fig. 2-1-11 Increase in Tunnel Length.

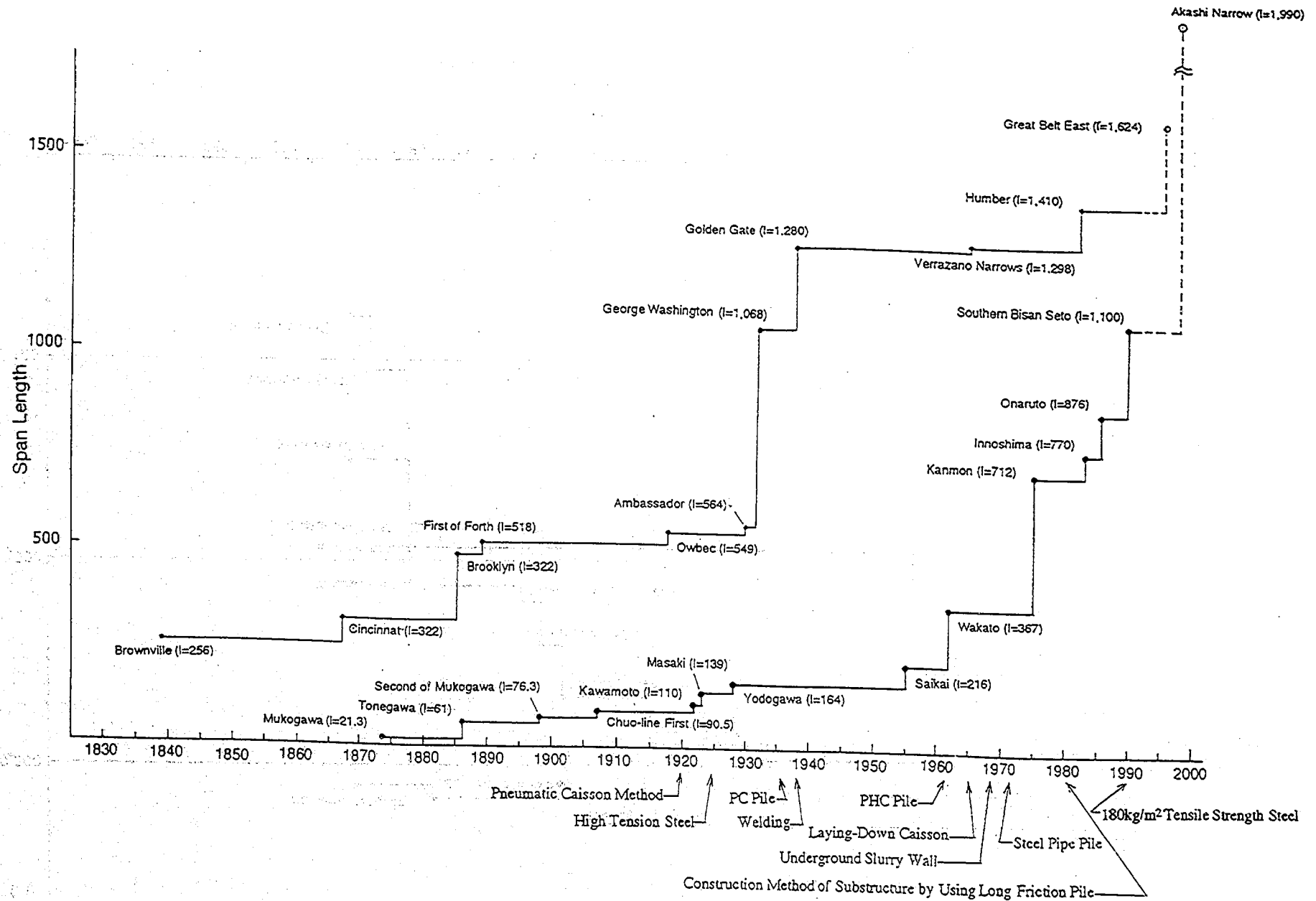


Fig. 2-1-12 Increase in tBridge Span Length.

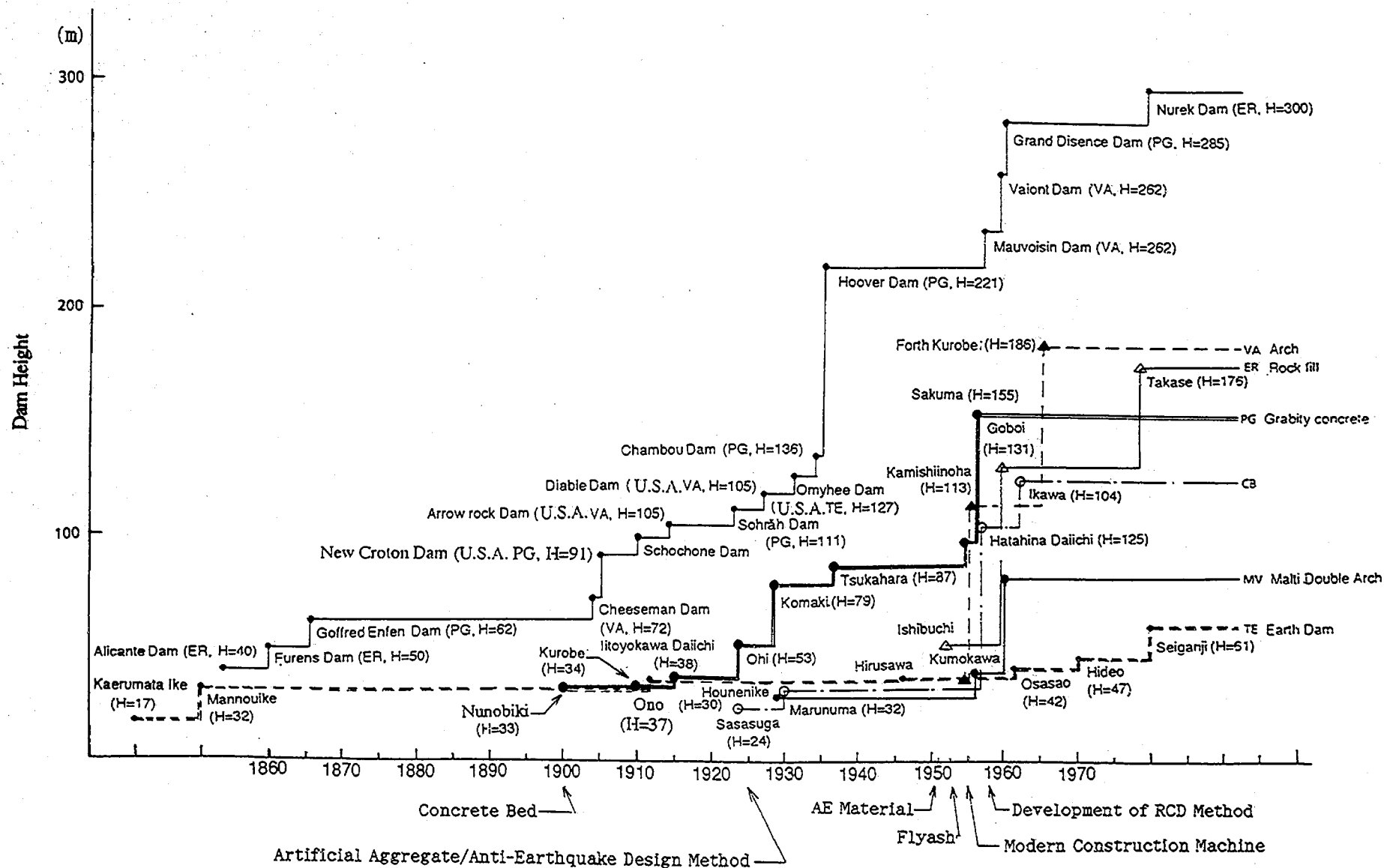


Fig. 2-1-13 Increase in Dan Height.

Factors which contributed to the enlargement of the center span of suspension bridges were welding technology and high-strength steel wire. High-strength steel wire had been imported from Germany before the end of World War II. After World War II, 80kg/mm² steel could be made in Japan with the development of the steel industry. The Akashi Narrows Bridge, which is the longest bridge in the world, uses 180kg/mm² tensile strength wire. Advancement of welding methods and stress calculation methods by use of computer propelled the development of long span bridges. Also advances in foundation techniques such as pile foundation, and caisson has contributed to the enlargement of bridge span length. It can be considered that the development of placed caisson, multi-piled foundation contributed to the construction of the Honshu-Shikoku Bridges.

Enlargement of dam structures is dependent on the mechanization of the construction process. For example, during the construction of the Mihoro Dam, rock fill type dam, a power shovel, a bulldozer and a dump truck allowed the shortened construction term. Recently, 32t-45t trucks and 30t-40t bulldozers have been made in Japan.

As a whole, the enlargement of structures is achieved not only by the advancements of construction techniques but also by advancements in many industries related to construction.

2-2 HISTORY OF EDUCATION IN CIVIL ENGINEERING

Before the Meiji Restoration, there were no Japanese technical engineers who were educated in Western science practises. The first civil engineering education program began at the School of Engineering in 1872 at the suggestion of Mr. Morell from England. Fifty students of civil engineering graduated from the school every year. In 1877, the School of Engineering renamed as the College of Engineering, according to the establishment of the Department of Railway. On the other hands, the government established the Ministry of Hokkaido Reclamation in 1876 and opened the Sapporo Agriculture College (Now Hokkaido Univ.) to assist in the development of Hokkaido island.

The Ministry of Education united the College of Engineering with Tokyo University in 1885. All universities with a high level of education for civil engineering were soon put under the jurisdiction of the Ministry of Education. Also Sapporo Agriculture College was included in 1895. Figure 2-2-1 is a chart showing schools during the early Meiji era.

At first, lecturers were foreign engineers. But use of English technical terms which were obtained from their presentation obstructed the Japanese low level labor's understanding. Therefore, the Ministry of Education decided that Japanese would be used for engineering education instead of English in 1884. This, therefore, increased the numbers of skilled engineers.

Middle level education was done in each ministry during the Meiji era. The remarkable middle level education was started at the School of Engineer (now Kogakuin Univ.) established in 1888. It consisted of 8 course such as civil engineering, machinery engineering..., and reared engineers who worked under the high-level engineers. Establishment of a School of Engineering meant the beginning of an expansion of civil engineering education as a whole.

After World War II, the government reorganized the educational system under the guidance of GHQ(General Headquarter of the Occupation Army), aiming at an open-door policy to the public and equal opportunity. In 1949, national universities were established in accordance with the Law for the Establishment of a National University. In 1950, the Junior College System was established. Now 49 out of 100 Japanese national universities have a civil engineering course.

The industrial high school system was renewed, according to the establishment of a new high school system in 1948. The change aimed to rear the middle-class engineer and to educate in techniques, knowledge, and attitudes as engineers.

The rapid economic growth from 1950 required a large amount of skilled engineers. An Industrial Technical College School System was established in 1962. Now 25 out of 54 national industrial college schools have a civil engineering course.

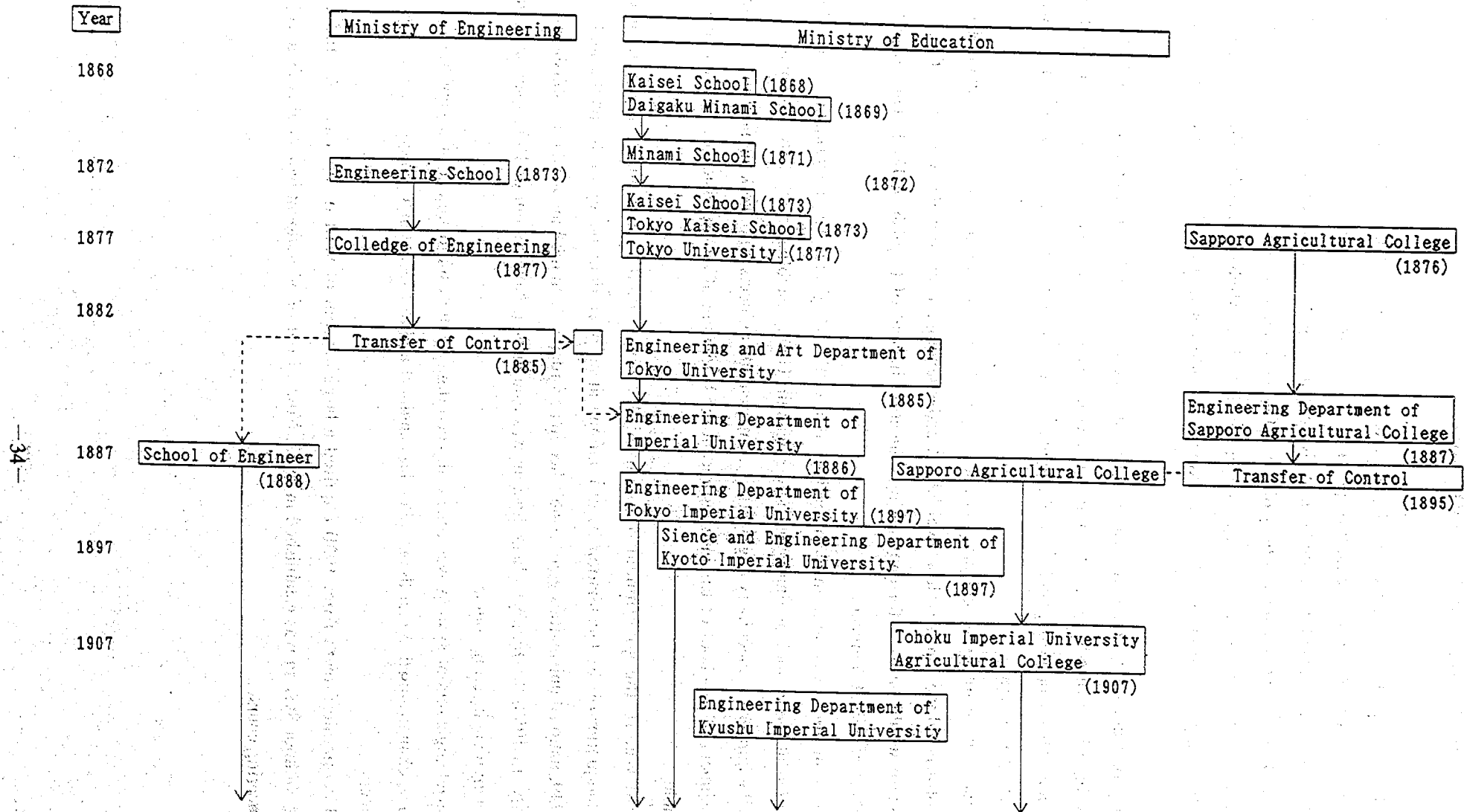


Fig. 2-2-1 Change of High Level Education Organizations and Their Competent Authorities.

The environmental problems and diversification of society in the 1970s demanded that universities open new departments for research and education in environmental pollution. Departments for sanitary engineering, traffic engineering, urban engineering and environmental engineering etc. were established in many universities and colleges. Figure 2-2-2 shows the number of undergraduate students in civil engineering. The upper line explains the number of students in the general civil engineering field including sanitary engineering, traffic one.... The lower line indicates the number of students in proper civil engineering excluding the field related to civil engineering. Therefore, the difference between the 2 lines indicates the number of students in each of the sanitary, traffic, urban, environmental engineering etc. courses, except for proper civil engineering. The number of students increased rapidly from 1960 to 1970 (the number tripled), and the differences still grow year by year. It suggests also the education system is changing in accordance to the "needs of the time".

As the whole, It can be considered that a continuous large supply of engineers is one of the reasons for economic growth in Japan.

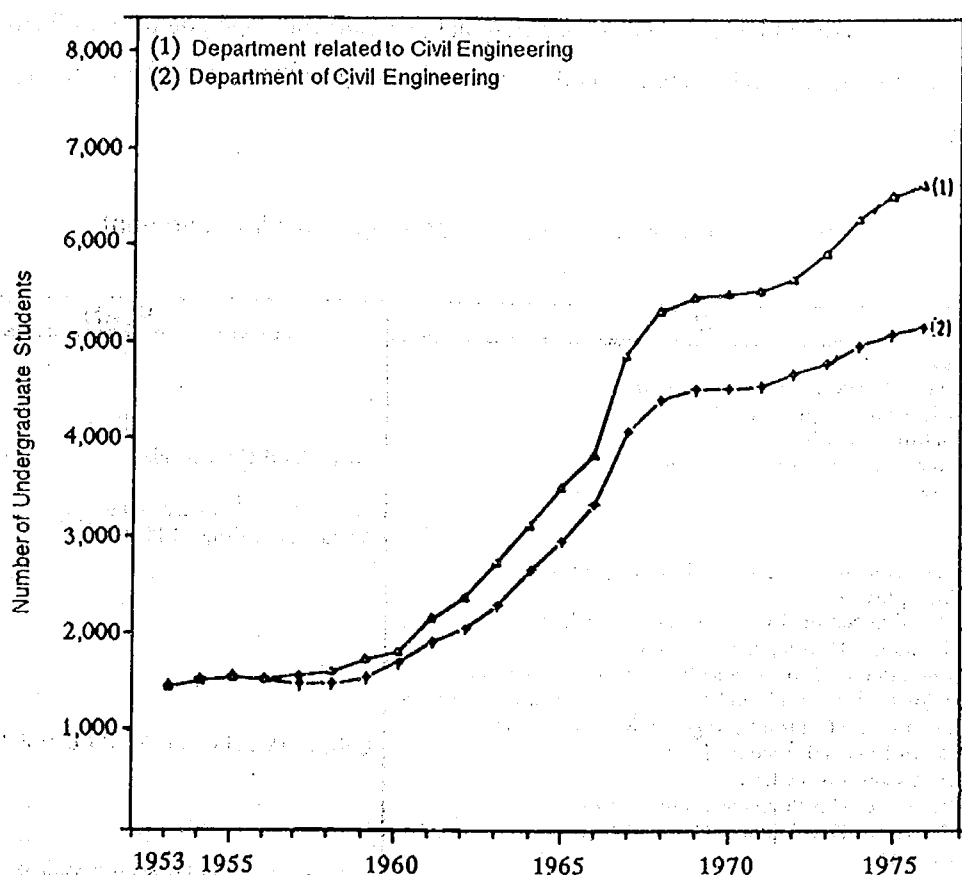


Fig. 2-2-2 Number of Undergraduate Students related to Civil Engineering.

2-3 HISTORY OF FINANCIAL ACT AND PLAN

Policies concerning infrastructure investment and finances have been supported by legislation in Japan. Programs for investment and financial acts are introduced in this section.

2-3-1 Law and Plan in River Improvement

Laws concerning river improvement are listed on Table 2-3-1. In the early Meiji era, the government emphasized low water improvement for ship transportation, and left the high-water improvement for flood control to the regional public bodies. But as the regional public bodies did not have a large enough budget for river improvement, flood disaster often occurred. In 1896, the government established the River Law and embarked upon high-water improvement for the 10 biggest rivers in Japan. In 1910, the first national project for flood control was started. However, the project was reduced soon by government financial distress. Only initial 3 years were able to get the prearranged budget. The second national program for flood control was formulated in 1918, and the third one was done in 1933, however, both programs were delayed or cut, obstructed by an increase in military spending.

Table 2-3-1 Laws and Plans Concerning River Improvement.

DATE	LAW	PLAN
1896	River Law	
1896	Additional Estimate for Specified River (Yodo River etc.) Improvement	
1897	Sand Control Law(Sabo Law)	
1911	Flood Control Fund Special Account	First Flood Control Plan
1913	Canal Law	
1921		Second Flood Control Plan
1933		Third Flood Control Plan
1932	Additional Estimate for National Recovery Project from Unemployment	
1950	Comprehensive National Land Development Law	
1952	Power Resources Development Promotion Law	
1953	Task Committee on Erosion and Flood Control Measures	
1953	Outlines for Erosion and Flood Control Fundamental Measures	
1960	Erosion and Flood Control Emergency Measures Law	
1960	Flood Control Special Account Law	Cabinet Decision for Flood Control Ten-Year Plan
1961	Disaster Measures Basic Law	
1961	Water Resources Development Promotion Law	
1961	Water Resources Development Corporation Law	
1964	New River Law	
1965		Cabinet Decision for New 5-Year River Improvement
1971	Special Measures Law Concerning Upstream Area Development	
1992		8th 5-Year River Improvement Program

On the other hand, river improvement was planned for the regional unemployed by World Crisis (1932). But in 1934 it was cut, facing an increase in military spending.

A suspension of infrastructure investment during World War II caused many flood disasters after World War II. In 1950, the Comprehensive National Land Development Law was established accordingly. The Law for

the Promotion of Electricity Development was formulated in 1952 to develop hydraulic electricity. Many multi-purpose dams were built from that point.

A Ten-year Program for Flood Control was formulated in 1953 in accordance with the formulation of Erosion and Flood Control Emergency Measures Law, and Flood Control Special Account Law. However, in 1961, heavy rain caused serious flood disasters around Japan. An amendment of the law and an addition to the program required. A new River Law and 1st Five-Year River Improvement Program were formulated as the result in 1964. After that, river improvement was promoted under the Five-Year River Improvement Program.

In 1992, the 8th Five-Year River Improvement Program was started. This one aims at building a safe infrastructure, the creation of comfortable living circumstances concerning the amenity, and the development for countermeasure against the exceptional floods or water shortages. The program propels many areas such as comprehensive flood disaster prevention, building of high-graded levees or so called "Super Levees", water resource development, sediment-related and volcanic disaster prevention, environmental improvement along river bank, river management, and marine development.

2-3-2 Law and Plan in Road Investment

Table 2-3-2 shows the main laws and programs concerning road improvement. The first Road Law was formulated in 1919. Because of the priority placed on railway construction, the formulation of Road Law was delayed compared to the River Law.

Table 2-3-2 Laws and Plans Concerning Road Improvement.

DATE	LAW	PLAN
1873	Domestic Barrier Stations were Abolished	
1876	River, Port and Road Improvement Regulations	
1919	Cabinet Order for Division of National, Prefectural and City Roads	
1920	Road Structure Ordinance	
1920	Road Law	First Road Improvement Plan
1922	Government Security for Road Construction Bond Law	
1922	renewal of Road Law	
1929		Industrial Road Improvement Plan
1931		Anti Unemployment Road Improvement Project
1932		Five Year Industrial Road Improvement Plan
1933	Additional Estimate for National Recovery Project from Unemployment	Second Road Improvement Plan
1936	National Road Improvement Continuing Expenditure	
1937		Five-Year Industrial Road Construction and Improvement Plan
1940		Road Paving Project
1952	New Road Law	
1952	Toll Road System	
1953	Temporary Measures Law Concerning Funds for Road Maintenance and Improvement	
1954		1st Five-Year Road Construction Program
1956	Law Concerning Special Measures for Improvement of Roads	
1956	Japan Road Public Corporation Law	
1957	Law for Construction of Arterial Motorways for National Land Development	
1957	National Expressway Law	
1958	Law Concerning Emergency Measures for Highway Construction	
1959	Metropolitan Expressway Corporation Law	
1962	Hanshin Expressway Public Corporation Law	
1966	Emergency Measures Law Concerning Construction of Traffic Safety Facilities	
1970	Basic Law for Traffic Safety Measures	
1970	Honshu-Shikoku Bridge Authority Law	
1986	Law Concerning Special Measures for Construction of Trans-Tokyo Bay Highway	
1992		Cabinet Decision, 11th Five-Year Road Improvement Program

During World War I, demand by the augmentation of city transportation capacity increased road investment. Also recognition that delays in road improvement worsened the disaster and that roads played an important role in the recovery from the Great Kanto Earthquake propelled the movement. Road investment became larger than river improvement at that time.

Many road programs such as First Road Improvement Program (formulated in 1920, 30 years), and The Second (formulated in 1934, 20 years) had been formulated. However, these programs were not being completed, facing the reactionary recession after World War I. The road improvement program as one of countermeasures to unemployment (1931-1935), and another programs was created one after another, but all the programs was discontinued because of an increase in military spending. It should be only noted that the formulation of the programs allowed the classification and regulation of roads, structures related to road, and penal, which was the foundation of road administration in Japan.

After World War II, many laws were formulated to obtain financial guarantee. Road Laws were completely reformed in 1952. A Law Concerning Special Measures For Improvement of Roads (1952) legislated to provide a legal basis for the Toll Road System. This allows to apply the Financial Investments and Loans System*, to borrow private funds for road construction, and to appropriate the toll fee for the repayment. In 1953, a Temporary Measures Law Concerning Funds For Road Maintenance And Improvement was formulated. This allowed the dedication of the gasoline tax monopolistically for road construction finance. In 1954, the First Road Improvement Program was formulated under law. In 1958, a Law Concerning Emergency Measures For Highway Construction was formulated. This legislated to provide a financial basis for next five-year road programs and the system of the appropriation of the gasoline tax. Now the 11th Five-Year Road Improvement Program is about to be carried out.

Improvement of national expressways began with the formulation of a Law for Construction of Arterial Motorways for National Land Development, and a National Expressway Law. Japan Highway Public Corporation was made the direct management organization under law. In 1966, a Law for Construction of Arterial Motorways for National Land Development was formulated by uniting several construction-related laws. In 1987, the High-Graded Trunk Road Project was created, aiming for the formulation of multi-polar of national land use. 14,000km network of high-graded trunk road will be completed by the year 2010.

From the 1960s, an increase in traffic accidents has occurred. A Emergency Measures Law Relating Provision of Traffic Safety Facilities was formulated in 1966, and the Five-Year Traffic Safety Facilities Improvement Program was established in accordance with it.

*) Financial Investments and Loans System; This system is a unique system. This allows to loan the funds for public investments from a reserve funds of postal saving, and a surplus funds of public welfare insurance etc..

2-3-3 Law and Plan in Port Investment

Main laws related to port management are listed on table 2-3-3. Port Law was legislated in 1950. This law separated the port administration from port construction. It was ruled that the administration should be carried out

by the port administrative association and port construction should be done by the government.

Law for the Promotion of Port Service was legislated in 1953, which allowed government financial support for port facilities.

The boom during the Korean War demanded the urgent construction and maintenance of ports in Japan in order to import large amounts of raw materials such as iron stone, oil and coal. Therefore, the Emergency Measure Law for Port Improvement was legislated in 1961. The First Five-Year Port Construction Program was started in accordance with it. Now, the 8th Program is under construction, and the law was amended in 1991.

Table 2-3-3 Laws and Plans Concerning Harbour Improvements.

DATE	LAW	PLAN
1871	Cabinet Declaration Concerning Toll Fees Collection of Road, Bridge, Harbour etc.	Decision for Selection of Important Harbours Establishment of the Ministry of Transportation
1873	Regulation for Repairs of River, Port and Road	
1897	Special Legislation(it was planned to divert effectively and use aggressively national harbour engineer groups and equipments.)	
1907		
1943		
1950	Harbour Law	
1953	Harbour Construction and Improvement Promotion Law	
1956	Seashore Law	
1959	Special Measures Law for Specified Harbour Facilities Construction	
1961	Emergency Measures Law for Harbour Construction and Improvement	
1961	Special Measures Law for Harbour Construction and Improvement	Cabinet Decision, 1st Five-Year Port Construction Plan Cabinet Decision, 8th Five-Year Port Construction Plan Cabinet Decision, 5th Five-Year Coast Improvement Plan
1962	Emergency Measures Law for Harbour Construction and Improvement	
1991		
1991		

2-3-4 Law and Plan in Railway Construction

Main laws related to railway construction are listed on table 2-3-4. The first cabinet order concerning railway construction was issued in 1869, and the first railway (Shinbashi-Yokohama) was completed in 1882. At first, the railway was seen as a symbol of modernization, but the government gave first priority to railway construction since a large amount of railway transportation was required during the Seinan Region Civil War (1877).

In the early Meiji era, a shortage of funds urged the introduction of private funding for the construction of the trunk railway. Therefore, the government furthered the private railway companies in many ways. The railway line forming the backbone of Japan was completed by the government, and branches were made by private companies till 1893. In 1901, construction of railways was started in the undeveloped, unprofitable areas by the government.

A National Railway Law which aimed at the nationalization of the railway industry was formulated in 1906. A Reformed Railway Construction Law promoted this construction, and almost all networks of the trunk railway were completed in the early Showa era.

A Light Railway Law in 1910 and a Local Railway Law in 1919 supported the construction of railway in local area of Japan. A Law for Regulation of Land Transportation issued during World War II united local railway

companies, in order to obtain reasonable fee, and stabilization in local railway management.

The Railway Construction Law was reformed again in 1951. Rapid economic growth in the 1960s urged new railway construction. Hence the government formulated three Five-Year Programs for railway construction from 1958 to 1971. By completion of these programs, rail transportation was modernized to the point of electrification, double-tracking and renewal of stations. The Tokaido Shinkansen, which was completed in 1964, achieved an average service speed of 210 km/h. It allowed the realization of the availability of railtravel at high speeds and mass transportation between large cities.

In the 1970s, non-policy management, stagnation in technical renovation, failing working vitality, and red-ink financing, was characteristic of bureaucratic management of the Japan National Railway (JNR). The government made a plan for rebuilding of the JNR, focusing on an increase in the transportation capacity for passengers. In 1976, it is planned in the Third Comprehensive National Land Development Program, that completion of the Tohoku and Joetsu Shinkansen lines, the construction of 5 shinkansen lines (Hokkaido, Tohoku, Hokuriku, 2 of Kyusyu), survey for a central shinkansen line, development of a public transportation system, and the introduction of a bus system. However, failure to rebuild forced the government to divide the JNR system into seven private companies. Unprofitable local lines were discontinued during the same period.

Today each railway company tries to develop higher-speed Shinkansen to 350 km/h, new urban transportation system combined automobile, monorail and railway transportation, 500 km/h at linear motor system as well as their effective management.

Table 2-3-4 Laws and Plans Concerning Railway Improvement.

DATE	LAW	PLAN
1869		Cabinet Decision for Railways Construction Plan
1892	Railways Construction Law	
1893		Regulation for Railway Construction
1906	Law for Nationalization of Railways	
1910	Light Railways Law	
1919	Local and Private Railways Law	
1921	Ordinance for the Ministry of Railways	
1923	Railways Construction Law(amendment)	
1929		Regulation for Japanese National Railway
1948	Japan National Railways Law	
1951	Establish of Japan National Railway(JNR)	
1957		1st Five-Year Railway Construction Law
1959		Beginning of Shinkansen Construction
1961	Railway Crossing Improvement Promotion Law	2nd Five-Year Railway Construction Plan
1964	Japan Railways Construction Public Corporation Law	
1965		3rd Long Term Construction Plan
1969		Financial Rebuilding Plan
1970	Honshu-Shikoku Bridge Authority Law	
1970	Law for National Shinkansen Improvement	
1973		Rebuilding Plan
1976	Partial amendment of Bill for Japan National Railways Fare	
1981		Managing Improvement Plan
1982		Idea for Divide and Private Management of JNR
1983	Temporary Measures Law for the Reconstruction of JNR	
1987	JNR was divided and placed under private management	

2-3-5 The Tax System and Support Program for Promoting Research and Development of Civil Engineering Technology in Private Companies

In this section the tax system and support programs established to promote research and development in private companies are described.

Before World War II, both basic and applied research were carried out by the the Civil Engineering Laboratory, the Ministry of Interior (now the Ministry of Construction), for almost all public works were carried out directly by the Ministry of Interior. After World War II, the system was changed, and most of construction works was carried out by private companies. The research and development of civil engineering technology by private companies has become important accordingly for the advancement of civil engineering since the end of World War II. Now, the role of private companies is important especially in applied technologies.

Some foundations created by the national government have supported the research activities of private companies. A tax deduction system is one of them. A tax deduction system for the increase in amount of research investment was established in 1967, in which 20% of a corporation tax of increased amount can be deducted if the amount of research investment is greater than the amount spent in the preceding year. For pioneering technology, 7% of the investment amount can be deducted from the amount for taxation, according to the tax system for the promotion of basic pioneering research. In addition, small business can be deduct 6% of their research investment from taxation by using the Tax System for Strengthening of the Research Ability in Small Industries (1985). In 1989, a Finance and Investment System was formulated, in which a low rate of finance and investment for technical R&D was legislated by the Japan Development Bank.

The Ministry of Construction provides support programs for the promotion of research and development in civil engineering technology by private companies.

(1) COMPREHENSIVE RESEARCH AND DEVELOPMENT PROJECT

Complication of recent social problems requires more specialized research systems. According to this movement, the Ministry of Construction established a Comprehensive Research and Development Project in 1972. This project supports interdisciplinary research and development of the systematic combination of universities and private companies with national research institutes.

(2) SYSTEM OF JOINT RESEARCH AND DEVELOPMENT

The combination is expected to develop achievements more efficiency and more economically in the case several institutes/laboratories conduct resemble research projects in purpose. A System of Joint Research and Development was founded in 1980, aiming at joint researches for public benefit between institutes/laboratories of the Ministry of Construction and other private research laboratories to promote efficient research work. In this system, 2 ways exist in the process of the combination, one is based on the proposals from the national side, and other is based on the proposals from the private side.

(3) GOVERNMENT/PRIVATE SECTOR JOINT RESEARCH AND DEVELOPMENT

A Government/Private Sector Joint Research and Development System was initiated in 1986. Basic purpose of this project is alike to the System of Joint Research and Development. This project mainly aims to apply germinal research achievements to practical construction, achievements which are developed through private companies. The proposals from the private side are respected in this system. The research subjects are decided on the Construction Technology Committee.

(4) SYSTEM FOR ACCEPTED RESEARCHER

A System for Accepted Researcher was established in 1980. This system allows researchers of private industries to be accepted to PWRI as extra researchers. The education of private researchers and the spread of advanced technologies are the main goals.

(5) CONSTRUCTION TECHNOLOGY EVALUATION SYSTEM

A Construction Technology Evaluation System was established in 1988. The main aim is the encouragement of the development of new technology related to public works by private businesses. The Ministry of Construction decides and announces the targets, and evaluate the technology.

Excellent achievements are certificated and are opened to the public.

(6) EVALUATING AND CERTIFICATING SYSTEM FOR ORIGINAL TECHNOLOGY DEVELOPED BY PRIVATE COMPANY

Evaluating and Certificating System for Original Technology Developed by Private Company was established in 1987. In this system, the Ministry of Construction evaluates the new technology and certifies the performance of the technology developed independently by private businesses.

The achievements are registered on the data bank of the Japan Construction Information Center, and are spreaded to construction-related organization.

(7) PILOT PROJECT FOR UTILIZATION OF NEW TECHNOLOGY

A Pilot Project for Utilization of New Technology was established in 1987. The capability and adaptability of new technology developed by private companies can be tested to field work by regional offices of the Ministry of Construction in hopes that it will be introduced into the government construction work.

2-4 FACTORS OF ADVANCE IN CIVIL ENGINEERING TECHNOLOGY IN JAPAN

In this section, the rapid advancement in civil engineering technology is examined especially during the Meiji era and after World War II.

It is remarkable that it took only twenty years to master western technologies during the early Meiji era because most of invited engineers returned to their native countries in the 1880s. The reasons for this rapid mastering of foreign technologies are considered as follows:

- (1) Japan had already entered the stage of early capitalism, therefore, it was easy for Japan to import systems and technology from advanced capitalist countries.
- (2) Japanese engineers tried to improve technologies introduced by foreign countries or by those engineers educated in foreign countries in order to adapt to the natural and socio-economic conditions in Japan.
- (3) Most engineers in those days were from the "Samurai" class before the Meiji restoration. They had a flourishing volunteer spirit to build a new country.
- (4) The invitation of foreign engineers to Japan, the opening of engineering schools and the dispatch of young students to foreign countries led to the absorption of advanced technology.

After the 1880's, efforts for adapt the introduced technology in accordance with the conditions in Japan were carried out. Planning techniques were introduced but the Japanese method was used in implementing them, the first big projects such as Osakayama Tunnel and Lake Biwa Canal used this system.

After World War I the following causes slowed the advance of the technology;

- (1) Most of the government budget was used for military equipment. Fewer finances were provided for infrastructure investment providing less opportunity for the development of civil engineering technology.
- (2) The focus of infrastructure investment was on military railway investment.
- (3) This military emphasis by national government policy would not allow the construction of large size structures because they were easily targetted by the enemy.

During World War II, Japan faced on a prosperity. This propelled the introduction of advanced machinery developed western countries, and industrial renovation was developed accordingly.

After World War II American technology, mainly characterized the increasing mechanization, shortened the construction term enormously. This introduction was carried out mainly under the guidance of GHQ (General Headquarters of the Occupation Army). After that time, Japanese engineers pursued civil engineering technology taking into consideration scientific advancements and the possibility of mechanization.

The rapid growth of the economy in the 1960s allowed a large amount of money added to the national budget. Financial backing for construction projects allowed the imported technologies to be applied to the natural, economic and social conditions unique to Japan. This process of technological digestion resembles that process of the Meiji restoration. However, the level and ability of the application were much greater than that of Meiji era, which was propelled by the following general policies concerning technology development.

- (1) The government encouraged the development of technology through private industries. In detail, the

government created legislation for tax deductions in technological development and joint research projects between government and private industry. Specialization in the process of construction work encouraged the technical renovation effectively. General contractor companies focused on the research of construction technology including construction methods and equipments. Construction consultation companies focused on investigation and design. As a result of this specialization, the government's institutes shifted towards basic leading research and development.

- (2) Task committees consisting of experts of university, private industry, and government were organized for each big construction project. These task committees were very useful for coordinating basic and applied research information.
- (3) The establishment of civil engineering departments in universities supplied many educated students.
- (4) Steel, machine and chemical companies developed technology related to civil engineering. These activities provided new material and construction technology.
- (5) Engineering researchers of universities, government and private industries are often experienced in actual construction processes at the construction site. This tradition has kept a focus on practical research at institutes in Japan.

As the whole, It seems that the combination research conducted by the government, private industries, and universities has played the most important role in the advancement of civil engineering technology.

3 SEVEN DECADES OF THE PUBLIC WORKS RESEARCH INSTITUTE

The preceding organization to PWRI was the Road Material Laboratory established in 1921. The laboratory became the Civil Engineering Laboratory in the next fiscal year. PWRI is one of the most historic civil engineering institutes, attaining its 70th Anniversary in 1992. This chapter describes the outline of R&D, change in the organization, and the achievements of PWRI in the advancement of civil engineering technology in Japan.

1.

3-1 HISTORY OF PWRI

At the time PWRI was born, Japan had little technological background in civil engineering, and technology was introduced from western countries. PWRI's initial work was the inevitable transformation of introduced technology using scientific insight, in order to fit Japanese natural, topographic, and socio-economic conditions. This experience raised the technical level of PWRI gradually, PWRI began to develop the original achievements after World War II. Now PWRI is one of the most advanced research organizations in the world.

Newly developed technologies by PWRI always applied to practical use, for PWRI's research targets were always characterized as "meet the needs of the time". This fact made PWRI more important, which reflected the expansion of the organization. Now PWRI has nine research departments, and a total of 472 people work in them.

As mentioned above, PWRI always changed and improved the research subjects, the target, and the organization in the seven decades history, according to the social movement. This chapter presents the history of research achievements, way of research, and the organization by dividing it into seven periods.

- 1) Before World War II 1922 - 1939
- 2) World War II 1940 - 1945
- 3) Post World War II Reconstruction 1946 - 1957
- 4) First Half of the Period of High Economic Growth 1958 - 1965
- 5) Second Half of the Period of High Economic Growth 1966 - 1973
- 6) Structural Changes 1974 - 1986
- 7) Present 1987 -

3-1-1 Before World War II (1922 - 1939)

1) BIRTH OF THE ROAD MATERIAL LABORATORY

As mentioned in Chapter I, railway construction was given the first priority in infrastructure investment during the Meiji Era. But in the 1920s, an increase in the number of automobiles and in the amount of domestic transportation following the after-war boom, and a recognition of the importance of car traffic in Europe, made road construction a very important national traffic system. The Road law and the Law of Government Security for Road Construction were formulated in 1920 introducing road construction in Japan. This was considered the beginning of proper road construction in Japan.

The Road Material Laboratory was built in 1921. The laboratory became the Civil Engineering Laboratory soon after in 1922. Figure 3-1-1 shows the main building at Komagome, Tokyo. The 1st director-general was Dr. H. Maki. This laboratory consisted of 38 members including 23 part time workers. Figure 3-1-2 shows the organization chart as of 1922.

At that time, Japan had no technological back-ground in road engineering such as paving material, plant and paving standards. Therefore, the initial work of the Civil Engineering Laboratory was the introduction of

information concerning the road construction. Translation of foreign information, and confirmation and supplementation through experiments was done at the Civil Engineering Laboratory during that time.

The work of the Civil Engineering Laboratory during this period was the study of the effect of smoothness and road surface gradient on transportation by wagon, and the study of asphalt material. The results were published as the first work by the Civil Engineering Laboratory. In 1928, the test standard for asphalt material was established, which was the first successful work conducted by the Civil Engineering Laboratory.

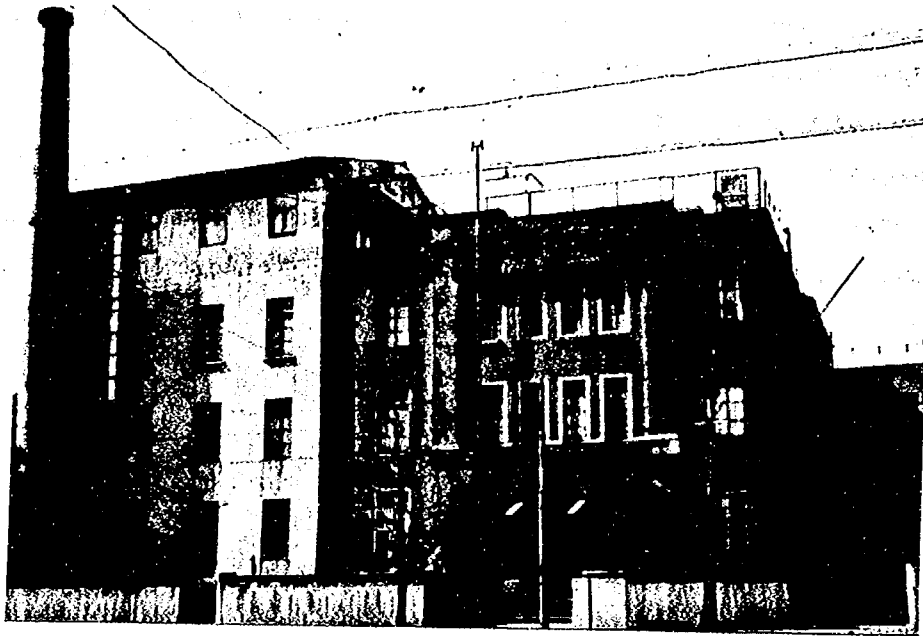


Fig. 3-1-1 Main Building (Komagome, Tokyo).

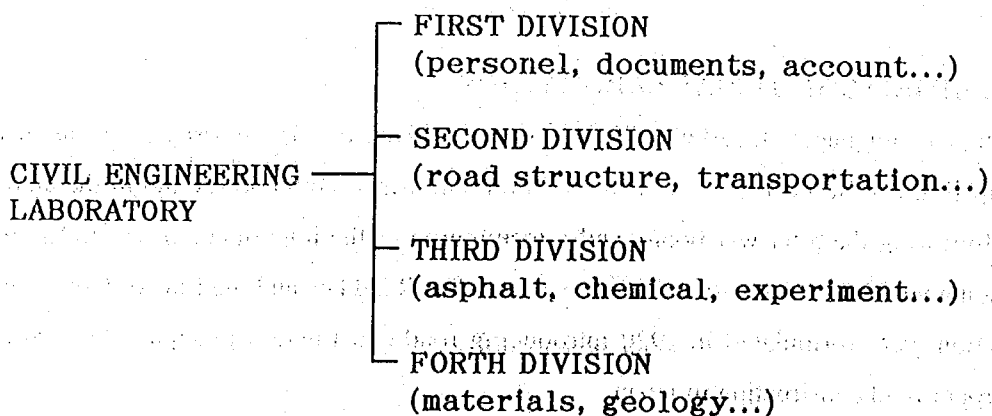


Fig. 3-1-2 Organization Chart (as of 1922).

2) GREAT KANTO EARTHQUAKE AND EARTHQUAKE ENGINEERING

Mid noon, September 1st, 1923, the Great Kanto Earthquake occurred with an energy level of M 7.9. Approximately 100,000 persons were killed, 40,000 persons were declared missing and 58,000 houses were

burned. Figure 3-1-3 shows the disastrous scene in the Ginza area in Tokyo. The Civil Engineering Laboratory conducted the disaster survey. As a result of the survey, Dr. Mononobe, director of the Civil Engineering Laboratory, emphasized research on earthquake engineering such as vibration characteristics and countermeasures for tower structures, support structures, suspension bridges and girder bridges. These work was presented in "EARTHQUAKE STUDY IN CIVIL ENGINEERING" published in 1934, and it formed the basis for research on earthquake engineering in Japan.

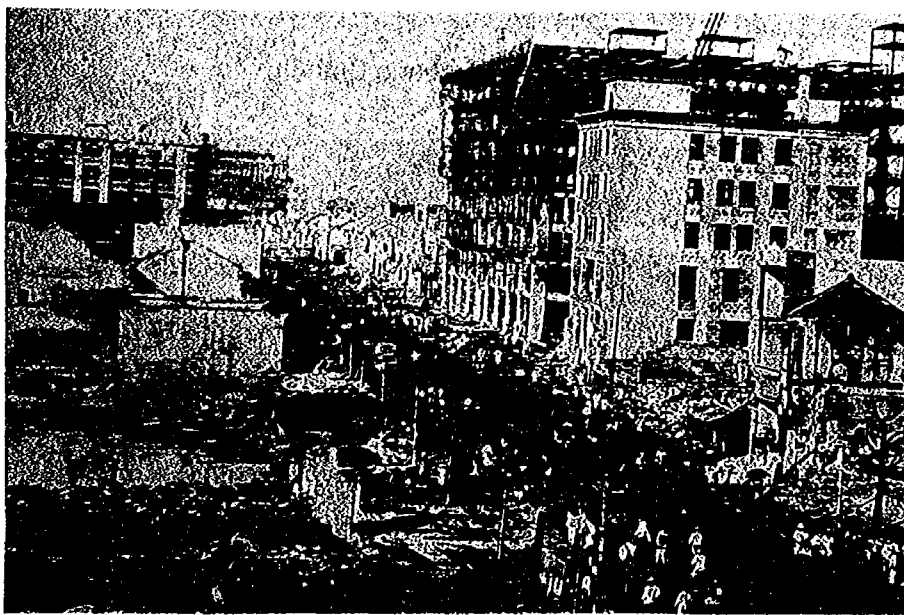


Fig. 3-1-3 Great Kanto Earthquake.

3)AKABANE RESEARCH BRANCH AND BEGINNING OF HYDRAULIC STUDY

An increase in the demands for river improvement caused the Civil Engineering Laboratory to establish the hydraulic research facility. The Akabane Branch shown in Figure 3-1-4 was founded in 1926 at Akabane, Tokyo, for the study on river engineering. Later this was renamed as Akabane Research Branch in 1967.

This facility was the first one for hydraulic research in Japan. The model for this facility was the Karlsruhe Hydraulic Laboratory in Germany. The model experiment for the Kitakami River Weir's tilting gate was the first hydraulic model experiment, the study on Arakawa Iwabuchi Watergate shown in Figure 3-1-5 and study on side-overflow levee were also conducted in the Akabane Research Branch.

Mainly basic research information was introduced at that time, but the Akabane Research Branch tried to provide supplement information through experiments and analysis. Analysis of a back water curve, characteristics of bent flow, scouring at the edge of ground sill, wind forecasting and high sea forecasting methods, and a similitude criteria were conducted. This work characterized PWRI as a laboratory which carried out both basic and applied research. This characteristics was inherited to the Shinozaki Experimental Laboratory and the Kashima Experimental Laboratory, which would be mentioned after. These efforts were published as "DR. MONONOBE'S HYDRAULICS", which was recognized as the origin of Japanese hydraulics.



Fig. 3-1-4 Akabane Branch.



Fig. 3-1-5 Hydraulic Experiment for Iwabuchi Water Gate.

4) OTHER RESEARCH DURING THIS PERIOD

Other research during this period concerned welding steel bridges and land sliding.

(1) Welding Steel Bridges

The progress of welding technology allowed the construction of many steel bridges in Japan. PWRI gathered the information concerning these bridges and published "WELDING STEEL BRIDGES", which presented the data base for the welding of steel bridges. It was very useful for planning new bridges.

(2) Survey on a Landslide in Kamenose Area

A large landslide occurred in Kamenose area, upper region of the Yamato River in 1931. Figure 3-1-6 shows the view of the landslide. This landslide destroyed the river and the road. PWRI surveyed the damage and analyzed the cause of the landslide. This work has been one of the exemplary research exercises conducted on landslides in Japan.



Fig. 3-1-6 Land Failure in Kamenose, Yamato River.

3-1-2 During World War II (1940 - 1945)

World War II forced PWRI to conduct much of the military research with a reduced research budget and staff. The military research conducted during this period included;

- * Reinforced concrete which used bamboo instead of steel.
- * River flashing for the clearing of mosquito larvae.
- * Durability of dams in the case of bombing.
- * Stabilization of red soil.

The research work was carried out with a poor budget. Therefore, the trend of research was shifted towards basic research and away from applied research which cost much more money. An approximate analysis of the specific number of vibration of girder with deformed beams, formulation of the standard for reinforced concrete cantilever beams, an investigation of the relationship between river gradient and the diameter of river bed materials, and formulation of the similitude criteria in hydraulic model experiments, were all carried out.

3-1-3 Post-War Reconstruction (1946 - 1957)

1) RECONSTRUCTION

After World War II, GHQ (General Headquarter of the Occupation Army) guided Japan's recovery from the war disaster as a countermeasure against communism. GHQ intended that Japan should be a key nation in Asia. Japan's reconstruction was accelerated by industrialization.

2) REORGANIZATION

After World War II, a reorganization of government was carried out. On December 31st 1947, the Ministry of Interior was scrapped, and the Prime Ministers office, Construction Board was established in 1948. At the same time the Civil Engineering Laboratory was renamed as the First Technological Laboratory.

On July 10th 1948, the Ministry of Construction was established and the Civil Engineering Laboratory was renamed again as the Public Works Research Institute (PWRI). Figure 3-1-7 shows the organization of PWRI as of 1948.

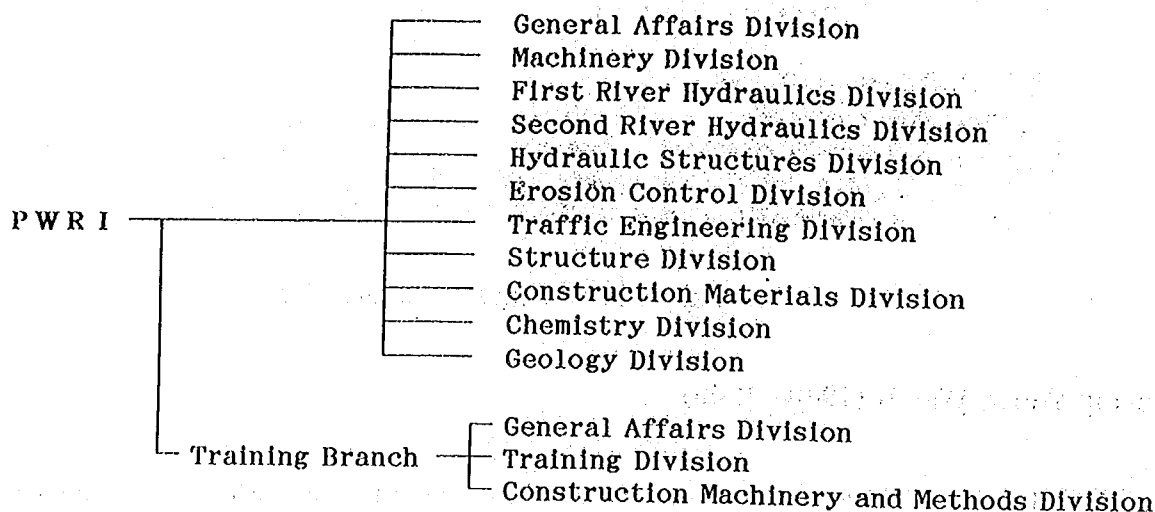


Fig. 3-1-7 Organization Chart (as of 1948).

3) SHINOZAKI EXPERIMENTAL LABORATORY AND REPEATED DISASTERS

The priority of military investment during the war period caused serious natural disasters after the war. Table 3-1-1 shows the natural disasters and the damages which occurred during the period of 1945 to 1965.

Initial work of PWRI was creating countermeasures against repeated earthquakes and typhoons after the war. Figure 3-1-8 shows the flood disaster caused by the Kathleen Typhoon in 1947. These natural disasters damaged Japan while it was under industrial recovery. Therefore, the first priority of public investment was given to river improvement projects, and the necessity for hydraulic research increased. However, there was no facility for large scale hydraulic model experiments at that time. For the prevention of flood damage the Shinozaki Branch Division of PWRI was established in 1952. This was renamed as Shinozaki Experimental Laboratory in 1967. The Shinozaki Experimental Laboratory was the largest hydraulic research laboratory in Asia at that time (see figure 3-1-9). Large scale hydraulic model experiments for dams and rivers were conducted there.

Table 3-1-1 Main Natural Disasters Occurred during 20 Years after World War II.

Date	Name of Natural Disaster	Number of Killed and Missed
1946	Nankai Earthquake	1330
1947	Kathleen Typhoon	1930
1948	Fukui Earthquake	3769
1948	Iona Typhoon	838
1958	Kakogawa Typhoon	1269
1959	Isewan Typhoon	5041
1964	Niigata Earthquake	25



Fig. 3-1-8 Enbankment Collapse of Tone River by Kathleen Typhoon.

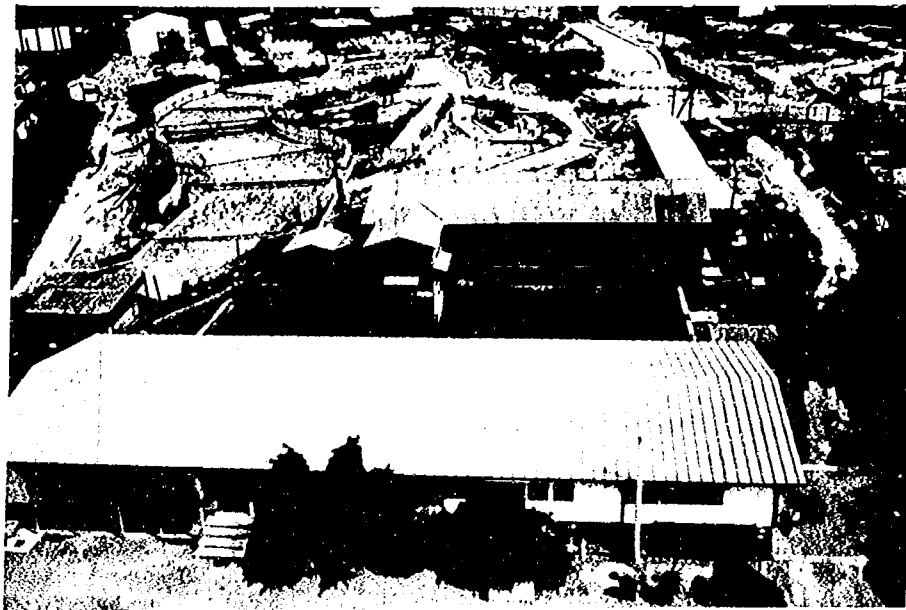


Fig. 3-1-9 Shinozaki Experimental Laboratory.

4)NUMAZU RESEARCH BRANCH

The training institute for machine engineer was established in 1949 for the promotion of machinery construction in Japan. It was renamed as the Numazu Research Branch in 1953. Figure 3-1-10 shows the views of the Numazu Research Branch at Numazu City in Shizuoka prefecture. The Numazu Research Branch conducted the education of mechanics and operators, and research in soil engineering, inspection methods for earthwork, and many tests for construction machines and snow plows. The data obtained in these tests has been very useful for improving Japanese construction machines. The test standards for construction machine were made and adopted

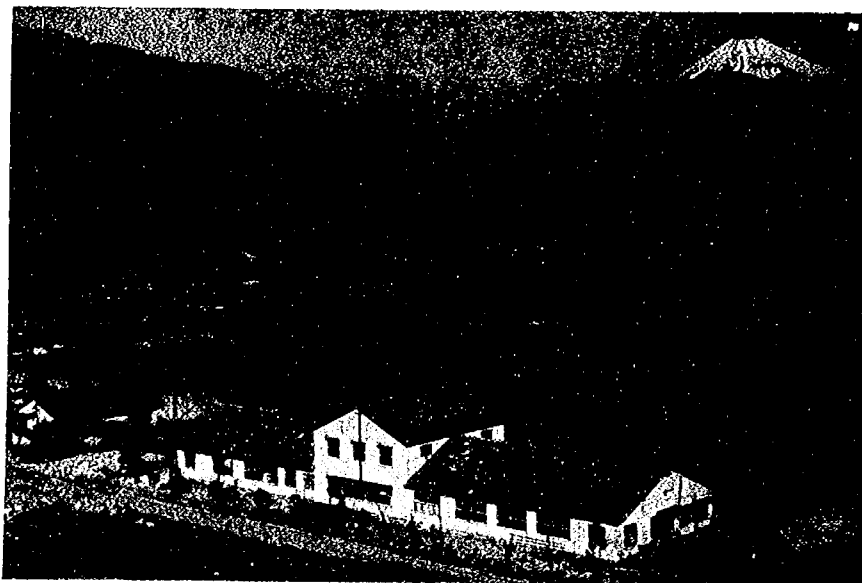


Fig. 3-1-10 Numazu Research Branch.

in the Japan Industrial Standard (JIS). Later, test work on construction machines was moved to the Japan Construction Mechanization Association which was established in 1964.

5)RESEARCH DURING THIS PERIOD

After World War II, capitalist western countries give up their secrecy concerning new technology which characteristic during war time, and free technical exchange was restored. Japan had the opportunity to receive introducing the advanced foreign technology and improved it in order to suit the social, economical, and geological conditions in Japan, the same as happened during in the early Meiji era. Also PWRI conducted the same work.

(1)Aerial Photography and Geological Survey.

At that time, aerial photography was often used for geological survey in Western countries, because the geological and topographical conditions of countries fit the characteristics of air photo, and the geological survey in their colonies was often required. A remote sensing by air photo was conducted by PWRI in the late 1940s. The aerial photography taken by the U.S. Army provided data on geology and landslides. Later the survey extended to the use of color photos and infrared photos. Now air photography is used not only for the geological survey but also for almost all surveys in the field of civil engineering.

(2)Research on the Outlet Conduit of Dam

The demand for development of flood control dam facilities under the condition of large water depth increased, as an increase in the multi-purposed dam construction. In 1953, the first facilities were imported from the U.S.A.. Although the imported facilities did not have the discharge control system, development of the control system was required. PWRI studied the cavitation and air entrainment in the outlet conduit of the dam and the designs of the inlet and outlet of the pipe. Figure 3-1-11 shows a hydraulic model experiment for the outlet conduit of the Taze Dam. By the late 1950s the facilities which could control the discharge were made in Japan and were set up on the Futase Dam.

(3)Design Standard for Composite Girder

In the early 1950s, the composite girder consisting of a concrete floor and a steal girder was often imported and used in the design of bridges. The German standard was used at the beginning. PWRI studied this by conducting model load tests on a large scale. Distribution of girders, structure and load distribution of the corresponding tilting channel and lateral channel, and the stabilization of main girder, the effect of much stopper, and the effect of bed plate on load distribution were studied. These studies resulted in the creation of the design standard for composite girder in 1959.



Fig. 3-1-11 Hydraulic Experiment for Toze Dam.

3-1-4 First Half of the Period of High Economic Growth (1958 - 1965)

1) RAPID ECONOMIC GROWTH

In 1956, the economic white paper described the famous declaration of "reconstruction period has passed". In 1960, the government formulated an "Income-Doubling Program". This program resulted in high economic growth which continued from 1960 to 1973. It should be noted that big projects such as Honshu-Shikoku Bridges, and Trans-Tokyo Bay Highway were first planned at that time. The organizational change and research work by PWRI during this period are presented in this section.

2) CHIBA RESEARCH BRANCH

The First Five-Year Program for Road Improvement formulated in 1954, started modern road construction in Japan. That advanced road study. The Chiba Research Branch was established in 1960, uniting the Structure Bridge Branch of the main office, The Road and Pavement Branch of the Akabane Research Branch, and the Construction Mechanization Branch of the Numazu Research Branch (see figure 3-1-12).



Fig. 3-1-12 Chiba Research Branch.

As for road studies, research on testing methods for asphalt stability, traffic signs, clothoid in road geometric design and estimation methods for future traffic volume were carried out during this period.

As for machines, construction techniques, and geological studies, trafficability of lime stabilization, the destruction of levee by penetrative water, performance tests for construction machines and geological survey by a sounding method were mainly studied.

As for structural and bridge studies, welding technology and the joint structure were studied for the creation of design specifications and structure standards. For the introduction of prestressed concrete into bridge design for Japan's PC rigid frame bridge, the pretension PC girder and PC box girder were experimented with the focus of bridge research has become the prolongation of span since the 1960s.

The research during this period is characterized by movement from digesting western technologies to technological independence.

3) ISEWAN TYPHOON AND KASHIMA EXPERIMENTAL LABORATORY

Casualties of the Isewan Typhoon (1959) reached up to 5,000 killed or missing. The major cause for this disaster was a high tide as shown in figure 3-1-13. This large disaster yielded a number of river improvement projects. Therefore, the Kashima Experimental Laboratory, shown in figure 3-1-14, was established in Ibaraki prefecture in 1952, in order to study port and river hydraulic model experiments.

Three hydraulic research offices of PWRI share these roles. Basic research and seashore research was studied in the Akabane Experimental Branch, hydraulic experiments for dam were conducted in the Shinozaki Experimental Laboratory, and large scale model experiments for rivers were conducted in the Kashima Experimental Laboratory.



Fig. 3-1-13 Invasion of Seawater around Yamazaki River's Mouth (Isewan Typhoon).

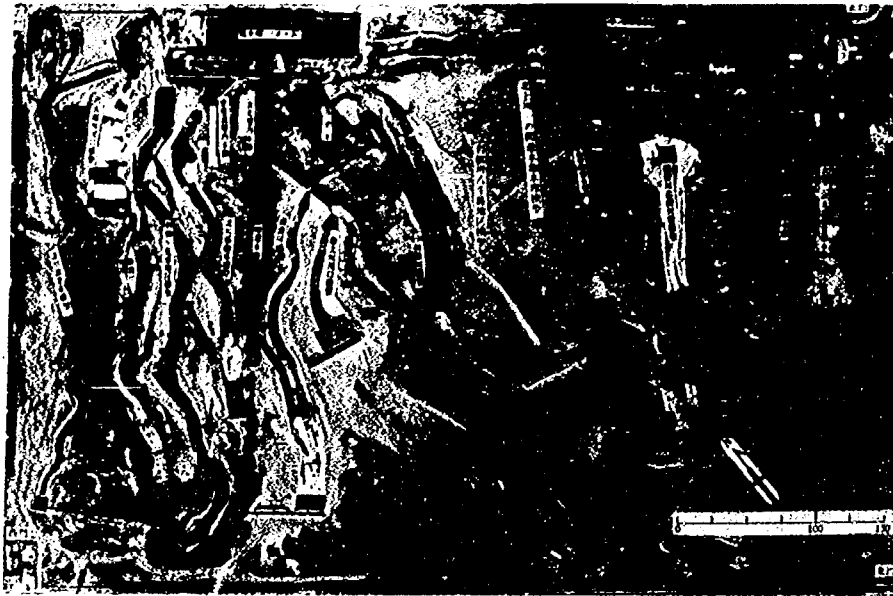


Fig. 3-1-14 Kashima Hydraulic Laboratory.

4) NIIGARA EXPERIMENTAL LABORATORY

In 1960, the Niigata Experimental Laboratory was built at Arai city in Niigata prefecture. This laboratory aimed to study the landslide as shown in figure 3-1-15. The initial work is the research on the method for landslide survey and countermeasure to landslides at the test site of the Sarukuyouji Landslide. Later the Niigata Experimental Laboratory was added a research branch for snow avalanches in 1963, when the Japan sea area was badly damaged by the heavy snow disaster.



Fig. 3-1-15 Niigata Experimental Laboratory.

5)INTRODUCTION OF THE DEPARTMENT SYSTEM

In 1958, the department system has introduced into PWRI because of an increase in research subjects and budget. Figure 3-1-16 shows the organization as of that time.

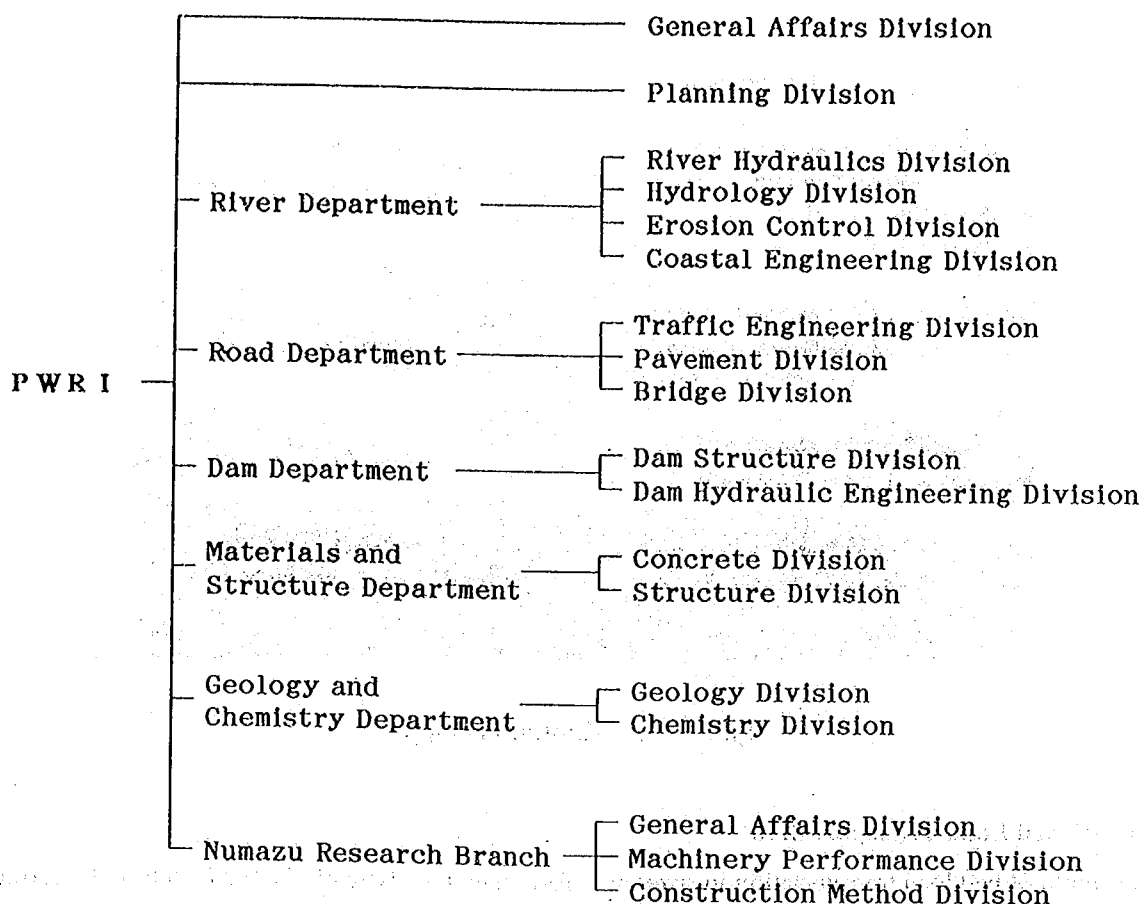


Fig. 3-1-16 Organization Chart (as of 1958).

6)OTHER RESEARCH DURING THIS PERIOD

High economic growth during the 1960s produced many infrastructure construction projects which supported the activation of research in civil engineering. The research during this period was characterized by a transition from the introduction of western technology to the development of Japan's original technology. A lot of original technology has been developed through the experience of designing big projects.

(1)Survey and Research on Honshu-Shikoku Bridges

In 1959, PWRI started the geological survey by air photo, the sounding of the Setouchi sea bottom, and the research for the construction method concerning pre-fabric strand cables for the construction of the Honshu-Shikoku Bridges. The research related to the Honshu-shikoku Bridges is changing as the progress of implementation continues. Seismic design of substructure, rust proof painting, electric rust proof, wind effect on suspension bridge were all analyzed for the construction of the long span suspension bridge.

These studies were reported in the task committee paper or manual, which supports the construction of the Honshu-Shikoku Bridges. These achievements were applied to the construction of the Kanmon Bridge built in 1973. The experience encouraged the success of the Honshu-Shikoku Bridges Project. Figure 3-1-17 shows the outlook for Kanmon Bridge.

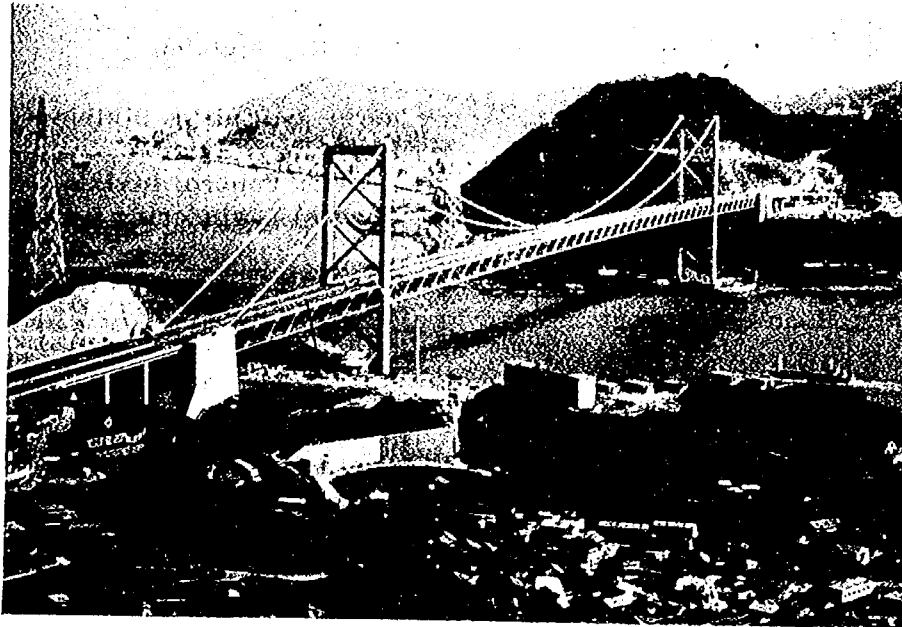


Fig. 3-1-17 Kanmon Bridge.

(2)Formula of Bed Load Transportation

A Formula of bed load transportation in rivers was formulated analytically in 1957. Before the formulation, there had been only an equation by a dimensional analysis for the relation between river flow and the motion of sand particles on the river bed. The formula is called PWRI's formula or the Sato, Kikkawa, Ashida Formula, which was named after the researchers' name. It was useful for the calculation of river-bed fluctuation because of its theoretical strictness and easy utilization. The formula triggered not only systematization of river planning but also the expansion of river-bed fluctuation analysis in two dimensional or three dimensional forms.

(3)Storage Function Method

In 1961, a method for the prediction of run-off was formulated by using an equation of motion called the storage function method. This method solved the difficulty in selection of the model parameter and allowed easy calculation. This method is indispensable for river improvement design today.

(4)Processing of Activated Sludge in Factory Waste Water

It became necessary to process both factory waste and house waste concurrently in urban areas. PWRI built the pilot plant for the sludge processing system (see figure 3-1-18) in Ichinomiya, Aichi prefecture, in order to study the processing of activated sludge in 1961. As a result of the experiment, it was found that concurrent

processing was superior in cost economization and keeping constancy of processed matter, and it could work even if one part of factory or house waste were stopped.

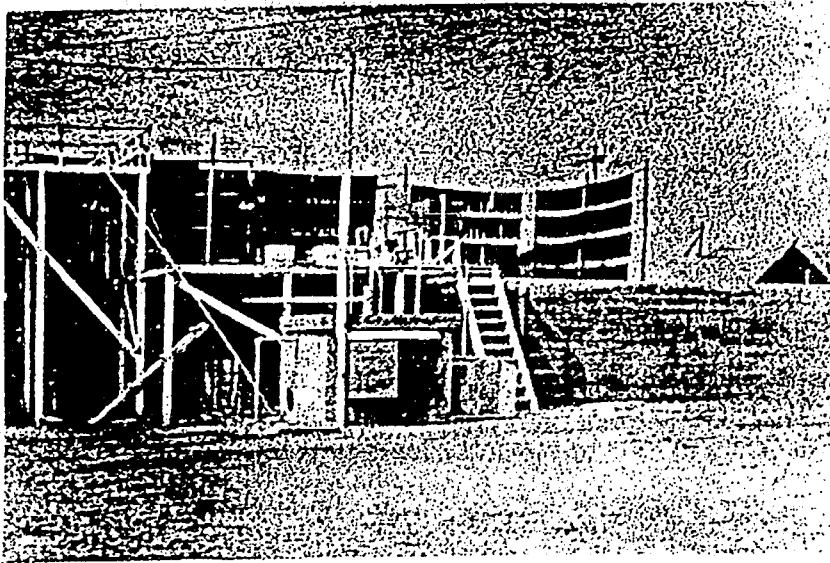


Fig. 3-1-18 Pilot Plant for Waste Water Treatment in Aichi Prefecture.

(5) Estimation Method for Sediment Yield

It is important to promote the research on sediment yield for the effective estimation of the sedimentation capacity of dam lakes or sabo plans. Since 1960, PWRI has begun research in areas such as the evaluation method for hydraulic characteristics in the basin, geographical change by river erosion, and sediment yield. The deductive formula for the sediment yield was proposed through studies including the field survey of sedimentation in 40 dams.

Now this formula is often used in estimating the amount of sediment yield for the dam, sabo, and river planning.

(6) Traffic Capacity

During this time there was no basic data on traffic capacity in Japan. Therefore, the data provided by the U.S.A. was referred to during initial road design in Japan. The first survey for traffic capacity was carried out during this period, and the data was used in the reformation of the national design standards in 1970.

(7) Traffic Signs

Traffic signs were studied through basic or field experiments in order to find a suitable size for characters, colors and so on, since the Chiba Research Branch was established in 1960. The results were applied to the Meishin Expressway which was the first expressway in Japan.

(8) Strong Motion Earthquake and Liquefaction

In 1964, a great earthquake occurred around Niigata prefecture. Figure 3-1-19 shows the damage due to the Niigata Earthquake. The data measured by seismometers for strong earthquakes was very useful in research on the Niigata Earthquake. From this experience, PWRI developed a plan for making a network of seismometers in 1960. Today, they are set in 352 places (as of May 31st, 1992) in Japan. This contributes to the analysis of strong earthquakes.

The cause for the severe disaster due to the Niigata Earthquake seemed to be liquefaction. PWRI started research on the prevention of liquefaction such as mechanisms for liquefaction, designs for vertical crasher dredge and so on. The research on liquefaction has been engaging. Recently a formula for the prediction of reformation was established.



Fig. 3-1-19 Niigata Earthquake.

3-1-5 Second Half of High Economic Growth (1966 - 1973)

1) NEW RESEARCH DIVISION AND DISTORTION BY HIGH ECONOMIC GROWTH

The first half of the period of the high economic growth caused an environmental pollution. These issues were represented in decisions for the plaintiff in the case of the Itai-Itai Disease (1971), the Minamata Disease (1973), which results from the discharge of factory waste, and noise emission problem at Osaka International Airport. Another distortion during this period was a lot of traffic jams in large cities. An increase in traffic accidents became notable. The keyword "Traffic War" became popular at that time.

These distortions forced PWRI to build new research divisions studying these environmental problems. The Foundation Engineering Division 1966., the Ground Vibration Division, 1968., the Urban River Division, 1969., the Traffic Safety Division, the Planning Division, the Slope Failure Division, 1970., the Water Quality

Division, the Traffic Environment Division, the Fill-Type Dam Division, 1972, the Advanced Waste Treatment Division, the Water Resources Engineering Division, the Soil Dynamics Division, and the Earthquake Engineering Division, 1975 were established in PWRI.

2)RESEARCH DUING THIS PERIOD

As the research, aimed at efficiency in infrastructure construction was near completion at that time, PWRI changed gradually its trend of research. More diversificated or complex research began to be taken on from that time. The following research is the most notable.

(1)Lithological Classification of Ground Rock

Dam building was often obstructed by unsuitable geological bed conditions at that time, because suitable sites were rare. The survey for damsite geology was becoming more important. PWRI carried out the lithological classification for damsite geology in order to estimate the strength and reformation characteristics of the rock plate. This work resulted in an increase in the number of possible-damsites in Japan. The research is still ongoing now, aiming for further progress in utilization and for wider application.

(2)Detached Breakwater

At that time, examples that the beach erosion was increasing because of the construction of harbor facilities or the utilization of river sand for construction materials. In order to prevent the beach erosion, the detached breakwater built parallel with the seashore was developed. Moreover, it has also the faculty for impetus of the sedimentation of sand. The first detached breakwater was built in 1971 at the Kaike Beach at where almost all of the beach sand had run off. Figure 3-1-20 and 3-1-21 shows the same site at Kaike Beach. Figure 3-1-20 shows the beach without the breakwater, and 3-1-21 shows the beach revived by the breakwater. This success made it the popular method for the protection of sand run-off from beaches in Japan.

(3)Numerical Simulation Model of Water Pollution

It was difficult to predict the level of water pollution which began to be apparent in the period of high economic growth. The luck of a prediction method for water pollution resulted in Itai-Itai disease and Minamata disease. This situation demanded the development of countermeasures to water pollution. PWRI studied the diffusion of contaminants to rivers and lakes, re-aeration, river self-purification and developed a numerical simulation model for water pollution.

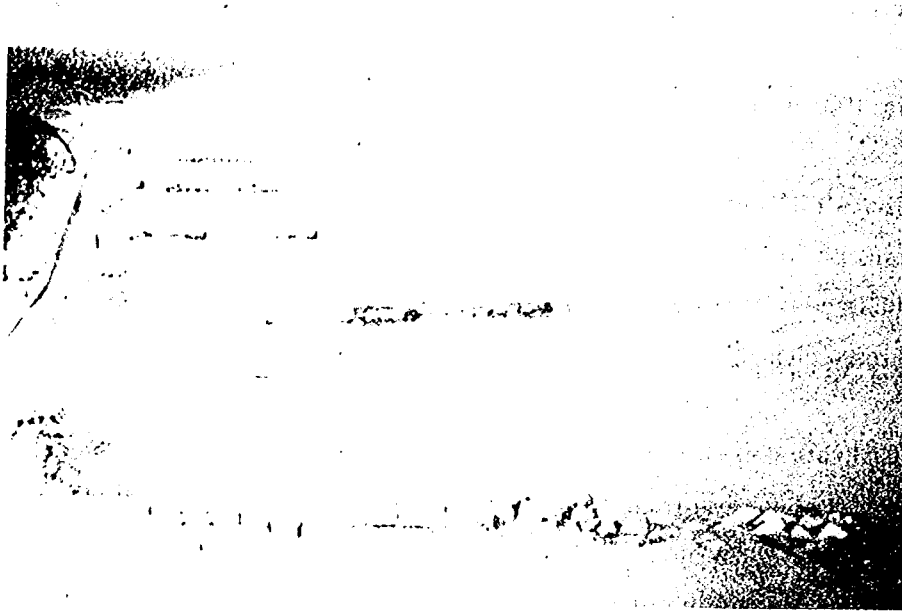


Fig. 3-1-20 Kaike Beach (before the construction of detached breakwaters).



Fig. 3-1-21 Kaike Beach (after the completion of detached breakwaters).

(4)Design of Flat Arch Dam

The collapse of the foundation of the Malpasset Dam in France focused attention on the foundation design because it had been considered that the rock plate was harder than the dam.

Designs for the flat arch dam, developed by PWRI, reduced the shear force in the rock plate without changing the inside stress of the dam. The design method for flat arch dams improved the stability remarkably. Figure 3-1-22 shows the Yahagi Dam which has typical flat arch dam features.

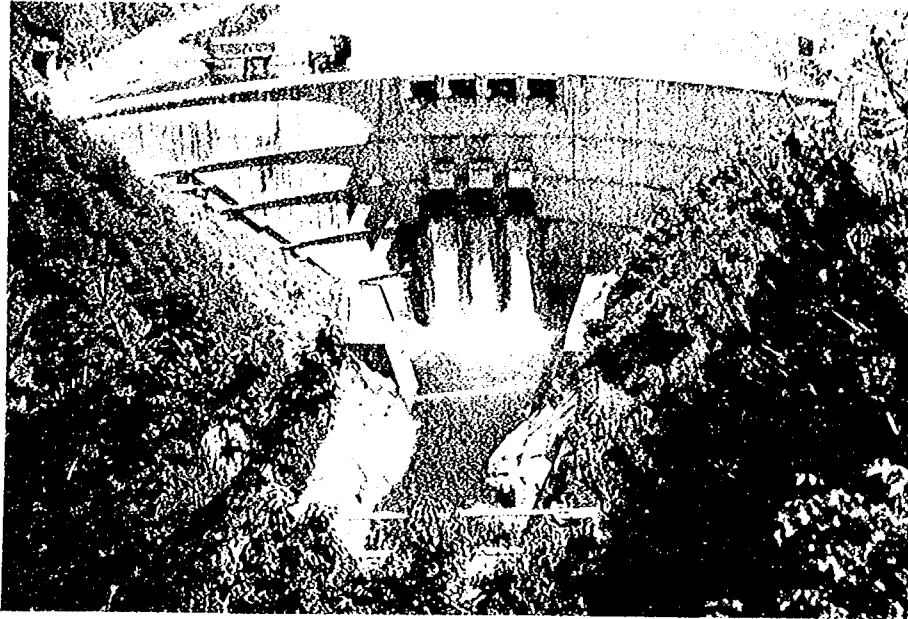


Fig. 3-1-22 Yahagi Dam.

(5)Over Flow Levee

The major reason for the Uetsu disaster in 1967 seemed to be the destruction of the levee by over flow. PWRI developed an "Armored levee" in which non woven fabric of high polymer material was laid just beneath the slope of levee. Figure 3-1-23 shows the experiment for over flow on the "Armored levee". Today an "Armored levee" was built at Kako River etc.. The work pioneered a new policy for protection against exceptional flood.

(6)Effect of the Honshu-Shikoku Bridges on Local Economy

Effects of the Honshu-Shikoku Bridges on local and national economy were simulated economically. At the beginning of this research, impact on a mileage was investigated, and this improved the standards for road geometry. But a more elaborate analysis was required after a problem concerning the regional economic differences occurred. Research on the development of numerical models concerning local economics and their simulation method were carried out since 1967. PWRI is now conducting the research on the method for estimation of the effects of infrastructure investment.



Fig. 3-1-23 Real Scale Experiment for Armored Levee.

(7) Analysis of Traffic Accident

The number of traffic accidents became an urgent problem in this period of economic growth. PWRI began to carry out research on the relationship between traffic safety and road geometry such as the intersections, road width, and facilities for traffic safety since the foundation of Traffic Safety Research Division in 1970. The research carried out up until now are as follows;

- Sampling of the dangerous zone (-1979)
- The effects of countermeasures against traffic accident on transportation, and statistical measuring methods for the efficiency of the countermeasures ensuring safety (1980-1984)

Recently a data base for traffic accident information was created.

3-1-6 Stable Growth (1974-1986)

1) STABLE GROWTH

A Dollar Shock (1971) and a Oil Shock (1973) discontinued the rapid economic growth in Japan. The government carried out a policy for a reduction of domestic demand and the economization of energy consumption. Stable economic growth began.

The policy for an activation of regional areas was created at that time. Balanced deconcentration of industry in regional areas was the focus of the 3rd Comprehensive National Land Development Program.

2) MOVE TO TSUKUBA CITY

PWRI moved to Tsukuba city in 1979. That was decided by the Cabinet in 1963. This movement was undertaken in order to promote a deconcentration of government offices to rural areas from Tokyo. Migration began in 1971 with the construction of a test track and was completed in 1979, uniting all departments in Tsukuba

City. New divisions such as the New Transportation Systems Division, the Ultimate Disposal Division, the Flood Disaster Prevention Division, the Dam Hydraulic Engineering Division, the Planning Division, the Personnel and Welfare Division, were established at that time. The main office and the Chiba, Akabane Research branch, and Shinozaki, Kashima Experimental Laboratories were united in Tsukuba city (see figure 3-1-24,25). Today PWRI has about 500 staff members compared to 38 staff members at PWRI's inception.

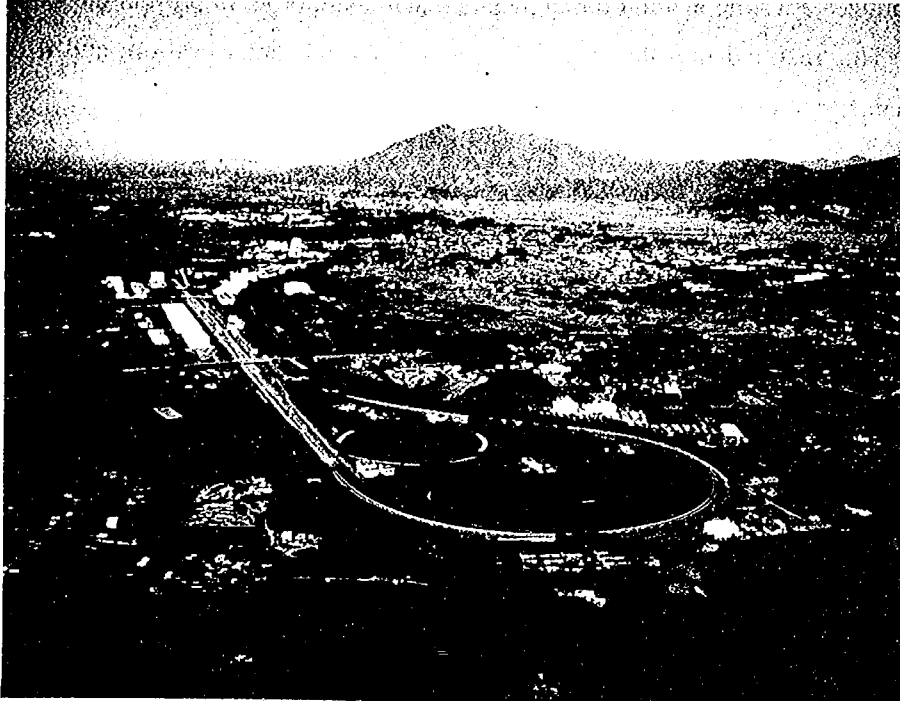


Fig. 3-1-24 Bird Eye's View of PWRI.

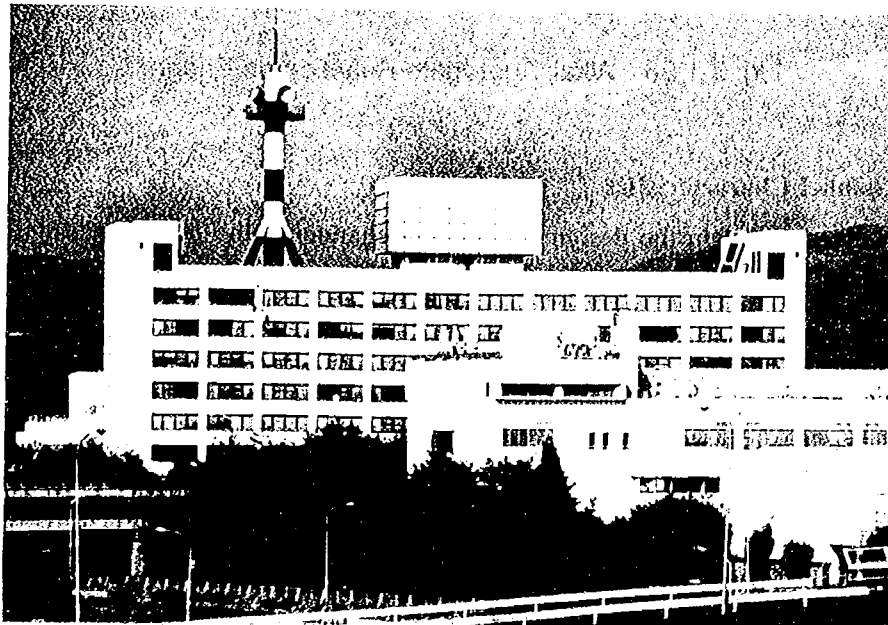


Fig. 3-1-25 Main Building of PWRI.

3)RESEARCH DURING THIS PERIOD

Research during this period was characterized by the development of original technology and this way reached the same level as in Western countries.

(1)Study on Alkali Aggregate Reaction

Alkali aggregate reaction, shown in figure 3-1-26, is one of the causes for the deterioration revealed in the 1970s. PWRI standardized a testing method for aggregate materials in order to prevent the expansion of an alkali aggregate reaction. This resulted in a decrease in the case of rapid deterioration, and it contributes to the maintenance-free character of newly constructed concrete structures.



Fig. 3-1-26 Alkali Aggregate Reaction on Bridge.

(2)Study of River Channel Characteristics

In a river improvement plan, the design of the river channel is the most important factor to prevent disasters, because large scale construction becomes possible as construction technology progresses. PWRI proposed a method for obtaining the river width and the main channel width by finding the relationships among bed material, width of main channel, gradient of river bed and hydraulic characteristics of flood. Today river improvement projects are formed based on this idea.

(3)Study on the Use of Waste Sludge for Construction Material

An increase in waste sludge is one of the most serious problems in Japan. PWRI discovered a way to reuse waste sludge for construction material such as pavement, and concrete chemicals for subsoil improvement. Many of the local governments which have the problem of sludge pressing, apply PWRI's ideas for waste sludge.

(4) Study on RCD Method

It is well known that a gravity concrete dam is the most suitable type for Japanese mountainous geography and a large amount of flood flow compared to the capacity of a dam lake. However, high labor costs due to high economic growth pushed up total construction cost. The high-rise of costs required the economization of the construction of gravity dam. RCD (Roller Compacted Dam) established by PWRI has many advantages in terms of allowing both economical and rapid construction. Figure 3-1-27 shows the view of the dam construction site using RCD method. Now RCD is popular in Japan and is exported to foreign countries.

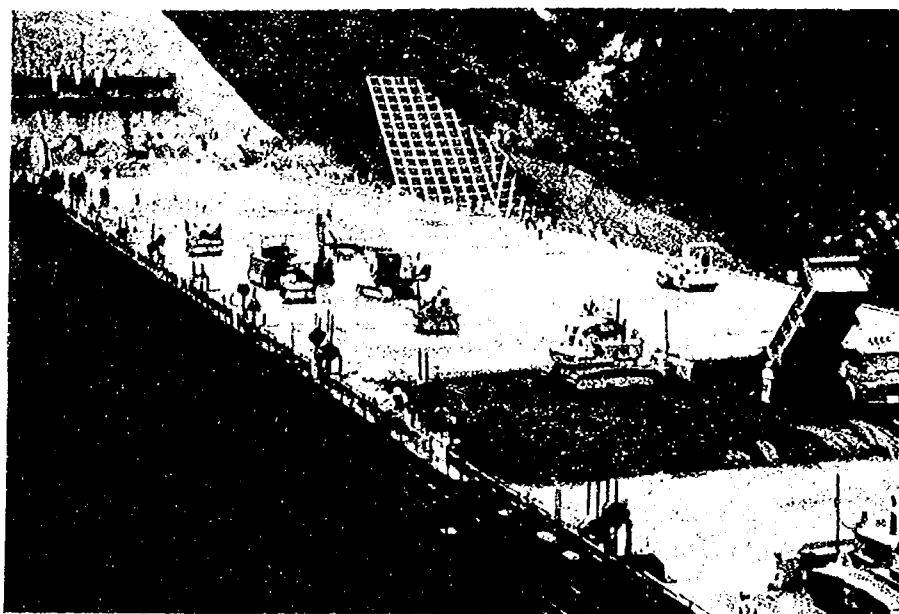


Fig. 3-1-27 RCD Method in Dam Construction Site.

(5) Field Survey of Dangerous Sites due to Sand and Soil Collapse

High land value made the residential area narrow and steep. That led to an increase in accidents by landslide. PWRI conducted the field survey, the topographical and statistical analysis, and the numerical calculation of land collapse including debris flow, landslide, slope failure, snow avalanche in order to develop countermeasures and to prevent disasters. This study resulted in the discovery of 180,000 places in danger of collapse and the development of new countermeasure methods.

(6) Study on the Ventilation of Road Tunnels

Long distance road tunnels have the problem of a lack of ventilation for emission gas. From 1975, PWRI studied the electric dust collectors and a longitudinal ventilation system. The results advanced the ventilation efficiency of systems and economized the set-up cost for these systems.

(7) Development of a DJM Method

The hardening of soil is one of the most important problems for construction in city areas in Japan, because almost all large cities are built on weak stratum. The DJM (Dry Jet Mixing) method developed by PWRI aims to

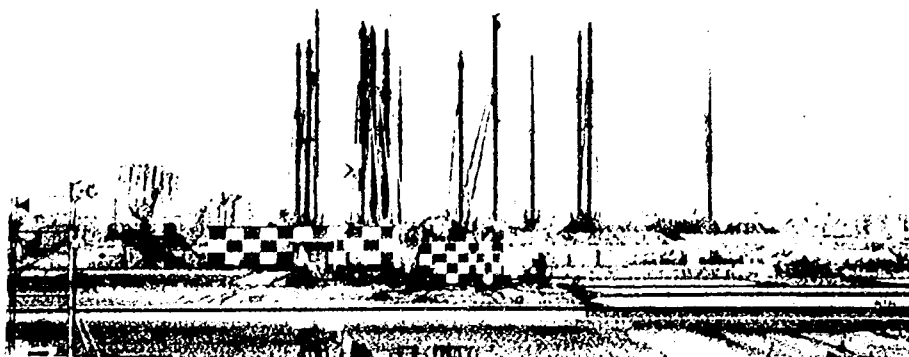


Fig. 3-1-28 DJM Method on Haneda Offshore Expansion.

harden the soft ground plate. Dry cement or lime is directly mixed with soil by this method. Many advantages such as the firmness, and quickness have made DJM very popular. The total volume of soil hardened by the DJM method had reached 780 million m³ by 1991. Figure 3-1-28 shows the DJM method at the Haneda International Airport offshore expansion.

(8) Study on the Stabilization of Road Cut and Bank

The high cost of land forced the slope of road banks and road cuts to be steep, therefore increasing the dangerous possibility of landslides. PWRI cleared the mechanism of sliding by water penetration and studied the prediction method for landslide and design method by using a geotextile as shown in Figure 3-1-29.

(9) Study on the Recovery from Earthquake

Anti-earthquake bridge design created a new problem while preventing bridges from perfect destruction. The problem was that there was no criterion for rebuilding damaged bridges. The Miyagi Offshore Earthquake (figure 3-1-30 shows crack on bank), which occurred in 1978, triggered the study on repairing earthquake-damaged bridges.

PWRI published the "MANUAL FOR REPAIR METHODS OF CIVIL ENGINEERING STRUCTURES DAMAGED BY EARTHQUAKES" in 1985, for repairing earthquake-damaged structures. This method includes the criterion to evaluate whether damaged bridge should be repaired or newly built. This manual was used for the recovery after the Mexican Earthquake.

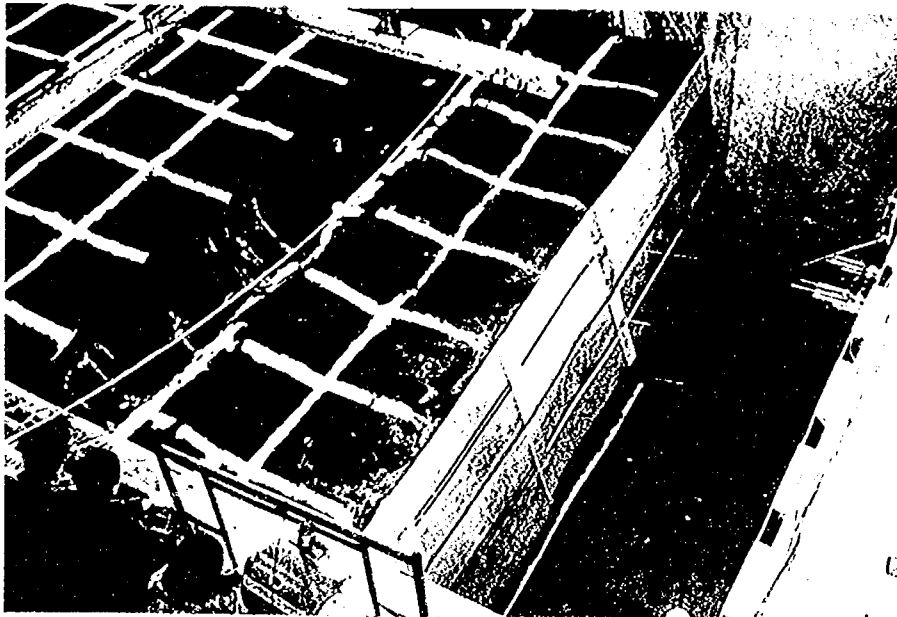


Fig. 3-1-29 Experiment for Reinforcement of Embankment.



Fig. 3-1-30 Miyagi Offshore Earthquake.

3-1-7 Present (1987 - present)

1)SOCIAL AND ECONOMIC BACKGROUND

The Forth Comprehensive National Land Development Program, formulated in 1987, aimed at;

- *Developing functions in regional cities.
- *Making regional areas competent.
- *Creating unique regions.
- *Sharing roles and creating a cooperative relation among regions.

In order to complete the project, the Honshu-Shikoku Bridges are scheduled to be completed in 1998 (see figure 3-1-31), as well as the Trans Tokyo Bay Expressway, and the Second Tomei- Meishin Expressway have been planned.

The break-up of the U.S.S.R. signaled an end to the Cold War. This has revived nationalism and has created instability in world politics. Japan's economic and technical cooperation is needed to help maintain world political order.

Global warming, acid rain, deforestation, the ozone hole and abnormal weather in parts of the world demand economic cooperation and new technology. In addition, the demands for improvement of life standards became larger.

2)SYSTEM AND ORGANIZATION OF RESEARCH

(1)Organization and Budget

The Construction Management Engineering Center was founded in 1991 for the purpose of research in



Fig. 3-1-31 Honshu-Shikoku Buridges.

construction management for both government and private company and the activation of the construction industry as a whole. Figure 3-1-32 shows the organization of PWRI as of January, 1993. Now PWRI has 9 departments, 1 center, 1 experimental laboratory and two support departments. The legally fixed number of officials is 472, and 50 accept researchers. Figure 3-1-33 shows the research budget during the recent 10 years. As shown in this figure the peak of the budget was 46 million dollars in 1987. However, the number of joint projects with private companies is increasing recently, therefore the real research budget is much larger than the 1987 level.

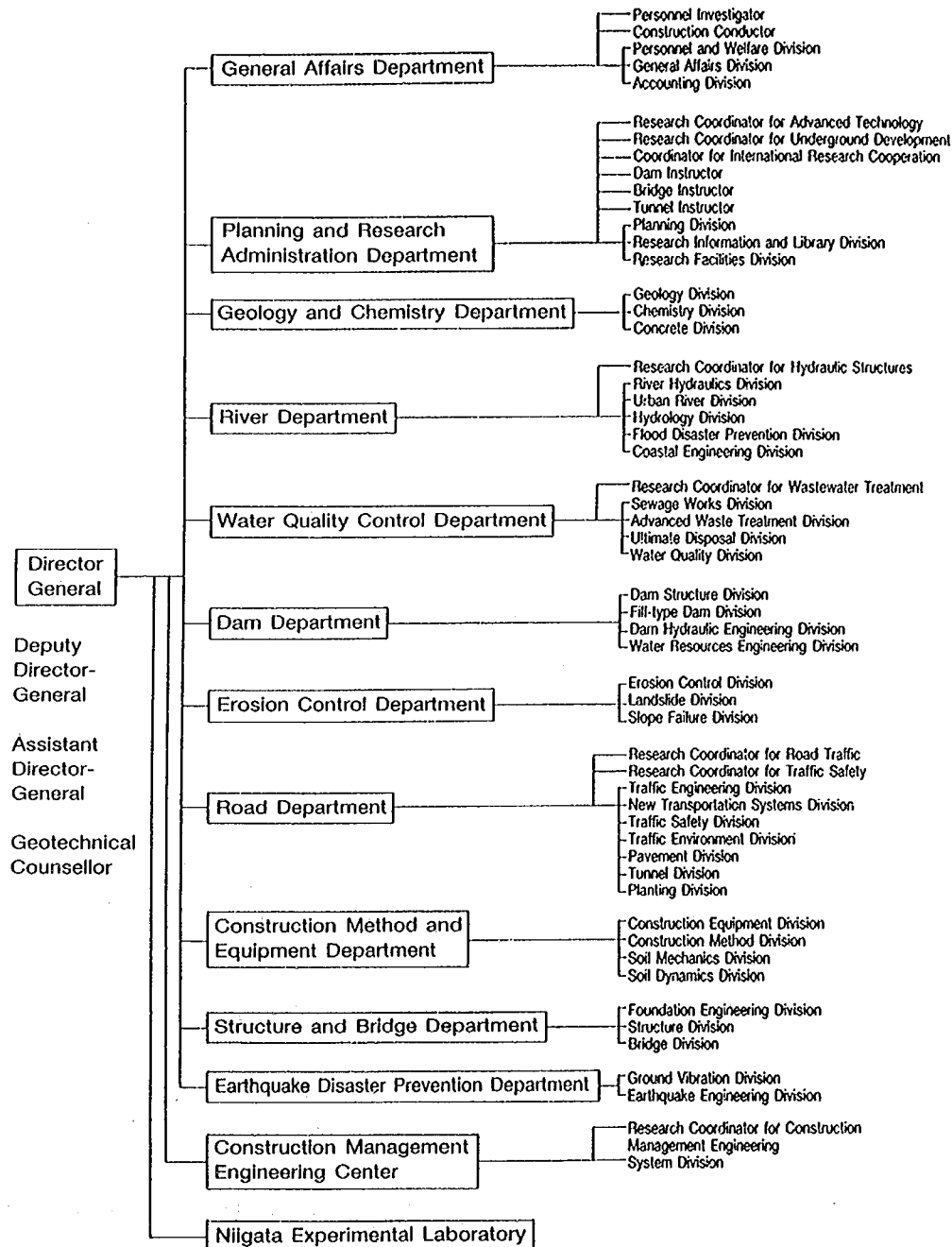


Fig. 3-1-32 Organization Chart (as of January, 1993).

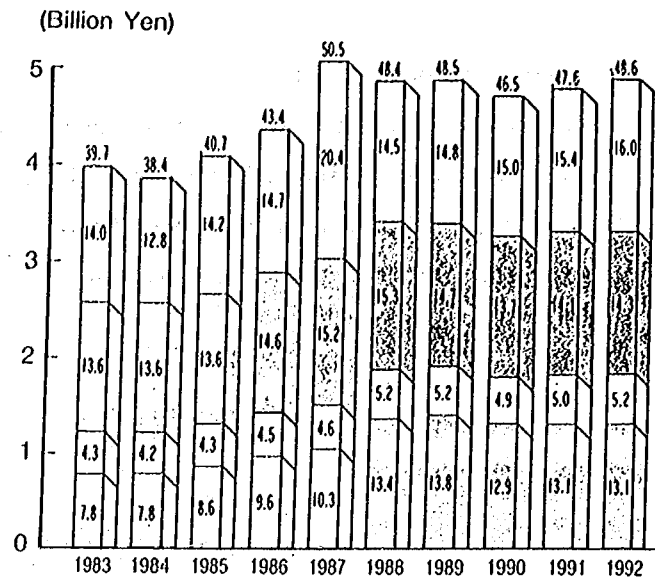


Fig. 3-1-33 Research Budget during the Recent 10 Years.

(2) Research System

The Five-year Research Plan characterizes research at PWRI. This plan aims to make clear the direction of research in response to social and administration side's needs through a project plan. Now, research in PWRI is carried out under the Third Five-year Research Plan (1992-1997) formulated in 1991. 478 different kind of research are being carried out in PWRI during the 1992/1993 fiscal year.

An other characteristic of research in PWRI is the practice of joint research programs with other organizations such as divisions in PWRI, universities, or private companies. For the rationalization of joint research projects, it is noted that a precise plan for research is to be made by sufficient discussion and management. Joint research programs were managed in order to gain a achievement within 3-5 years.

3) PRESENT RESEARCH

Most of present research aims at effective utilization of national land, economization of materials and energy and environmental problems. Especially in the case of the environmental problems the scale of experiments becomes large. Furthermore, interdisciplinary research among the physical sciences including biological, chemical, and material engineering, electronics, human engineering, and information engineering characterize recent research conducted by PWRI.

(1) Environmental Problem

Climatic change through global warming is feared in the future. The research on predicting change is being conducted by many scientists all over the world. PWRI has established research programs concerning the environmental problems. A numerical simulation method for reversing the effects of global warming on rainfall in a river basin is being studied in PWRI. Management methods for river channels, seacoasts and dams are also

being studied in PWRI due to effects of global warming.

PWRI is also studying amenities. The research includes on enhancing the river landscape, a method for improvement by natural materials, tree planting on the road side, construction of the "Eco-road" concept in which animals could cross the road (see figure 3-1-34) and anti-eutrophication in reservoir using biotechnology.



Fig. 3-1-34 An Animal Pass of the "Eco Road".

(2) Technology for Maintenance and Reforming of Structures

The alkali aggregate reaction was discovered through the experience of repeated accidents on concrete structures in Japan during the 1980s. Prevention methods for alkali aggregate reaction were studied at PWRI. These included selection of material, the repairing method for deteriorated concrete by covering material, the non destroy method to inspect the repairing effect quantitatively by using the infrare, the super sonic and the elastic wave.

On the other hand, the field survey for fatigue and damage at the welding point of plate girder was conducted. The repairing method and the reinforcement method for members were studied using the surveying results.

(3) Sewage Processing Technology Using Biotechnology.

Biotechnology is applied to advanced sewage processing systems. In detail, micro capsules of bacterium which cleanse waste water and absorb rare material, by fixing to the bacterium on plastics surfaces, and the development of a bioreactor (see figure 3-1-35) have been studied. This research downsized the processing unit by 1/2 - 1/10 compared with the usual, and the high condensing of special bacterium.

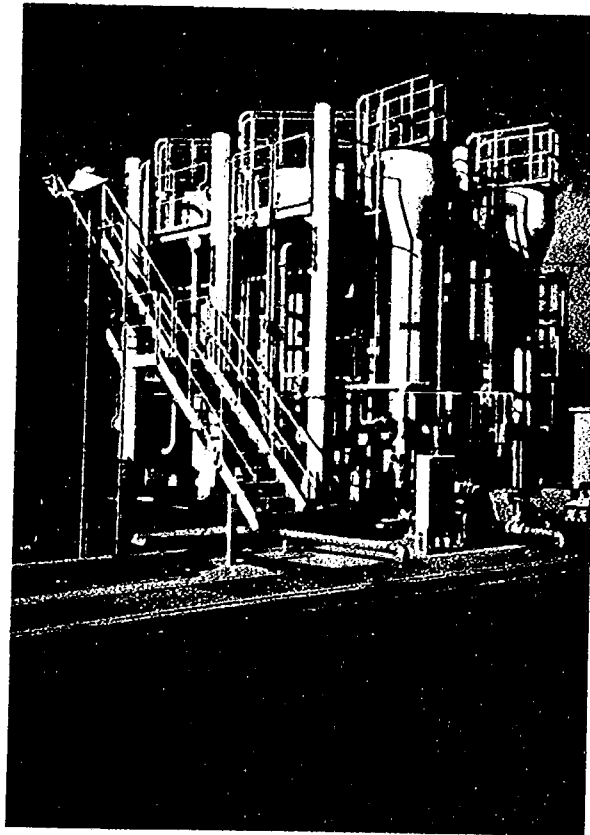


Fig. 3-1-35 Bio-Reactor at Pilot Plant.

(4) Seismic Design for Fill-Type Dam.

Obtaining analytic results concerning the dynamic characteristics of the fill-type dam, materials and the relation between the motion of earthquakes and the seismic response of dam, all makes it possible to develop the seismic design for the fill-type dam. Now this method is popular as a guideline for the seismic design of newly built fill-type dams.

(5) Research of Pyroclastic Flow

The eruption of Mount Unzen (1991) caused disaster through pyroclastic flow. This disaster urged research on pyroclastic flows. PWRI is studying the basics of the vertical or longitudinal distribution of velocity and density, and pressure. Figure 3-1-36 shows the model experiment for pyroclastic flows. PWRI is also studying the research for developing countermeasures against pyroclastic flows.

(6) Research on the Second Tomei-Meishin Expressway

The Second Tomei-Meishin Expressway will be the new major transportation line between the Tokyo area and the Osaka area. Maximum design speed of these expressways are 140km/h, higher than that of the First Tomei-Meishin Expressway for the purpose of increasing transportation capacity. It is expected that both new expressways will face difficulty in their construction, because construction sites are in mountainous area. PWRI is

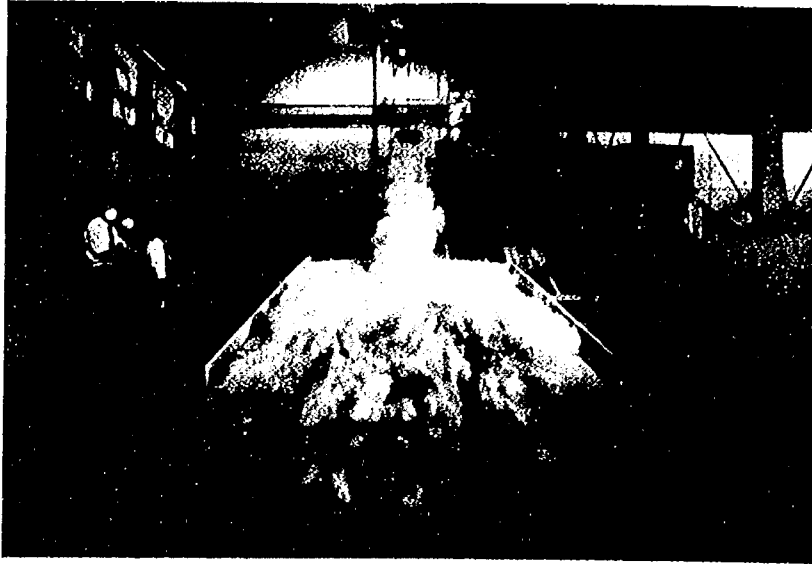


Fig. 3-1-36 Experiment for Pyrocrastic Flow.

studying tunnel technology especially with large cross sectional areas and wide bridges with multi lanes.

Other problems in a design speed of 140km/h are the psychological effects on the drivers. Psychological reaction to this driving speed was tested by using driving simulator. These tests include sight distance at 140km cruise, the road alignment, gradient and width of the road, lighting in tunnel, visibility of traffic signs, safety systems, dispersion of emission gas or noise. Countermeasures against these problems are studied now.

(7) New Technology in Pavement

High speed driving in the rain creates the hydroplaning and noise problems. PWRI studied the way to reduce these problems, and the permeability of pavement.

Moreover, the RCCP (Roller Compacted Concrete Pavement) developed in PWRI is one of the new technology for pavement. According to the RCCP method, zero-slump lean concrete is rolled at road construction sites. RCCP provides effective and low-cost construction and the best design mix in concrete. Recently the Ministry of Construction has pilot plants using RCCP.

(8) RACS (Road-Automobile Communication System)

RACS presents an information service linking car drivers and the road administration office. PWRI developed RACS by which information about the position, accidents and road implementation is relayed to cars through beacons at the road side set directly (see figure 3-1-37). RACS is in the field testing stage in Tokyo, Nagoya and Osaka. The next step of the development of RACS is facsimile transport.

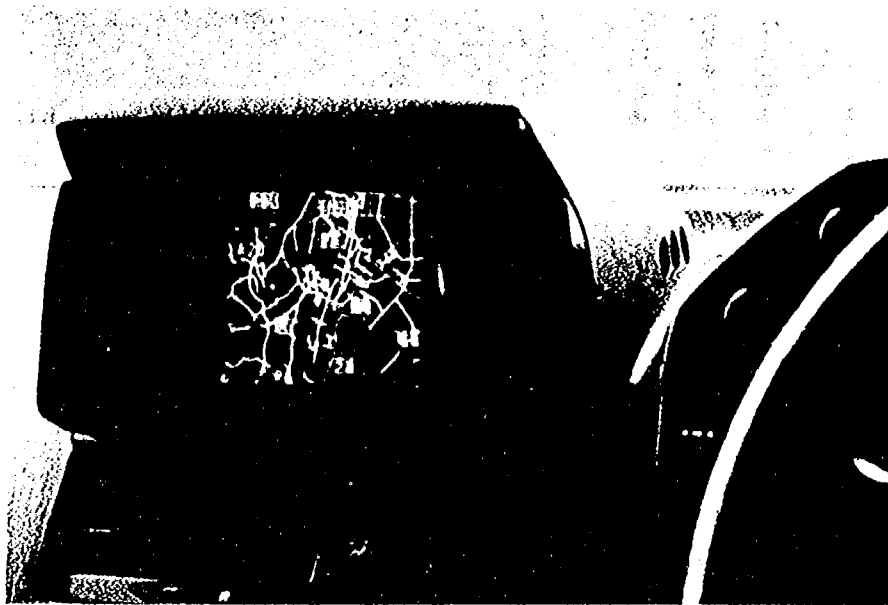


Fig. 3-1-37 Road/Automobile Communication System.

(9) Technology for Utilization of Underground Space

Over population in cities, demands for construction of infrastructure, and expensiveness of the land value require the use of underground space. PWRI conducts research on utilizing underground space using surveys on existent underground facilities, design and construction methods, development of environmental control systems, fire control systems, and underground transportation systems.

(10) Large Scale Wind Tunnel Experiment

The Akashi Narrow Bridge with a 1990m length and 4000m in its whole length would become the largest suspension bridge in the world when it is completed. It was simulated with a scale of 1/100 in the wind tunnel with a width of 41m, and a height of 4m. Figure 3-1-38 shows the experiment for bridge stability against strong wind. In this experiment, countermeasures against vibration both under and after construction would be studied under the every-directional winds.

(11) Information System for Disasters

For effective recovery from disaster and prevention of the expansion of disasters due to earthquakes or heavy rain fall, a system for the gathering and communication of information concerning disasters requires development.

PWRI is developing the disaster recovery planning support system. This system presents the information which is necessary for quick recovery by using helicopters in the case of serious disasters occurring in large cities. The results published on the "GUIDELINES FOR DISASTER INFORMATION SYSTEMS (proposal)".

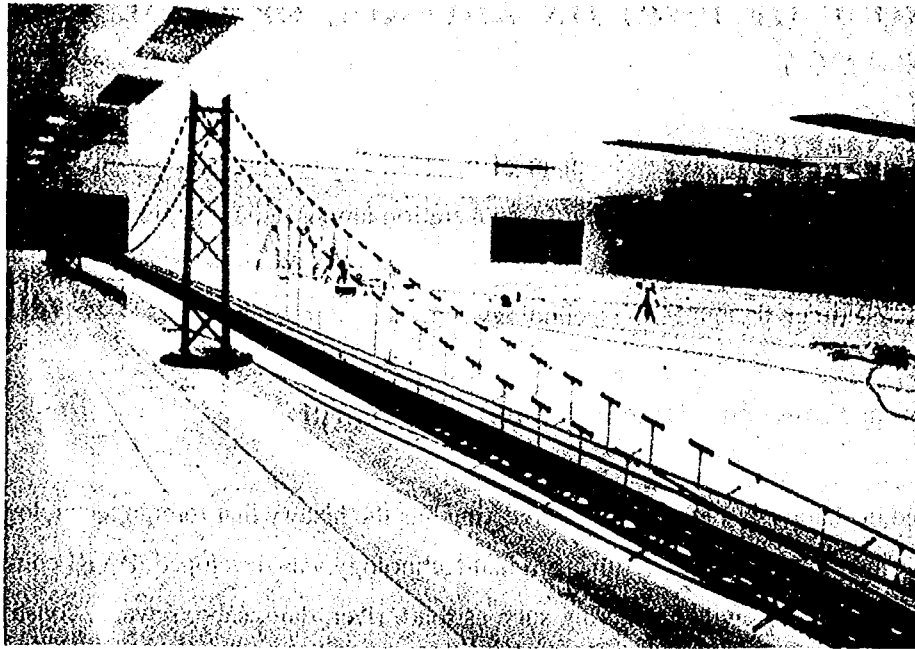


Fig. 3-1-38 Aerodynamic Experiment for Akashi Bridge.

(12) Research on Construction Management

In order to activate the construction industry and to raise the Japanese technical level, PWRI conducts research in construction management, the improvement of the cost-estimating methods, investigation of foreign construction management systems, and the system for smooth application of new technology to practical construction, and structural standard.

3-2 THE ROLE OF PWRI ON ADVANCE OF CIVIL ENGINEERING TECHNOLOGY

PWRI plays many roles in the development of the civil engineering industry in Japan. Contributions to leading technological development, arrangement of cooperation among industry, university and government, and engineering education are notable.

The role of PWRI in civil engineering technology is presented in this chapter.

3-2-1 Promotion of Pioneering Research and Development

As mentioned in chapter 2, Japan's civil engineering has the history that foreign technology was introduced at the beginning of modern Japan, and after that original technology was developed. PWRI contributes to making history in every field related to civil engineering such as road, river, dam, sabo, sewage, construction machinery and technology, bridge, wind and seismic engineering. Today almost all Japanese technology is at the highest level in the world. Main applied research fields conducted by PWRI in the past are;

- Methods for control of alkaline aggregate reaction
- River planning method including the prediction of sediment yield, bed fluctuation, movement of bars
- Sewage processing technology in narrow land area
- RCD method (Roller-compacted Dam method) which can economize the construction work
- Erosion control techniques surmounting rigorous topographical and geological conditions
- Roads with high efficiency, durability and safety : lighting systems/tunnel ventilation systems/information systems
- Construction machinery with easy operation, safeness, and hi-c/p
- Technology for long span suspension bridge
- Seismic engineering which prevent earthquake disasters on soft ground
- Automatic design system clearing worker's pain

Also PWRI has contributed to basic research. Research work completed by PWRI has been adopted in digesting western technologies. It often seems that the technology named by PWRI are seen in the publications of civil engineering. In the beginning of civil engineering in Japan, PWRI had done much basic research, and moreover many researchers of PWRI moved to universities.

Needles to say, the role of PWRI as an organization of the Ministry of construction is very important. The most important work of PWRI is in proposing new projects with new technology to the administrative organization of Ministry of construction through the process of analysis of social and economic problems, investigation of new projects, technological development concerning new projects, and evaluation of the plan.

Direct management of construction work includes roads, river improvement, dam construction, and sabo works. PWRI supports this construction from a technical aspect. PWRI evaluates the construction plan, and gives advice for the plan. Researchers from PWRI would go and support if problems occurred at the construction site.

PWRI often publishes manuals and standards for construction work. These are very useful for the systematizing and rationalization of construction.

For obtaining the cooperation of residents near construction sites, it is important for them to recognize the excellency of the Ministry of construction in the technological and administrative fields. In order to show the excellency of researchers at PWRI, they attend the symposiums and the Civil Engineering Society's research conference, and arrange joint projects with universities.

3-2-2 Job Training

In the education of civil engineers PWRI has played an important role. In the beginning of civil engineering education in Japan, PWRI supplied researchers as faculty staff to universities. This faculty staff had experience in practical research at PWRI, therefore, they taught in universities from the stand point of not only theory but also practice. As a result of it, many students graduated from universities to be engineers with practical sense.

The Construction College of the Ministry of Construction is a unique educational organization for the Ministry of Construction staff. Engineers of government and local public bodies study the newest technologies there. Many research members of PWRI teach civil engineering as the college temporary tutors.

On the other hand, young researchers belonging to PWRI were educated through the short-term training programs, but mainly through the job training.

An interchange of engineers between PWRI and the administration division of the Ministry of Construction has merit in that the engineer from the administration division is able to study the basics of civil engineering through the experience of research and development of new technology and of making a technical manual, while researchers of PWRI are able to absorb the practical know-how from the construction side, trends in social problems, and the demands from the administration side.

3-2-3 Coordination of University and Private Company with PWRI

The total management of civil engineering technology in Japan is an important role of PWRI. It is well known that private industry studies practical subjects and the university studies basic or theoretical subjects. PWRI has both faces of practical and theoretical. The neutral position of PWRI allows the position of coordinator. Joint projects between PWRI, universities and private construction companies allow the transiter of technology from university to construction company or from construction company to university.

(1) Giving Research Information to Universities and the Practice of Joint Research

It is well known that universities can concentrate on special subjects but rarely gather information for practical construction work. Furthermore, they have a high ability but not a large enough budget and facilities.

In the relationship between PWRI and universities, PWRI gives practical information to university staff

through attending research conferences, and promoting joint research programs, then they utilize the analytical ability of universities for practical construction work. This makes it possible to join PWRI's large and expensive facilities with the theoretical and analytical ability of universities.

(2)Coordination with Private Companies

Direct cooperation with private companies was obviously seen with the establishment of the Construction Mechanization Association in 1964. It promotes the mechanization of construction work through cooperation with private companies.

Because of an increase in construction work, the role of private industry is becoming important. Recently, the practical work was often left to private companies. Development of applied technology by the private sector is expected to be strong.

Private companies characterized these items such as difficulty of conducting basic researches, poor research budget and facilities, and the production of original technology only for their own use. PWRI supports the applied research of private companies through research funds. The details are written in chapter II. The results of the research are opened to the public through the publication of several journals.

4 PERSPECTIVE ON ECONOMY, SOCIETY AND PWRI

"Meet the needs of the time" has been an ideal of PWRI, therefore, prediction of problems concerning future economy and society are some of the most important work of PWRI. Trends in the Japanese economy and society, and how it affects future perspectives in research subjects for PWRI are introduced in this chapter.

the needs of the community, the needs of the individual, and the needs of the nation. The needs of the community are the needs of the people who live in the community. The needs of the individual are the needs of the person who is living. The needs of the nation are the needs of the people who live in the nation. The needs of the community, the needs of the individual, and the needs of the nation are all interconnected. The needs of the community are the needs of the people who live in the community. The needs of the individual are the needs of the person who is living. The needs of the nation are the needs of the people who live in the nation. The needs of the community, the needs of the individual, and the needs of the nation are all interconnected.

4-1 GENERAL TREND OF SOCIETY

Key concepts which characterize future trends are Aging, Women Labor, Information-Oriented Society, Comfortableness in Living, Environmental Conservation, Natural Resources and Energy Economizing, Urban Problems and Internationalization. There may be clues for the examination of future trends among the above concepts. These key concepts are discussed in this section.

1) SHORTENING OF LABOR

Average longevity in Japan is the longest in the world, and the average number of children in a family is less than 2.0. A population pyramid in 1950 and 1988 in figure 4-1-1 shows the decrease in new-born babies and the increase in aged people. The base of the pyramid in 1950 is the largest and it shifts to the middle generation in 1988, whereas the youngest generation in 1988 is much smaller than that in 1950. These features of population and family statistics indicate that Japan will become an aging society as shown in this figure. Figure 4-1-2 shows the comparison of the rate of aged persons (above 65 years) between Japan and other advanced countries. This figure shows that the labor force in Japan will age much sooner than that in others. This is a big disadvantage for the labor force.

On the other hand, there is an advantage. Figure 4-1-3 shows the share of women in the labor market. There is a possibility that the number of women in labor force will increase in response to a shortage of labor because Japanese women in their thirties are often without an occupation. This situation might be positive from the view point of feminism.

However, such situation could not solve the problem perfectly even if labor-saving by technological improvement and a rise in the age limit would be considered. The analysis of the Ministry of Labor expects that a shortage of 1.6 million-1.0 million (in anticipation of industrial renovation) number of labor will occur in the 2000s in the case that a 5-day week work system (1800-1900/hour work in a week) is perfectly introduced.

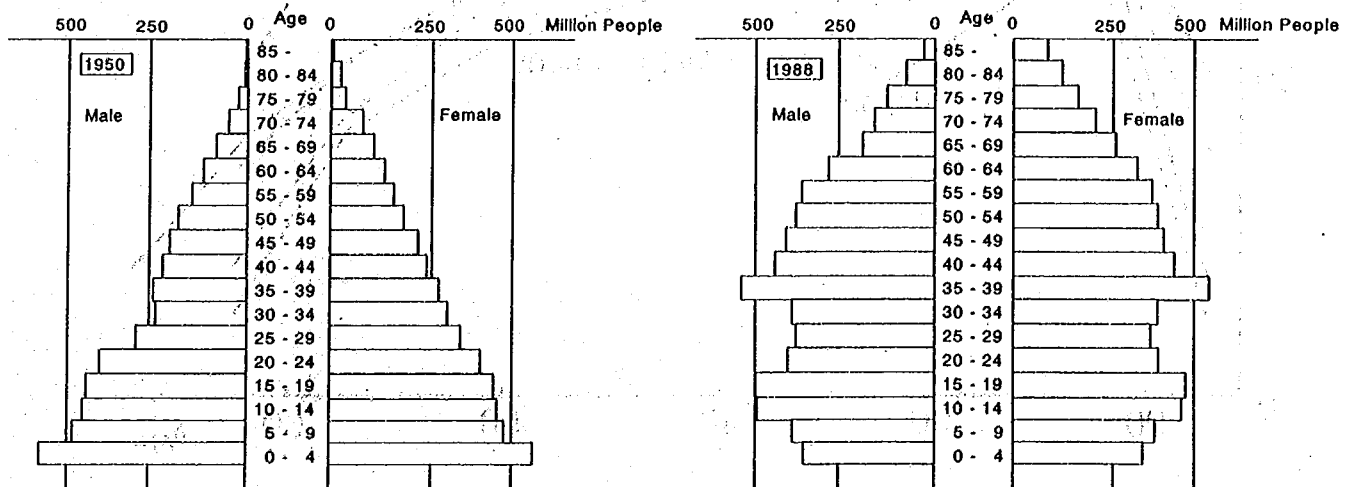


Fig. 4-1-1 Population Pyramid in 1950 and 1988.

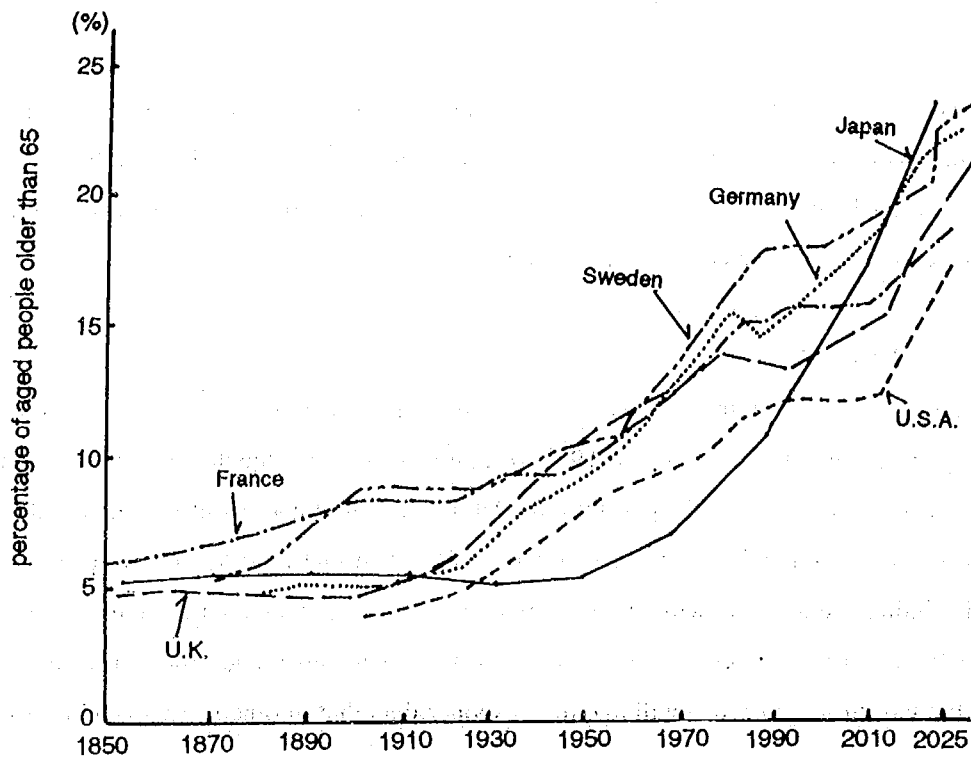


Fig. 4-1-2 Rate of Aged Persons (above 65 years).

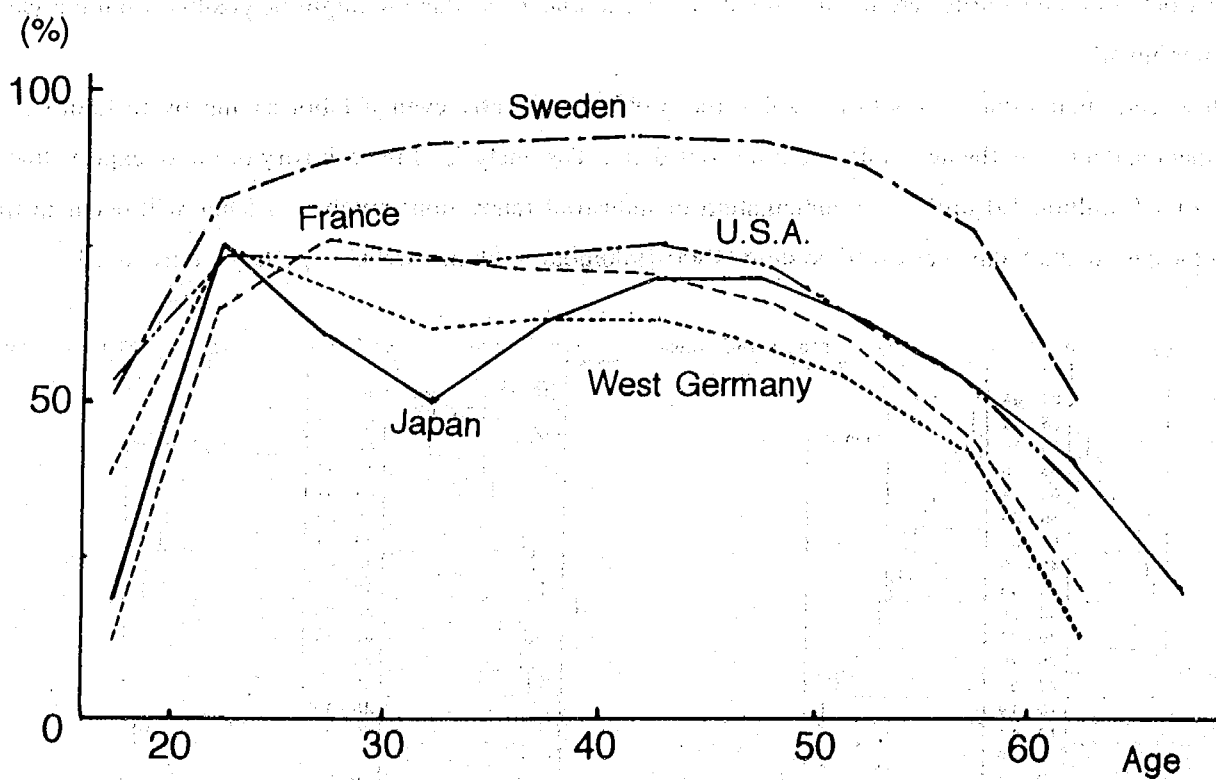


Fig. 4-1-3 Share of Women Labor in Labor Market.

2) INFORMATION NETWORK

Figure 4-1-4 shows sales figures for the information service industry. This figure shows a rapid growth in the market larger than the growth rate of GNP. This movement produces new information industries such as the data-base industry and the system integrated industry. The information industry will be more and more important for the national economy in the future for the promotion of rationalization and labor-saving in service, sales, distribution, and transportation.

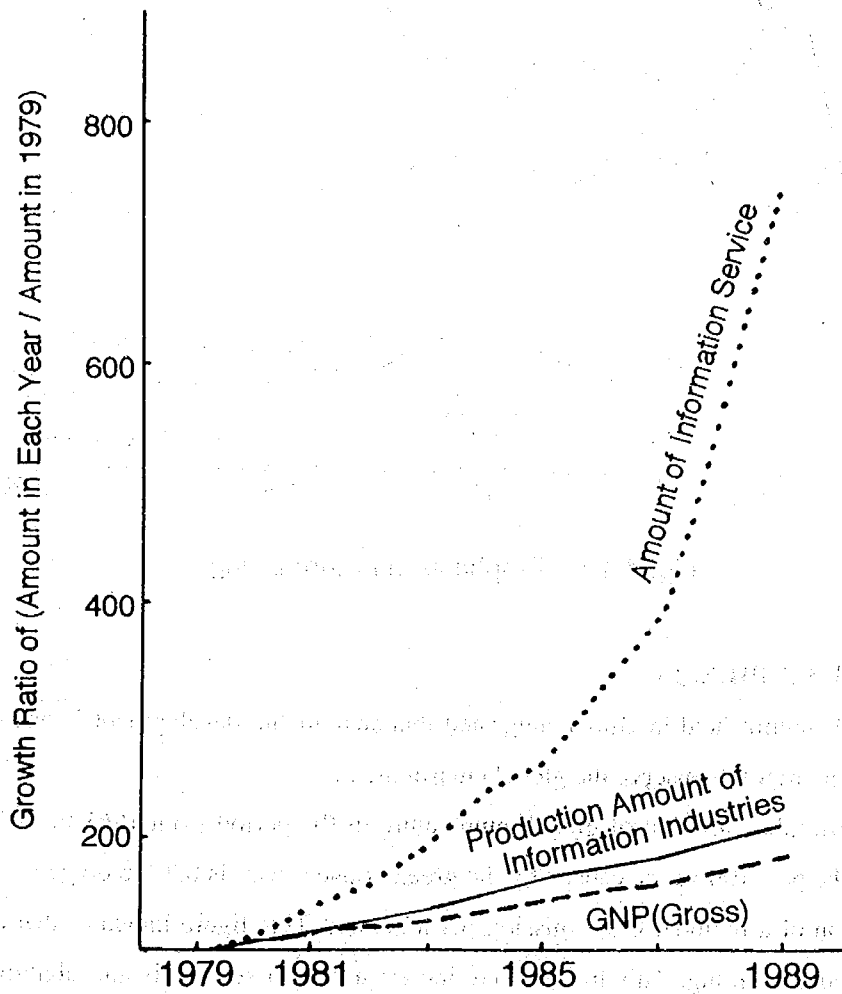


Fig. 4-1-4 Sales Figures for the Information Service Industry.

3) BETTER QUALITY OF LIFE

It is well known that many Japanese people do not feel satisfied with their standard of living though Japan has the second largest GNP in the world. The dissatisfaction is characterized by a so-called rabbit hitch, expensive land value, overcrowding and a long commuter time to the office from home, long working hours, and a lack of greenery. Figure 4-1-5 shows a poll result. This result suggests that the emphasis of individuals is on leisure and the pursuit of a better quality of life since the 1980s. These results show that the consciousness of Japanese people about their standard of living is changing.

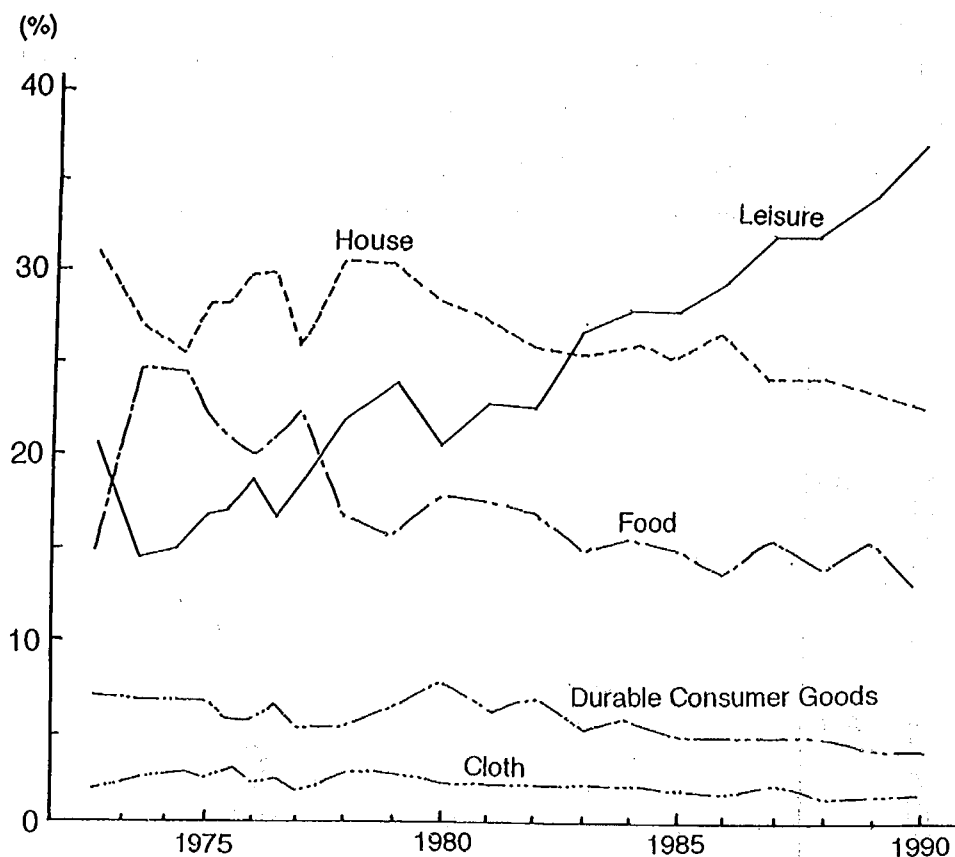


Fig. 4-1-5 Emphasis in Future Living.

4) ENVIRONMENTAL PROBLEMS

The 1992 global summit held in Brazil suggested that sustainable development is one of the most urgent problems to be solved in order to conserve the global environment.

Figure 4-1-6 shows the variation of global temperature in the period from 1861 to 1989. The increase of global temperature in the past 100 years, caused by the green house effect, is 0.3-0.6 degree centigrade. Figure 4-1-7 shows the prediction of a regional CO₂ emission per a person. This figure indicates that advanced countries are responsible for global warming. This in turn may induce a rise in sea levels and abnormal weather. These phenomena give cause for anxiety in terms of hydraulic structures built in river and coastal areas. Emission of CO₂ which might be the cause of the greenhouse effect will necessitate the development of new clean energy substitutes for fossil fuel energy.

When the stratospheric ozone layer is depleted and ultraviolet radiation increases, a wide variety of effects are expected on man, fauna and flora and materials (including synthetic resin). These may include adverse effects on the ecosystems, and in addition to adverse impacts on man's health, increases in the incidence of skin cancer and cataracts.

The disappearance of forests in Africa and South America is dramatic as shown in Figure 4-1-8. FAO issued a stern warning in their report in 1990. In detail, the dissipation of forests is widening twice as fast as the case reported in 1981. Figure 4-1-9 shows the expansion of desert areas. the expansion is serious especially in

south area of the U.S.A., east area of South America, middle-east area of Asia, and Australia.

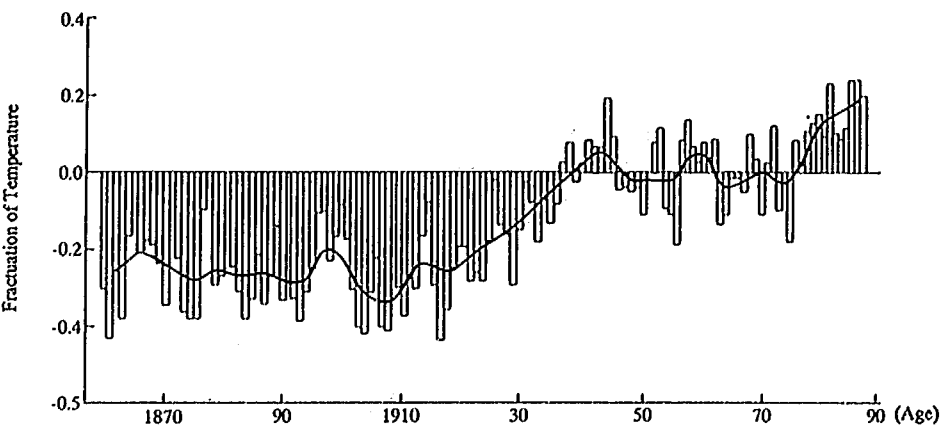


Fig. 4-1-6 Fractuon of Global Temperature.

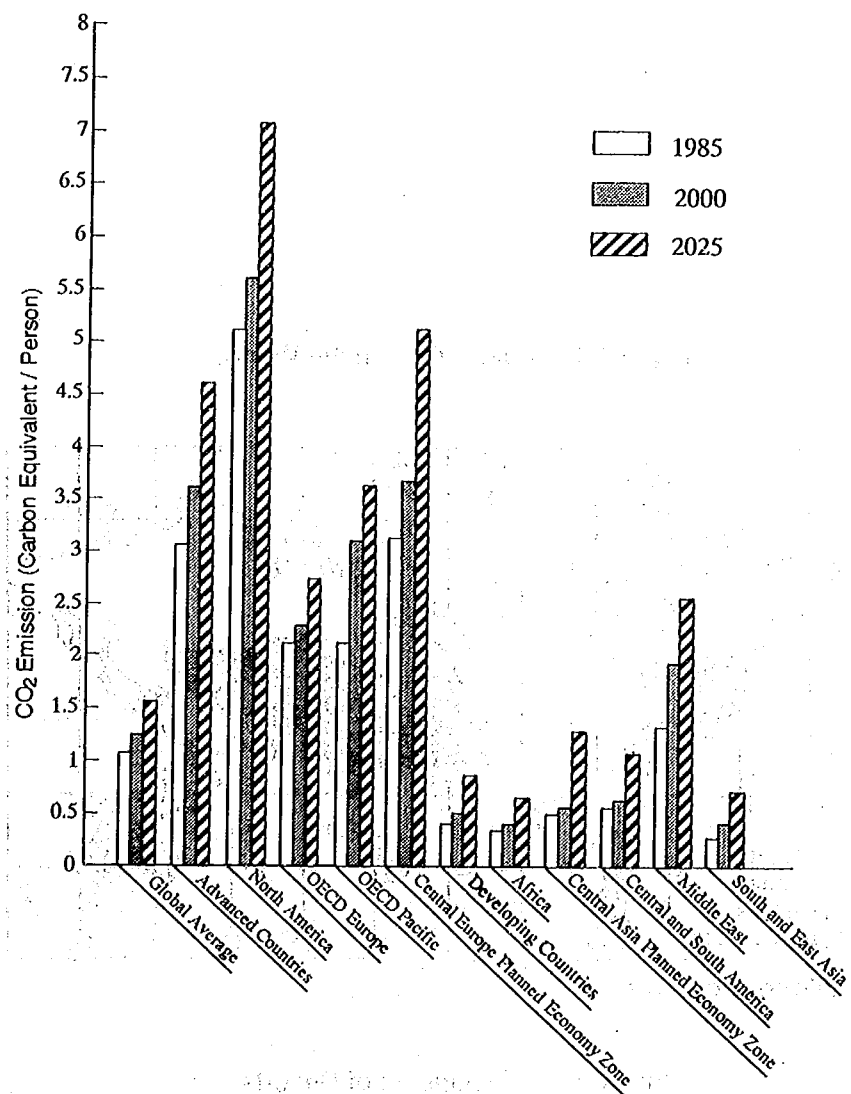


Fig. 4-1-7 Prediction of a Regional CO₂ Emission/a person.

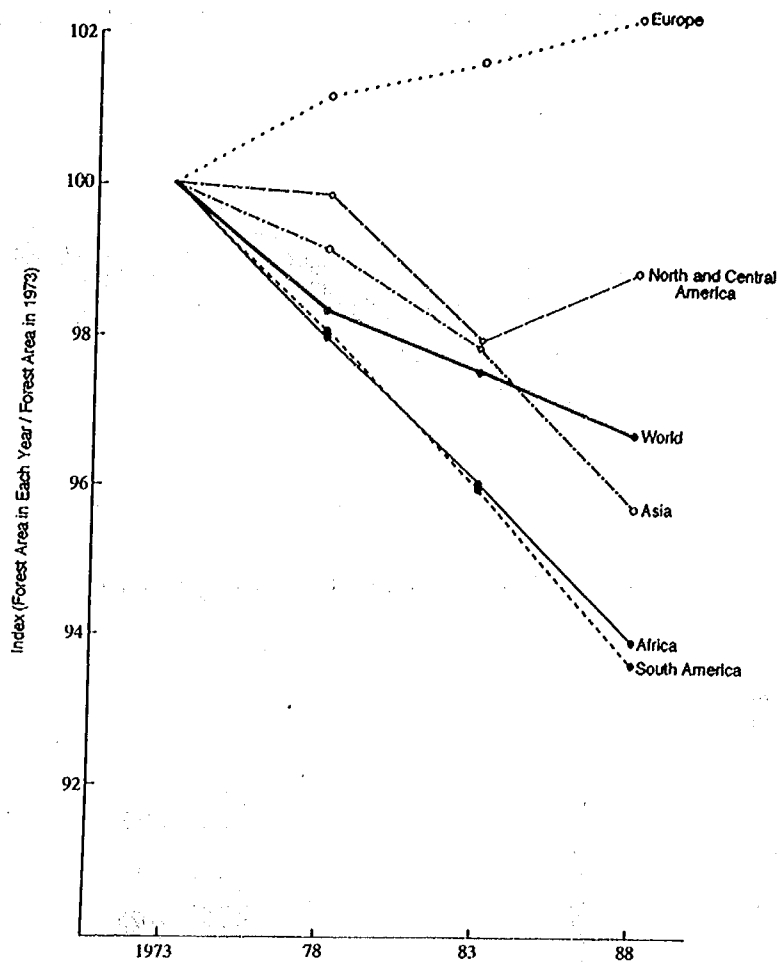
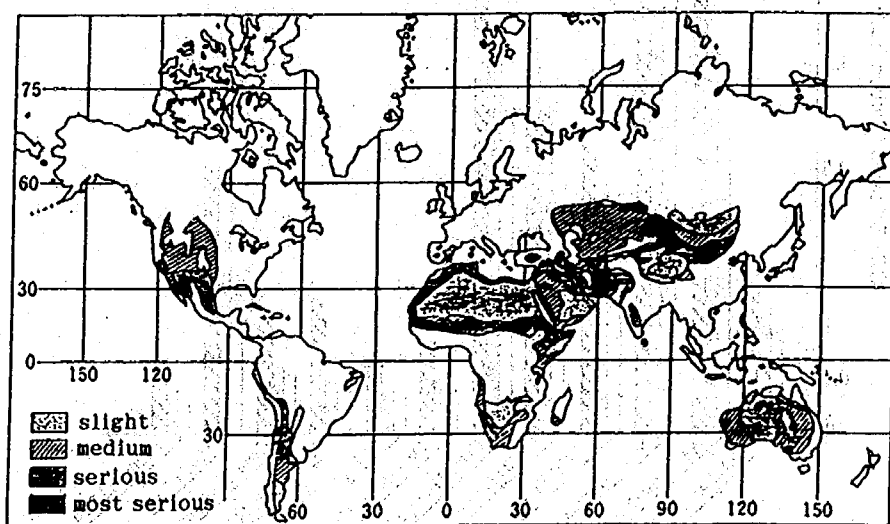


Fig. 4-1-8 Forest Area in the World.



Reference: UNED

Fig. 4-1-9 Expansion of Deserts.

As mentioned above the quality of life demands environmental conservation on both global and local scale, such as the improvement of sewage systems and parks, the enhancement of landscape, river environment, conservation of ecosystems, and the recycled utilization of construction products and the processing of urban waste by Government.

5) URBAN PROBLEM

The most serious obstacle to urban infrastructure investment in Japan is an extraordinary high land value. For example, loop highway 2 from Shiodome to Toranomon in Tokyo has only a 15.4 million dollar construction cost, while the land price of the construction site reached up to 6.9 billion dollars.

There is the possibility that the concentration of industry and population in the Tokyo area will cause traffic jams, environmental problems, and a shortage of countermeasure against disasters. A deconcentration from the Tokyo area to rural areas should be promoted in the future, being supported by the Fourth Comprehensive National Land Development Program, by means of improvements in local areas, networking, and transportation systems between big cities and local areas.

6) THE INTERNATIONALIZATION OF JAPANESE SOCIETY AND ECONOMY

Recently it is required for Japanese society and its economy to be open to foreign countries. The following are the conditions for opening to foreign countries.

- (1) Reformation of business customs to allow foreigners easy access to the Japanese Market.
- (2) Allowing access to information regarding research and technology completed in Japan.
- (3) Adding an international division to regional cities and creating a network among cities.

4-2 BASIC CONCEPT OF RESEARCH

PWRI must coordinate the direction and subjects for research constantly to keep up with the changing needs of society. Therefore, certain key concepts must characterize this research.

1)RESEARCH AND DEVELOPMENT FOR DEMANDS FULL OF VARIETY

To study and develop the detailed demands on the technology concerning disaster prevention and construction is indispensable because people's demands on the infrastructure are diversifying and complicating.

2)RESEARCH AND DEVELOPMENT FOR ADVANCE OF PEOPLE'S UTILITY

It must be noted that infrastructure investment should always consider the user side. Public facilities should be easy to use, and construction technology should be easy for the builder to adopt in practice.

3)RESEARCH AND DEVELOPMENT FOR ENVIRONMENTAL PROSPERITY

It is important that construction works utilize the natural condition at a site, minimize environmental effects, create a pleasant-looking construction site, and conserve the environment after construction.

4)RESEARCH AND DEVELOPMENT FOR INTERNATIONAL UNIVERSALITY

Japan's role is becoming bigger, especially in the field of economics and scientific technology. Recently PWRI has been asked to supply technical information to foreign countries. Therefore, the technologies developed by PWRI should be applicable to the conditions of other countries in the world.

5)RESEARCH AND DEVELOPMENT FOR TECHNOLOGICAL ORIGINALITY

Original technology must be developed to overcome severe natural conditions and the changing social needs in Japan. Japan must lead foreign countries as one of the most advanced technological countries in the world. Therefore there is a responsibility to develop original technology by applying former achievements and through cooperation with academic and private interests in society.

6)RESEARCH AND DEVELOPMENT FOR FINE FEATURES, GOOD PERFORMANCE, AND HIGH DURABILITY

Roman Water Bridge is one of the favor remains of infrastructure, because it can work still now, and its fascinating feature gathers the sightseers from all over the world. PWRI should study the methods for the construction of artificial structure which are superior in their performance, feature, durability like the Roman bridge. The study for preservation technology of them is also important.

4-3 RESEARCH TO BE STUDIED IN THE FUTURE

Research subjects to be studied in the future based on social and economic trends are discussed in this section.

1) HIGHLY ADVANCED UTILIZATION OF NATIONAL LANDS

A concentration of industry and information, which can be seen in the Tokyo and Osaka areas, disturbs not only the urban performances, but also growth of local cities. To obtain further economic growth, balanced deconcentration will be achieved by the construction of expressways with new design standard, long span bridges and tunnels. These projects will compose the new multi-polar national land in which local cities will be connected to each other by transportation networks. PWRI has to study the methods for planning, design, and construction of these new transportation facilities.

Inflated land value is the major reason for long commuter time that residents in large cities must travel. Therefore, they can not feel comfortable in their everyday living. It is very hard to improve road traffic in large cities because of this excessive cost for land. Deflation and stabilization of land value, well-designed urban plan, supplement of land for residences, and improvement of roads and subways would be indispensable in order to solve the urban problems. One solution is to use large under ground spaces, which could be called "the new frontier" for urban areas. PWRI has to study construction technology to utilize underground space.

Recently shortages of water supply often occur in Japan, and these often damage big cities. New technology for improving water resources and water supply systems should be developed soon.

2) INFRASTRUCTURE INVESTMENT FOR DISASTER PREVENTION

Japan is often damaged by natural disaster, such as earthquakes, floods and eruptions of volcanos, that's why disaster prevention is an essential policy. Especially, large cities are not considered durable against disasters because they have too many necessary functions that would have to be maintained in the case of a disaster. Research on forecast, prevention, refuge and recovery from disaster is important for PWRI's future.

It will become important to study the technology for minimizing flood damage even in the case of an overflowing levee. High-graded levee, which has a hundreds of meters wide and would be expected never to collapse against overtopping flow, is considered to be one way to minimize flood damage.

Development of earthquake resistant design methods, estimation of earthquake disasters, the establishment of countermeasures before and after major earthquakes, methods for refuge and recovery, and fail-safe systems in traffic, transportation, information networks are also important studies for large cities.

Traffic accidents are serious problems in modern cities. Safe traffic practices aimed at protecting the aged or handicapped is an urgent problem to be solved.

3) CO-EXISTENCE HUMAN BEINGS AND THE EARTH

Because environmental problems are global and common, Japan has to lead environmental conservation of

the world.

Energy and material economizing must be studied for the prevention of global warming, and survey and analysis of the influence of global warming on infrastructure development must be conducted. There is a possibility that the extinction of tropical forests through deforestation causes the destruction of the global ecosystem, desertification, and abnormal weather. Technology for environmental conservation is a problem awaiting solution.

Waste produced by construction work is a problem to be solved because it may be the cause of pollution. The reuse or the recycling of construction waste is a subject to be studied.

In order to conserve and create a better environment, PWRI has to study river and coastal environment, ecology, sewage systems, roads for ordinary use, greenery and landscape, the promotion of research for environmental assessment, and data-base systems, and their effective utilization.

4)SAFETY IN CONSTRUCTION WORK

A lack of skilled workers and the aging of labors will perhaps cause many problems in construction work. Safe, and effective construction work is required. Mechanization, pre-fabric construction, renovation of design method, virtual reality and simulation of construction work at a site, construction machines and construction methods with easy operation, construction machines with energy saving and reduction of emission gases, are important studies to be conducted.

5)NEW MATERIAL FOR CIVIL ENGINEERING

The movement of extension of life cycle and maintenance-free of public structures requires new materials with further durability. On the other hand, enlargement of newly-developed projects causes an increase in the design load in the plan. Discovery of new materials which have much more performance than existing materials would contribute to the economical and reasonable design and enlargement of structures.

Recently, advancement in the field of electrics, information technology, robotic engineering, biochemics, and high polymer is remarkable. These achievement could be applied to construction work. PWRI studies for their application to construction work. Also improvement of existing materials such as concrete, steel and rock should be investigated for the application to new structures.

6)REALIZING MAINTENANCE FREE

The next step for Japanese technology is pursuing maintenance free structures and materials. Therefore, the administrative and maintenance method for them will become important to keep and extend the life cycle. Reduction of structural life cycle cost, reinforcement, inspection, and rehabilitation methods should be studied.

7)SPACE AND MARINE TECHNOLOGY

A space station is expected to provide many advantages for human beings. The U.S.A. is promoting a space station program and Japan would join it. On the other hand, there is a possibility that the sea provides the

safest transportation lane because under-surface transportation is not influenced by typhoon, rainfall and wave. In addition, these two projects have the possibility of changing military industries into civil industries. PWRI promotes the new frontier development.

Further research related to the development of new frontier is necessary. Existing subjects are effects of inner condition on human, estimation of design load, design process, construction work by robotics, and new materials applied to universal and marine space.

8)CONSTRUCTION MANAGEMENT

Development of construction management systems is very important to realize efficiency and durability in construction work, using new technology, new methods, and new materials. This contributes to the rationalization and improvement of the process of planning, investigation, design, construction and maintenance.

9)PROMOTION OF INTERNATIONAL COOPERATION WITH GLOBAL VIEW POINT

Demands for focusing on basic research are increasing. PWRI develops original technology and is open to the world through international cooperation and technical assistance.

Especially the environmental problems associated with global warming such as the climatic change, and the relationship between forests and runoff of rainfall water should be studied in future with foreign research organizations.

PWRI will cooperate developing countries and the countries of transition economy, and study on utilization of national land, construction of roads, development of water resources, disaster prevention and environmental conservation considering their characteristics. PWRI thinks research on methods for technology transferring is also important.

4-4 PROMOTION OF SYSTEMATIC RESEARCH

This section describes the future research system of PWRI.

1) RESEARCH MANAGEMENT

(1) Management of Intentional Research

The complication and diversification of society forces PWRI to prepare research systems for large scale research projects with long research duration time. It is necessary to set up research programs to conduct rational research activities.

The Ministry of Construction drafted its "Long-term Program for R&D in Construction Technology" in 1983, and its "Long-term Perspective for Research and Development in Construction Technology" in 1988. PWRI formulated its Five-Year Research Plan based on these programs to expedite the systematic management of research and development in next five years. PWRI Five-Year Research Plan indicates the direction of the research and the portion of which they are responsible for. Recently changes in society and economy are so rapid that the flexibility for reforming the plan must be indispensable.

(2) Securing Budget

Sufficient budget for research is necessary for perfecting research work effectively. Economic recession cuts the research budget first. Because it is expected that there will be no sharp increase in research fund of the general accounts, PWRI has to secure the research funds into the road and river special accounts. In addition, to arrange the joint research programs with other national research organizations and private companies is another method to obtain additional research funds.

(3) The System and Organization for Comfortable Research

Flexibility in an organization, such as the rearrangement of an organization, the increase in the number of research staff, is very important for obtaining effectiveness in research work.

The most important motivation of research is the interest of the researchers. Especially in basic scientific research the penetration of the ideas of researchers allows a scientific discovery. The subjects, being relieved from the restriction of money and research duration limit, are very important for free inspiration.

2) COOPERATION WITH OTHER ORGANIZATION

(1) Sharing Roles

Recently there are many interdisciplinary research subjects in civil engineering. The importance of PWRI is in sharing the role as a coordinator.

Private companies are superior in applied research and Universities are excellent in basic research. PWRI

has both characteristics of basic and applied research. The deference among the organizations expects that PWRI should be a kind of coordinator of civil engineering research. This coordination seems to be very important for the advancement of civil engineering in Japan.

(2) Systems for Expansion of Research Network

PWRI has already some systems for exchanging researchers, joint research programs, accepting researchers, a construction technology evaluation system from private companies. To improve the systems is necessary in order to expand the further prosperity of research cooperation with university, and in order to give incentives to private companies for the development of research motivation.

3) RESEARCH COOPERATION WITH INTERNATIONAL ORGANIZATION

As of April 1st, 1993, PWRI has mainly 7 international joint research cooperation programs;

- *The Conference on Public Works Research and Development in Asia
- *The U.S.-Japan Conference on the Development and Utilization of Natural Resources (UJNR)▽-Panel on Wind and Seismic Effects
- *The Japan-U.S. Conference on Sewage Treatment Technology
- *The Japan-U.S. Committee on Hydrology, Water Resources and Global Climate Change
- *The Japan-U.S. Workshop on Advanced Technology in Highway Engineering
- *The Japan-Germany Workshop on Waste Water and Sludge Treatment
- *The Japan-Canada Conference on Paving in Cold Areas

UJNR Panel is planning to hold the commemorative meeting of 25 years in 1993. In addition UJNR Panel has many task committees, and each T/C is holding international meetings frequently.

30 joint research areas under the science and technical cooperation agreement are running with the U.S.A., Canada, China, Australia, the U.K., Italy, Sweden, India, Korea, Germany, and Norway. 8 programs are in the planning stage, and 4 research programs with several countries are running (as of April 1st, 1993).

79 researchers of PWRI were dispatched to foreign countries in order to attend international research meetings, 64 were for technology transfer supported by JICA. 7 researchers are staying in foreign countries to study.

The number of visitors from foreign countries is 273 (50 groups), and the number of group trainees is 171, individual visitors are 62, which are supported by JICA (during the 1992/1993 fiscal year, from April 1st, 1992 to May 31st, 1993).

PWRI will make a research information network for cooperation with foreign research organizations to solve global environmental problems to realize global super projects, and to support infrastructure development of developing countries and East European countries.

AFTERWORD

This paper is prepared for the commemorative lecture meeting of PWRI's 70th Anniversary held in October 1992, and for the Conference on Public Works Research and Development in Asia in February 1993.

Since the Meiji Restoration, Japanese society, economy, and civil engineering technology have been growing rapidly. It is evident that this rapid growth owes to efficient and deliberate improvement of infrastructure, needless to say, Fortunate sometimes smiled upon Japan. Although Japanese infrastructure investment repeated the increase and decrease according to the socio-economic conditions such as wars, recessions, or prosperities, our senior engineers continued to exert themselves for deliberate improvements of infrastructure, and it was supported by research and development activity with correct prediction on a changing society and the pursuit of good infrastructure.

It is expected that the importance on R&D is becoming greater because the socio-economic demands are also changing continuously. Researchers should pursue further discovery and creation through R&D. PWRI should have many researchers who are knowledgeable of the beauty of discovery and creation through R&D. The authors wish that this paper would give some interests to future infrastructure investments and the research which supports it.

The authors also wish to thank the department directors and some researchers of PWRI for their cooperation in publishing this paper.

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* are translated by the author.

APPENDIX

SUMMARY OF INTERNATIONAL COOPERATION IN PWRI

as of April 1st, 1993

1. RESEARCH COOPERATION

1) Research cooperation based on Agreement on Cooperation in the field of Science and Technology

(1) Bilateral cooperation

Nation	Number of Subjects	Nation	Number of Subjects	Nation	Number of Subjects
U.S.A.	8(4)	Korea	2	Sweden	2(1)
Canada	4	China	6	Norway	2
Germany	1	Italy	2		
Australia	4	U.K.	1(1)		

*the parenthesized number is the number of the pending subjects

(2) Multilateral cooperation

*Organization for Economic Cooperation and Development (OECD)

*Permanent International Association of Road Congresses (PIARC)

*Economic and Social Commission for Asia and the Pacific (ESCAP)

*The International Union of Testing and Research Laboratories for Materials and Structures (RILEM)

*World Meteorological Organization Commission for Hydrology (WMO)

2) Cooperative Research Subjects

(1) Research on Hybrid Control of Bridges (U.S.A.)

(2) Research on Testing Pavement (U.S.A.)

(3) Study on the Countermeasures to Sediment Disasters on a Alluvial Fan (Indonesia)

(4) Research on the Method for the Prediction of Sediment Disasters at Volcanic Areas (U.S.A.)

(5) Complex and Advanced Processes for Phosphorous Removal (Germany)

(6) Study on Mechanism of Movement of Large Organic Debris with Debris Flows and Landslides (U.S.A.)

(7) Study on the Formation of Stable Beach (Australia)

(8) Joint Research Project on the Change of Tropical Forest and Their Influence (Thailand)

(9) Study on the application of micro wave data for the advancement of remote sensing technology (Thailand)

(10) Research on the impact of global warming to water balance (U.S.A.)

---Study on the Development of a meteorological and hydrological simulation model for the prediction of

hydrological cycles at a catchment scale---

2. EXCHANGE OF RESEARCHER

1) Invitation of foreign researchers

Fiscal Year	86/87	87/88	88/89	89/90	90/91	91/92	92/93
Number	3	2	9	7	9	7	18

*counterpart nation:U.S.A.(18), Thailand(5), China(10), U.K.(5), Korea(3), Canada(2), New Zealand(2), Germany(2), Switzerland(2), Italy, France, Malaysia, Norway, Sweden, Australia

2) Dispatch of PWRI's Researcher

OBJECTIVE	87/88	88/89	89/90	90/91	91/92	92/93
Conference	32	30	44	37	49	79
Technical Assistance	35	54	63	41	36	64
Study Abroad	3	4	5	1	6	7
TOTAL	70	88	112	79	91	150

3. VISITORS AND TRAINEES FROM FOREIGN COUNTRIES

1) Visitors

Fiscal Year	86/87	87/88	88/89	89/90	90/91	91/92	92/93
Number of Groups	60	52	57	45	44	35	50
Number of Visitors	217	226	191	205	190	213	273

2) Trainees

Fiscal Year	86/87	87/88	88/89	89/90	90/91	91/92	92/93
Group Training	167	109	155	202	223	209	171
Individual Training	77	88	107	54	47	50	62
TOTAL	244	197	262	256	270	259	233

(1)JICA Training Courses(92/93 fiscal year)

- *Volcano/Volcanic Erosion Control Course
- *Regional Administration Course
- *Construction Machine Equipment Course
- *Bridge Engineering Course
- *River/Dam Engineering Course
- *Construction Method Course
- *Highway Seminar
- *International Earthquake Engineering Course
- *Environmental Monitoring Course
- *Sewage Engineering Course
- *Soil and Foundation Engineering Course
- *Manager for Construction Work Course
- *Advanced Technology in Construction Work Course
- *Comprehensive Plan for Urban Traffic Facilities Course

CHRONOLOGY OF POLITICS AND ECONOMICS, DISASTER, CONSTRUCTION ACHIEVEMENT, LAW AND PLAN, EDUCATION

year	POLITICS AND ECONOMICS	DISASTER	CONSTRUCTION ACHIEVEMENT	LAW AND PLAN	EDUCATION
1868			*Kurogane Bridge	*withdrawal of seclusionism	
69					
1870				*Ministry of Implementation	
71					*est. of Training Branch in Ministry of Implementation
72			*Shinbashi-Yokohama railway		
73			*introduction of Dutch protection in Yodo River	*Regulation for river, road harbour	*est. of Training Branch in Ministry of Interior
74			*Kobe-Kyoto railway		*Sapporo Agricultural Col.
1875					*Univ. of Tokyo, Col. of Engineering
76					
77	*financial trouble due to		*Nobiru Harbour		
78	Seinan Civil War		*Osakayama Tunnel		
79		*cholera in Hokuriku area	*Kyoto-Otsu railway		
1880	*policy for encouraging	*earthquake in Yokohama			
81	industrialization				*Tokyo Col. of Worker
82	*Est. of the Bank of Japan	*cholera in Yokohama	*Asaka Cannal		
83					
84					
1885					*Civil Eng. Course in T.U.
86		*typhoon(Yodo, Tone river)	*Mikuni Harbour		*System of Imperial Univ.
87		*cholera in Hokuriku area			*Eng. Course in Sapporo Agricultural Col.
88			*Sankyozawa elec. gener.		
89	*Constitution of the Japan		*Tokaido railway		
1890	Empire	*cholera in Nagasaki pref.	*Lake Biwa Cannal		
91		*Noubi Earthquake	*Tohoku Railway		
92				*Railway Construction Law	
93					
94	*Sino -Japanese War				*High School Ordinance
1895					
96		*Sanriku Great Tsunami	*imp. of Yokohama Harbour	*River Law	
97	*introduction of the gold	*flood in Tokyo	*Joban Railway	*Sabo Law	*Kyoto Imperial University
98	standard system				
99	*permission for introducti-				*Private University
1900	on of foreign money	*eruption of Mt. Zao	*Nunobiki Dam		Ordinance
1			*Sanyo Railway		
2			*Sasago Tunnel		
3					
4	Russo-Japanese War				*Technical Education School Ordinance
1905					
6	nationalization of railway			*Nationalization of Railways Law	
7					
8					
9					

ABBREVIATION: est. : establishment, col. : college, eng. : engineering, Univ. : University

CHRONOLOGY OF POLITICS AND ECONOMICS, DISASTER, CONSTRUCTION ACHIEVEMENT, LAW AND PLAN, EDUCATION

year	POLITICS AND ECONOMICS	DISASTER	CONSTRUCTION ACHIEVEMENT	LAW AND PLAN	EDUCATION
1910					
11		*flood disaster(Tone, Ara, Kitakami, Abukuma River, killed and missing:14000)	*completion of flood protection work in Yodo River	*1st Flood Prevention Plan	*Kyusyu Imperial Univ.
12	*Specie Crisis *recession				
13					
14	*beginning of World War 1	*eruption of Sakurajima Volcano	*introduction of double-tracking on Tokoido Railway		*Japan Civil Engineering Society
15	*prosperity*indastrization				
16					
17		*typhoon(Yodo River was broken)			
18	*end of World War 1				*University Ordinance, High School Ordinance
19			*Yatsuyama Bridge	*Road Structure Ordinance	
1920	*reactional recession			*1st Road Improvement Plan	*est. of Engineering High School under Nihon University
21				*Tramway Law	
22	*establishment of the USSR				
23		*Great Kanto Earthquake (killed and missing : 140 thousand)	*Sizugawa Dam & Ooi Dam		
24					
25	*Law for Keeping Public Order				
26					
27			*Okozu Flood Channel		
28	*universal election		*subway *Sumida R. famous 6 bridges *Komaki Dam		
29	*World Crisis				
1930					
31			*comp. of Tone R. flood protection work *Simizu Tunnel		
32	*Est. of Manchukuo *5.15				
33	Affair *secession from U.N.	*Sanriku Earthquake, Tsunami *Muroto Typhoon	*San-in Railway		
34			*Tan-na Tunnel		
35					
36	*2.26 Affair				
37	*China Incident				
38		*landslide on Mt. Rokko	*Tsukahara Dam		*Education Evaluation Committee
39	*beginning of World War II				
1940	*Japan-Germany-Italy Alliance *beginning of Pacific War				
41			*Kanmon Railway Tunnel		*National School Ordinance
42		*Tottori Earthquake	*Suiho Dam	*establishment of the Ministry of Transportation	Japan Education Society Univ, H.S., Jr.H.S., Tech. Educ.H.S. Ordinance
43			*Azigawa Under River Tunnel		*War Time Education Ord.
44			*Sagami Dam		*Basic Education Law
45	*end of World War II	*Makurazaki typhoon			*School Education Law
46		*Naikai Earthquake			
47	*Constitution of Japan	*Kathleen Typhoon		*Japan Road Association	
48	*est. of M.O.C.	*Fukul Earthquake, *Iona Typhoon, Kitty Typhoon,		*reorganization, Ministry of Construction etc.	
49	*Japan Industrial Standard	*Jane Typhoon			*National Univ. System
1950	*beginning of Korean War			*Comprehensive National Land Development Law	*Jr. College System
51	*Japan -US Security Treaty		*Imp. of Tomakomai Harbour		

ABBREVIATION: est.:establishment, R.:River, univ.:university, P.C.:Public Cooperation, exp.:expressway, H.S.:High School, Ord.:Ordinance, educ.:education
imp./improvement

CHRONOLOGY OF POLITICS AND ECONOMICS, DISASTER, CONSTRUCTION ACHIEVEMENT, LAW AND PLAN, EDUCATION

year	POLITICS AND ECONOMICS	DISASTER	CONSTRUCTION ACHIEVEMENT	LAW AND PLAN	EDUCATION
52			*Rokko Sabo Dams	Road L., Toll Road System	
53	*end of Korean War *Japan-US Commerce Treaty		*Yanase Dam	*Special Measures Law for Road Improvement	*12 postgraduate schools
54		*Doyamaru Typhoon			*Soil Engineering Society
55	5-Year Plan for Economical Declaration, Join in U.N.		*Kamishiba dam	*Aichi Irrigation P.C.	
56			*Sakuma Dam, Ikari Dam	*Japan Highway P.C.	
57		*Isahaya Heavy Rain	*Ikawa Dam, Naruko Dam	*National Exp.L., Specified Multipurpose Dam L.	*Law, concerning financial aid to private universities
58		*Kanogawa Typhoon	*Kanmon Highway Tunnel		
59	*Meter Ordinance	*Isewan Typhoon		*Metropolitan Exp. P.C.	
1960	*Income Doubling Program	*Chile Earthquake Tsunami	*Kaiyo Expressway, Mihoro Dam, Okutadami Dam	*10-Year Program for Erosion and Flood Control	
61			*Wakato Bridge, Hokuriku Tunnel *Kurobe No.4 Dam	*Water Resources Development P.C., Hanshin Exp.P.C.	*20 Thousand Engineering Students Gain Program
62	*1st nuclear generation		*Metropolitan Expressway, Amagase Dam, Tokaido Shin-kansen, Meishin Exp., New Shimizu Tunnel, Tyuo Exp., Yagisawa Dam *Tone R. Weir	*Railway Construction P.C.	*Introduction of 5-Year graduate System in college of technology
63		*Niigata Earthquake		*New 5-Year R. Improvement Program	
64	Tokyo Olympic, Join in OECD		*Tomei Exp. Kashima Har.	*Basic L. for Environmental Pollution Control	
65	*New Industrial City Construction Plan	*Uetsu Disaster	Kobe Bridge, Rokko Tunnel	*Urban Renewal L.	*system for exchange of students among Asian countries
66		*Tokachi Earthquake	*Tone R. Mouse Weir, Yahagi Dam *Sanyo Shinkansen	*Honshu-Shikoku Bridges P.C., *Environmental Agency	
67		*Hida R. Traffic Accident	*Kanmon Narrow Bridge	*Okinawa Development Agency	*system for international exchange of students
68				*National Land Agency	
69					
1970	*International Exposition				
71	*reversion of Okinawa *Doller Shock *Sapporo Olympic *Japan-China Declaration/ Oil Shock	*heavy rain at Amakusa			
72		*typhoon(Tama R.) , Izu Earthquake			
73	*Okinawa Ocean Exposition	*typhoon(Nagara R.)			
74		*eruption of Mt.Usu			
75		*Miyagi Earthquake, Izu-Oshima earthquake *Tomei-Nihonzaka Tunnel Fire	*Managawa Dam		
76		*typhoon(Kokai R.)	*New Tokyo International Airport, Takase Dam	*Agriculture, Forestry, and Fisheries Agency	
77		*Nagasaki Great Disaster			
78	*Japan-China Peace and Amity Treaty	*Otaki Vil. Landslide	*Oshimizu Tunnel, Shimajiri-awa Dam, Tohoku-Joetsu Shinkansen		
79		*typhoon(Kokai R.), eruption of Mt.Mihara	*Nunobiki Tunnel		
1980					
81	*Idea of Assessment Law				
82	*Zero-Ceiling Financial Policy				
83	*present bank note				
84	*NTT				
85					
86					
87	*Bubble Economy, est. of Japan Railway Corporations				
88					
89					
1990	*Japan-US Structural Impediment Initiative *Burst-Bubble Economy, Break up of the U.S.S.R.	*eruption of Mt. Unzen, pyroclastic flow		*devide of JNR, est. of JR 4th Comprehensive National Land Development Program	
91					
92					
93				11th 5-Year Road, and 8th 5-Year River Imp. Program	

ABBREVIATION: est.:establishment, P.C.:Public Cooperation, exp.:expressway, Ord. : Ordinance, L.:Law, R.:River

CHRONOLOGY OF PUBLIC WORKS RESEARCH INSTITUTE

YEAR	CHANGE OF ORGANIZATION	GENERAL HISTORY	GEOLOGY AND CHEMISTRY D.	RIVER D.	WATER QUALITY CONTROL D.
1920		*reactional recession/ Road Law			
21	*est. of Road Material Lab.				
22	*BIRTH OF PWRI	*est. of the U.S.S.R.			
23		*Great Kanto Earthquake	*Asphalt, tar, & cement test	*beginning of river hydrau- -ulic model experiment	
24		*Ara River Flood Channel			
25		*Law for Keeping Public Order			
26	*est. of Akabane R.B.	*subway(Ueno-Asakusa)			
27		*Sumida R. 6 Bridges			
28		*World Crisis /Komaki Dam			
29					
1930			*concrete mixture plan *survey of Kamenose Land- slide		
31		*Okozu Flood Channel			
32		*Manchukuo / 5.15 Affair			
33		*Sanriku Tsunami/secession from U.N. *Muroto Typhoon/ Tan-na Tunnel		"Dr.Mononobe's Hydraulics" *survey on Sanriku Tsunami disaster *bend flow experi- ment	
34		*2.26 Affair			
35		*China Incident			
36		*Tsukahara Dam	*elastic wave, electoric survey		
37		*beginning of World War II		*levee at river mouse	
38		*Japan-Germany-Italy Alliance *beginning of Pacific War *Kanmon Tunnel	*reinforced concrete using bamboo	*scour at groundsill site *similitude criteria *forecasting of wave	
39		*Suiho Dam		*river characteristics	
1940					
41		*end of World War II			
42		*Nankai Earthquake			
43		*Constitution of Japan			
44		*Fukui Earthquake			
45		*Kitty Typhoon / J.I.S.			
46		*Korean War/Jane Typhoon			
47		*Japan-US Security Treaty			
48	*1st Technological Lab./ PWRI / Numazu R.B.	*Toll Road System		*method for discharge mea- -surement *field survey on rainfall run-off *"IDA" me- thod	
49		*end of Korean War			
1950		*5-Year Road Improvement Program *Sakuma Dam	*AE concrete *elastic analysis on concr- -rete structure	*forecasting of high tide *high tide breakwater	
51		*Jinmu Prosperity	*underground water survey using radio isotope		
52				*Unsteady flow calculation *formula of bed load	*rapid filtration method
53					
54					
55					
56					
57					
58	*Introduction of department system	*Kanmon Road Tunnel	*BIRTH OF GEOLOGY & CHEMI- -STRY D. *aerial photo	*BIRTH OF RIVER D. *groin *River&Sabo Survey Manual	
59		*Isewan Typhoon			

ABBREVIATION: D. : Department, Lab. : Laboratory, R.B. : Research Branch, est. : establishment, R. : River

CHRONOLOGY OF PUBLIC WORKS RESEARCH INSTITUTE

YEAR	CHANGE OF ORGANIZATION	GENERAL HISTORY	GEOLOGY AND CHEMISTRY D.	RIVER D.	WATER QUALITY CONTROL D.
1960	*Chiba R.B./Niigata E.L.	*Income Doubling Program	*concrete strength under 3 dimensional stress	*density current	*processing of nactivated sludge *Sumida R. water pollution survey *aeration
61	*Kashima E.L. Tunnel Div.			*strage function method	
62	*General Affairs Dep.	*Wakato Bridge			*re-aeration
63	*Structure & Bridge Dep.	*Kurobe No.4 Dam			
64	*Landslide Div./System Div.	*Tokyo Orympic Games		*culculation of bed fluctuation /uprush and signifi-	
65	*Foundation Engineering Div.	*Tokaido Shinkansen	*rust proofing method	-cant wave	
66		*New Shimizu Tunnel/Kuriko Tunnel	*lithological classificati-	*rader rainfall survey	*self-purification in rivers
67			-on of ground rock	*microwave current meter	*distribution of the boxes
68	*Ground Vibration Div.	*Tokachi Earthquake		*a bar at river mouse	hastening permeation
69	*Urban River Div.	*Tomel-Meishin Expressway			
1970	Traffic Safety Div. / Slope failure Div./ Planning Div./	*International Exposition	*physical examination test		*rational&equivalent roughness methods *pilot plants at Yokosuka & kyoto
71	Water Quality Div./ Traffic	*reversion of Okinawa		*detached breakwater	
72	Environmental Div./ Fill-	*Sapporo Orympic Games			*organic impurities
73	type Dam Div./Advanced wa-	*Oil Shock / Kanmon Bridge	*evaluation of chemicals for grouting	*underground water survey	*BIRTH OF WATER QUALITY CONTROL D.
74	ste Treatment Div./ Water	*Tama R. bank collapse	*guidelines for chemical grouting	*roughness coefficient of rivers	
75	Resources Engineering Div.	*Sanyo Shinkansen/Okinawa Ocean Exposition	*rapid curing of concrete	*underground dams	*eutrophication
76	Soil Dynamics Div./ Earth-	*eruption of Mt.Usu	*high durability concrete		
77	-quake Engineering Div./	*water shortage in Fukuoka	*mechanical strength of	*local scour around a pier	
78	Resesrch Facilities Div./	*Oshimizu Tunnel			
79					
1980	New transportation systems	*Midokoro Dam	soft rocks/elastic wave survey	*rainfall penetration	*use of sludge for construction material
81	Div./Ultimate Disposal Div./	*Idea of Assessment Law		*armoured levee	*run-off
82	Flood Disaster Prevension	*Tohoku, Joetsu Shinkansen		*guidelines for caluculation of a flooded area	model of loadings in combined sewerage
83	Div./ Dam Hydraulic Engineering Div./ Planting Div./	*Japan Sea Offshore Earthquake *Otaki landslide	*development of geotomography	*beach erosion	
84	Personnel & Welfare Div.,	*Tsukuba Exposition / NTT	*new materials	*river characteristics	*advanced water processing system using biotechnology
85	Research Information & Library Div.	*eruption of Mt. Mihara	*evaluation of aggregate for protection of alkali aggregate reaction	*river scape/DND rader	*pressure & vacuum sewerage system
86		*est. of Japan Railway	*guidelines for prevention of A.A.R.	*guidelines for model test	
87		*Seikan Tunnel/Seto Bridge		*man-made reef	
88		*Start of implementation of Trans-Tokyo Bay Highway		*vane method	
89	Move to Tsukuba(1979)	*eruption of Mt.Unzen / break up of the U.S.S.R.	*guidelines for survey & test of soft rocks	*new river planning	*creation of hydrogen sulfide
1990				*amenity in river areas	*renewal & maintenance methods of sewerage systems
91	*Construction Management			*global climate change	
92	Engineering Center				
93					

ABBREVIATION: D : Department, R.B. : Research Branch, E.L. : Experimental Laboratory, Div. : Division, est. : establishment

CHRONOLOGY OF PUBLIC WORKS RESEARCH INSTITUTE

YEAR	CHANGE OF ORGANIZATION	DAM D.	EROSION CONTROL D.	ROAD D.	CONSTRUCTION METHOD AND EQUIPMENT D.
1920					
21	*est. of Road Material Lab.				
22	*BIRTH OF PWRI				
23					
24					
25					
26	*est. of Akabane R.B.			*application of random pa- ving *effect of traffic ability on mileage *method for asphalt material test	
27					
28					
29					
1930				*mix design and strength	
31					
32			*survey for a landslide at Kamenose area		
33					
34		*planning method for gra- vity dam concerning earth pressure during earthquake		*effect of tar pavement on rice plants	
35					
36					
37			*auxiliary dam	*slip on pavement	
38		*rock plate survey using physical sounding			
39					
1940				*method for economization of pavement materials	
41					
42					
43					
44				*chemicals for stabilizati- on of soil	
45				*theory on bearing power of foundation	
46					
47					
48	*1st Technological Lab./		*survey for a landslide at		
49	PWRI / Numazu R.B.		Mt. Cha-usu		
1950		*development of method for 3-dimensional analysis of gravity dam		*manual for asphalt pave- ment *guidelines for re- newal of roads *AE concrete	*beginning of construction machinery's performance *machinarization theory *relation between tire pat- tern and skids
51					
52					
53					
54					
55		*open channel at the exit of conduit	*survey for a landslide at Jin-nosuke valley *aerial photo for geological surv- ey	*evaluation of asphalt test methods	
56					
57		*geographical map using grid system BIRTH OF DAM D	*design method for sabo dam	BIRTH OF ROAD D.	
58	*introduction of			*research on road signs	*tractive characteristics of crawler tractors
59	department system				

ABBREVIATION: D. : Department, R.B. : Research Branch, Lab. : Laboratory, est. : establishment

CHRONOLOGY OF PUBLIC WORKS RESEARCH INSTITUTE

YEAR	CHANGE OF ORGANIZATION	DAM D.	EROSION CONTROL D.	ROAD D.	CONSTRUCTION METHOD AND EQUIPMENT D.
1960	*Chiba R.B. / Niigata E.L.		*prediction of sediment yield	*use of clothoid curve	BIRTH OF CONSTRUCTION METHOD AND EQUIPMENT D.
61	*Kashima E.L. / Tunnel Div.			*chart of bearing power-thickness of pavement	*bank collapse by seepage
62	*General Affairs Dep.	*in-site rockplate shearing test	*catchment wall work using liner plate	*traffic capacity survey	*evaluation of trafficability / soil characteristics under compaction
63	*Structure & Bridge Div.	*numerical analysis of arch dam	*sliding surface measurer using paper strain gage	*tunnel ventilation system	*pre-fabric strand cable
64	*Foundation engineering Div.	*free overflow discharge	*landslide survey using aerial photo	*manual for cement concrete pavement / person trip survey / immersed tunnel/	*levee collapse by overtopping
65		*lithological classification of rock plate	*prediction of sedimentation at a sabo dam	traffic weight/economic impact of Hon-Shi Bridges/	*soil stabilization using lime
66		"PWRI method" for estimation of sedimentation at dam		tunnel fire/hydroplaning/	*embankment reinforcement using high polymer textile
67				manual for pavement surface measurement	*automatic driving of bulldozer/use of RI in compaction measurement/man-made island construction method / terre-armee
68	*Ground Vibration Div.			*prediction of dangerous area in traffics	*high frequency vibration pile driver
69	*Urban River Div.			*roadside broadcasting	*bi-mode construction method
1970	*Traffic Safety Div. / Slope Failure Div. / Planning Div. / Water Quality Div. / Traffic Environmental Div. / Fill-type Dam Div. / Advanced waste Treatment Div. / Water Resources Engineering Div. / Soil Dynamics Div. / Earthquake Engineering Div. / Research Facilities Div.	*numerical analysis of flat arch dam	BIRTH OF EROSION CONTROL D	*NATM & Shield methods	
71			*classification of landslide mechanisms	*electric bug filter	
72			*mechanism of debris flow		
73		*unit discharge curve in each area			
74		*testing method of rock material	*estimation of dangerous areas due to land collapse		
75		*earthquake expectation calculation			
76					
77					
78					
79					
1980	New Transportation Systems Div. / Ultimate Disposal Div. / Flood Disaster Prevention Div. / Dam Hydraulic Engineering Div. / Planting Div. / Personnel & Welfare Div. / Research Information & Library Div.	*Spe. for RCD method	*vane method		*Dry Jet Mixing Method
81					*in-situ measurement for forecasting of liquefaction
82		*Spe. for grouting	*countermeasure to landslide	*pavement information data bank system	*vertical crusher dredge
83		*Spe. for lugeon	*prediction of debris flow area	*RACS / evaluation of impact on environment	*manual for soil stabilization concerning earthquake
84		*guidelines on crest radial gate/eutrophication	*impact load of debris flow		*embankment reinforcement using geo-textile
85		dynamic analysis on fill-type dam/manual for management of water quality in lake(proposal)	*mud-flow due to volcano	*renewal of asphalt pavement manual/underground transportation system/prediction of traffic noise under high speed driving / manual for RCCP	*3-dimensional seepage model/banking using styrene form
86			*design method for sabo dam with slits		*AI control
87			*countermeasure to flowing woods		*non-breaking measurement of piles
88			*sabo dam with a gate		
89	Move to Tsukuba(1979)		*pyrocrastic flow		
1990					
91	*Construction Management Engineering Center	*modified seismic design on fill-type dam			
92		*technical report on Nagara Weir			
93					

ABBREVIATION: D. : Department, R.B. : Research Branch, Lab. : Laboratory, est. : establishment

CHRONOLOGY OF PUBLIC WORKS RESEARCH INSTITUTE

YEAR	CHANGE OF ORGANIZATION	STRUCTURE & BRIDGE D.	EARTHQUAKE DISASTER PREVENTION D.	SYSTEM DIVISION	NIIGATA EXPERIMENTAL LABORATORY
1920					
21	*est. of Road Material Lab.				
22	*BIRTH OF PWRI				
23					
24					
25					
26	*est. of Akabane R.B.				
27					
28					
29					
1930					
31		*calculation of foundation settlement			
32		*design standard for reinforced concrete T-beam	*"Earthquake Study In Civil Engineering"		
33		*"Welding Steel Bridges"	*seismic design using seismic coefficient method		
34		*approximate calculation of ground reaction acting on base plate			
35					
36					
37					
38					
39					
1940		*Specifications for bridge with arc welding			
41					
42					
43					
44		*bearing power theory			
45					
46			*Survey of a stricken area due to Nankai Earthquake		
47			*Survey of a stricken area due to Fukui Earthquake		
48	*1st Technological Lab. / PWRI / Numazu R.B.				
49					
1950					
51					
52					
53		*experiment on load carrying capacity of piles			
54		*test of PC rigid frame			
55					
56					
57		*Spe. of welding steel road bridge			
58	*Introduction of Department System	BIRTH OF STRUCTURE & BRIDGE D. *design standard			
59					

ABBREVIATION: D.:Department, R.B.:Research Branch, Lab:Laboratory, Spe.:Specifications

CHRONOLOGY OF PUBLIC WORKS RESEARCH INSTITUTE

YEAR	CHANGE OF ORGANIZATION	STRUCTURE & BRIDGE D.	EARTHQUAKE DISASTER PREVENTION D.	SYSTEM DIVISION	NIIGATA EXPERIMENTAL LABORATORY
1960	*Chiba R.B. / Niigata E.L.	on PC slab bridges			*BIRTH OF NIIGATA EXPERIMENTAL LABORATORY
61	*Kashima E.L. / Tunnel Div.	*beginning of survey for Hon-Shi Bridges			*catchment well work using liner plate
62	*General Affairs Dep.				
63	*Structure & Bridge Dep.	*pre-fabric strand cables			
64	*Landslide Div./System Div.	Spe. for substructures of bridges*Spe. on reinforced concrete bridges*fomula on ultimate bearing capacity with eccentric battered load	*survey for Niigata Earthquake *network of seismometers guideline on seismic design of Honshu-Shikoku Bridges	BIRTH OF SYSTEM DIVISION *introduction of computer at Komagome Main Office	*landslide mechanism due to cut or embankment
65	*Foundation Engineering Div.		*1st UJNR conference	*introduction of computer at Chiba R.B.	*artificial avalanche
66					
67					
68	*Ground Vibration Div.				
69	*Urban River Div.	*aerodynamic design			*landslide distribution map in Hokuriku region
1970	*Traffic Safety Div. /Slope Failure Div. / Planning Div.	*bearing capacity of multi-piles	guideline on seismic design of road bridges		*classification of landslide motion *skid resistance of tires *landslide machine
71	Water Quality Div. / Traffic Environmental Div. / Fill-type Dam Div./Advanced Waste Treatment Div. / Water Resources Engineering Div.	*Spe. for design of road bridges		*automatic design program *research on development of local areas	*gun for artificial avalanche *prediction of snowfall using glometric data
72				*system on-line with special permission	*thermal mapping on roads
73					*fractuation of ground water
74					*device for prediction of landslide *snow melting
75					*guard fence against snow
76					*design method for pile work against landslide
77	Soil Dynamics Div. / Earthquake Engineering Div. / Research Facilities Div. /	*manual for design on reinforced concrete base plate	BIRTH OF EARTHQUAKE DISASTER PREVENTION D. *draft of design standard on Trans Tokyo Bay Highway	*introduction of new computer	*sliding surface gauge
78					*countermeasure to avalanches
79					*method for forecasting of snowfall
1980	New Transportation systems Div./Ultimate Disposal Div./ Flood Disaster Prevention Div./Dam Hydraulic Engineering Div. / Planting Div./ Personnel & Welfare Div./ Research Information & Library Div.	*renewal of Spe. for design of road bridges	*Spe. for seismic design of road bridges *guidelines of earthquake countermeasures for sewage facilities * handy-type seismometers *guidelines for design of common duct *manual for repair methods of structures damaged by earthquakes	*manual for management of electric information system *road disaster information system *data base system *introduction of remote sensing to construction work *information system for refuge *introduction of LAN	*landslide survey using satellite information
80					
81					
82					
83					
84					
85					
86					
87					
88					
89	Move to Tsukuba(1979)	*renewal of Spe. of road bridges*guidelines for wind design of bridges *support system for bridge planning	*seismic design of Akashi Bridge *hybrid control	BIRTH OF CONSTRUCTION MANAGEMENT ENGINEERING CENTER *research on construction management	*snow flowing ground sill
1990					
90					
91	*Construction Management Engineering Center		*information system *manual for menshin design		*guidelines for design of coutermeasures to snow avalanches
92					
93			*fomula of earth reforming		

ABBREVIATION: D. : Department, R.B. : Research Branch, E.L. : Experimental Laboratory, Div.:Division, Spe. : Specifications