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FATIGUE DESIGN OF STEEL PLATE DECK BRIDGES

鋼床版橋の疲労設計

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要 旨

この報文は1974年6月24～26日に米国スタンフォード大学で開かれた米国土木学会主催の「工学における確率的手法」に関する特別会議に提出されたものである。この論文は、鋼床版橋の疲労強度を取扱っており、疲労寿命の推定方法および疲労を考慮した許容応力度を提案している。

Synopsis

The paper was presented to the ASCE Specialty Conference on Probabilistic Methods in Engineering held at Stanford University in U.S.A. on June 24 - 26, 1974.

In this paper, fatigue strength of steel plate deck bridges is dealt with and recommendation has been made to the method for estimation of fatigue life and to the allowable stresses for fatigue design.

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ま え が き

この報文は1974年6月24~26日に米国カリフォルニア州スタンフォードのスタンフォード大学 (Stanford University) において開かれた「工学における確率的手法 (Probabilistic Methods in Engineering)」に関する特別会議 (Speciality Conference)に提出されたものである。

この会議は米国土木学会 (American Society of Civil Engineering) の応用力学部会 (Engineering Mechanics Division) の主催のもとで開催されたものである。

会議に提出されたレポートはつぎのとおりである。

Session I Risk Analysis

Chairman: C. Allin Cornell, Massachusetts Institute of Technology

1. Risk Methodology Applied to Nuclear Power Plants, Saul Levine, Atomic Energy Commission.
2. Predicting Damage Probabilistically for Buildings Subjected to Ground Motions, John W. Reed and John A. Blume, URS/John A. Blume and Associates, Engineers.
3. Risk Analysis in Seismic Design of Nuclear Power Plant Structures, S. L. Chu and A. K. Singh, Sargent and Lundy, Engineers.
4. Failure Modes of Offshore Platforms, P. W. Marshall and R. G. Bea, Shell Oil Company.
5. Rational Development of the Operational Basis Earthquake, OBE Design Requirement, John D. Stevenson, Consulting Engineer, Nuclear Structural System Assoc.
6. Tsunami Risk, Octavio A. Rascon, and Augusto G. Villarreal, Universidad Nacional Autonoma de Mexico.

Session II Quality Control and Variability in Materials and Construction

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1. Concrete Strength and Bar Location of Reinforced Concrete Columns, Robert Drysdale, McMaster University, Canada.

2. Simple Interaction Equations for Reinforced Concrete Columns Based on the Variability of Experimental Evidence, Frederick Webster, University of Illinois at Chicago.
3. Bonus and Penalty in Acceptance Criteria for Concrete, E. Rosenblueth, L. Esteva and J. Damy, Universidad Nacional Autonoma de Mexico.
4. Production and Compliance Testing - Their Influence on the Distribution of Concrete Strength, Rudiger Rackwitz, Technische Universität München, West Germany.
5. On Optimum Geometric Standards for Steel Shapes, E. Rosenblueth, Universidad Nacional Autonoma de Mexico.

Session III Code Formulation and Optimization

Chairman: Niel C. Lind, University of Waterloo, Canada

1. Calibration of Second Moment Format for Steel Construction, T. Galambos, Washington University and M. Ravindra, Sargent & Lundy, Engineers.
2. A Concept for Determination of Most Invariant Design Values of Structural Code Parameters, Rudiger Rackwitz, Technische Universität München, West Germany.
3. Strength Design Criteria in Reinforced Concrete, Robert G. Sexsmith, Cornell University.
4. Optimization With Uncombinable Multiple Sources of Values, Jack R. Benjamin, Stanford University and EDAC.
5. "A Practical Approach to Code Calibration," W.W. Siu, Hatch Associates Ltd., Canada and S.R. Parimi and N.C. Lind, University of Waterloo, Canada.
6. Safe Regions and Second Moment Reliability Vectors, D. Veneziano, Massachusetts Institute of Technology.
7. Incremental Cost-Benefit Approach to the Design of Structural Members, Ram Kulkarni, Stanford University.
8. Design Criteria Based on Permissible Risk, A.H.S. Ang, University of Illinois, Urbana-Champaign.

Session IV Soils and Foundation

Chairman: Warren J. Baker, University of Detroit

1. Slope Stability Reliability as a Spatial First Passage Problem, J. Morla-Catalan and C.A. Cornell, Massachusetts Institute of Technology.
2. Probability-Based Design of Earth Slopes, Wilson Tang, University of Illinois, Urbana-Champaign.
3. Simplified Reliability Approach for Foundation Design, P.K. Niyogi, H.H. Su, J. Siddiqui, California State University, Sacramento.
4. Probabilistic Prediction of Settlement of Shallow Foundations, Jorge Diaz Padilla, FELIPE OCHOA y Asociados, Mexico and Erik H. Vanmarcke, Massachusetts Institute of Technology.
5. A Model of Soil as a Random Medium, Erik H. Vanmarcke, Massachusetts Institute of Technology.
6. Probabilistic Approach to Undrained Bearing Capacity, Robert A. D'Andrea and Dwight A. Sangrey, Cornell University.
7. Seismic Soil Liquefaction as a Fatigue Problem, N.C. Donovan and J.E. Valera, Dames & Moore.
8. Statistical Evaluation of Grain Size, Grain Size Distribution, and Slope Effects on Hydraulic Conductivity of Sands, Mehmet T. Tumay, Bogazici University, Istanbul, Turkey.

Session V Seismic Analysis and Design

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1. Generalized Decision Analysis for Seismic Problems, Jack R. Benjamin and Haresh C. Shah, Stanford University.
2. The Role of Load Factors in Seismic Design Methods Using a Response Spectrum Load Criterion, T.C. Zsutty, San Jose State University.
3. Nonlinear Filtering and Modeling of Earthquake Data, F. Kozin, Polytechnic Institute of New York and R. Gran, Grumman Aerospace Corporation.

4. Design of Underground Facilities Using Probabilistic Methods, Garrison Kost, Engineering Decision Analysis Co.
5. A Probabilistic Approach for Seismic Load Determination, Anne H. Kiremidjian and Christian P. Mortgat, Stanford University.

Session VI Engineering Materials

Chairman: J. T. P. Yao, Purdue University

1. Statistical Aspects of Strength of Aluminum, John W. Clark, ALCOA Research Lab.
2. Statistical Analysis of Concrete Strength, Robert Crist, National Bureau of Standards.
3. Material Properties of Steel for Use in Probabilistic Design Methods, T. V. Galambos, Washington University, and M. K. Ravindra, Sargent and Lundy, Engineers.
4. Statistical Aspects of Wood Properties, S. K. Suddarth, Purdue University.
5. Statistical Analysis of Composite Material Properties, R. A. Heller, A. S. Heller and A. B. Thakker, Virginia Institute and State University.
6. Reliability-Based Design for Fatigue, A. H. S. Ang and W. H. Munse, University of Illinois, Urbana-Champaign, and L. Knab, U. S. Army Corps of Engineers.
7. Design of Structural Components for Fatigue Under Stationary Wide Band Random Stresses, P. H. Wirsching and E. B. Haugen, University of Arizona.
8. Fatigue Design of Highway Bridge Floor Members Subjected to Repeating Stresses Due To Traffic Loading, Ichiro Konishi, Kyoto University, and Tetsuo Kunihiro and Minoru Fujiwara, Public Works Research Institute, Ministry of Construction, Chibashi, Japan.

Session VII Wind Load Analysis and Design

Chairman: Michael P. Gaus, National Science Foundation

1. Some Aspects of Reliability Assessments of Slender Structures Under Wind Action, G.I. Schuëller, Technische Universität München, West Germany.
2. Tornado Design Winds Based on Risk, R.C. Garson, J. Morla-Catalan, C.A. Cornell, Massachusetts Institute of Technology.
3. Random Motions of a Suspension Bridge Subjected to Buffeting and Self Excited Wind Loads, J.G. Beliveau, R. Vaicaitis and M. Shinozuka, Columbia University.
4. Nonlinear Panel Response to Nonstationary Wind Forces, R. Vaicaitis, Columbia University.
5. Motion Control of Buildings Subjected to Wind Loads, S. Sae-Ung and J. T. P. Yao, Purdue University.
6. Probability Distribution of Wind Pressure Fluctuations on Buildings, J.A. Peterka and J.E. Cermak, Colorado State University.
7. Probabilistic Structural Response to Random Wind Loads, S. M. Iyer and K.C. Mehta, Texas Technological University.
8. The Probabilities of Tornado Intensity and Occurrence Based on Available Weather Records, James R. McDonald, Texas Technological University.
9. Probabilistic Modeling of Tornadic Wind Load on Structures, Yi-Kwei Wen, University of Illinois at Urbana.

Session VIII Stochastic Hydraulics

Chairman: Chao-Lin Chiu, University of Pittsburgh

1. Spectral Evolution of Ice Ripples, K.S. Hsu, F.A. Locher and J.F. Kennedy, Institute of Hydraulic Research, University of Iowa.
2. A Statistical View of Parameter Estimation in Multi-Response Hydraulic Systems, I. Rodriguez-Iturbe, Massachusetts Institute of Technology, and N.C. Matalas, U.S. Geological Survey.

3. Stochastic Models of Dispersion and Sediment Transport, C.F. Nordin, Jr. U.S. Geological Survey.
4. Dividends From Stochastic Analysis, C.J. Posey, University of Connecticut.
5. Application of Decision Theory to Hydraulic Engineering, L. Duckstein and D.R. Davis, University of Arizona, and I. Bogardi, Water Resources Center, Budapest, Hungary.
6. A General Report on the Current Status of Stochastic Hydraulics, Chao-Lin Chiu, University of Pittsburgh.

Session IX Reliability Studies in Structures

Chairman: Fred Moses, Case Western Reserve University

1. Probabilistic Methods in Ship Primary Structures, A. Mansour, Massachusetts Institute of Technology.
2. Probabilistic Application to Rigid Pavement Structures, M.I. Darter, University of Illinois, Urbana.
3. Reliability Applications in Nuclear Power Plant Design, A. Marcos and S. Singh, Sargent and Lundy, Engineers.
4. Evaluation of an Offshore Platform Using Probabilistic Methods, B. Stahl and A.E. Knapp, Amoco Production Company.
5. Application of the Error Disclosure Philosophy to the Fatigue Design of Structures, I. Bouton, Rockwell International, Los Angeles.
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7. On the Reliability of Structures Subjected to Independent Parameter Loads, F. Casciati and G. Sacchi, Istituto di Scienza e Tecnica delle Costruzioni dell'Universita di Pavia, Italy.

Session X Probabilistic Dynamic Analysis

Chairman: M. Shinozuka, Columbia University

A. H. S. Ang, University of Illinois

1. Identification of Structures Subjected to Dynamic Loads, R. Rodeman, Sandia Laboratories, and J. T. P. Yao, Purdue University.
2. On the Time Dependent Frequency Content of Oscillator Response, R. B. Corotis, Northwestern University, and E. H. Vanmarcke, Massachusetts Institute of Technology.
3. A Numerical Method for Nonstationary Nonlinear Random Vibration, Yi-Kwei Wen, University of Illinois, Urbana.
4. Disordered Periodic Structures, Y. K. Lin, University of Illinois, Urbana, and J. N. Yang, Air Force Materials Laboratory.
5. Response of a Multidegree Dynamic System With Statistical Properties, P. C. Chen, Bechtel Corporation, and W. W. Soroka, University of California, Berkeley.
6. Reliability Analysis of Fatigue Sensitive Aircraft Structures Under Random Loading and Periodic Inspection, J. N. Yang and W. J. Trapp, Air Force Materials Laboratory.

Session XI Risk Analysis

Chairman: Keshavan Nair, Woodward-Lundgren and Associates

1. Defining Acceptable Risks, Lester B. Lave, Carnegie Mellon University.
2. Decision Analysis for the Siting of Nuclear Power Plants - The Relevance of the Multi-Attribute Utility Theory, R. L. Keeney, Massachusetts Institute of Technology, and Keshavan Nair, Woodward-Lundgren and Associates.
3. The Treatment of Risk and Uncertainty in Cost-Benefit Analysis of Environmental Impact Statements for Nuclear Power Plant Licensing Actions, Miller B. Spangler, Chief, Cost-Benefit Analysis Branch, Atomic Energy Commission.

4. Fire Ingestion Risks Due to Flammable Chemicals at the Water Intake of Power Generating Plants, A.S. Kalelkar and J. L. Everett, Arthur D. Little, Inc.
5. Evaluation of Risk of Cargo Spills at Alternate Port Sites, Wayne S. Smith and Keshavan Nair, Woodward-Lundgren and Associates, and Haresh C. Shah, Stanford University.

Session XII Analytical Tools in Probabilistic Methods

Chairman: J. L. Bogdanoff, Purdue University

1. Digital Simulation of Random Processes with the Aid of FFT Technique, M. Shinozuka and P. Wai, Columbia University.
2. Mathematical Methods for Modeling Nonstationary Time Series, F. Kozin, Polytechnic Institute of New York, and R. Gran, Grumman Aerospace Corporation.
3. Highly Efficient Confidence Intervals for Reliability and Reliable Life From Censored Weibull and Log Normal Survival Data, Nancy R. Mann, Rocketdyne Rockwell International.
4. Measured Response Data and Analytical Structural Models: A Probabilistic Reconciliation, Gary C. Hart, University of California, Los Angeles.
5. A Linear Programming Approach to Tchebycheff-Type Inequalities, W.W.C. Siu, Hatch Associates, Ltd., Toronto, Canada, S.S. Sengupta and N.C. Lind, University of Waterloo.

以下に著者らが今回提出した報文を示す。

昭和49年10月

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FATIGUE DESIGN OF STEEL PLATE DECK BRIDGES

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Summary

Fatigue design of steel plate decks must be made taking into account the magnitude and the frequency of repetition of working stresses in the members. This paper deals with the estimation of probabilistic distribution of the magnitude of stresses likely to occur in the design life of the steel plate deck. The probabilistic distribution of the magnitude of stresses can be derived from the probabilistic distribution of the vehicular loads and their passage positions observed in the survey on the major highways.

1. Introduction

In conventional design of highway bridges, the effect of fatigue due to repeated loads has not been taken into account so far in Japan. But it is becoming increasingly more important to take the effect of fatigue into consideration, because of the factors listed below.

1) The increasing use of high strength steel in bridge construction has inevitably resulted in increased design stresses in various parts of bridge structure. But the fatigue strength particularly in welded joints is not so high as compared to increased static strength.

2) The ratio of the design dead load stress to the entire design stress has decreased as compared with the increased ratio of the design live load stress recently, because the design of very light weight bridges has now become possible from the use of high strength steel and progress in the

method of analysis. This means that the stress range due to live load has increased.

3) The frequency of repeated live load is increasing due to markedly increased traffic volume.

4) The weld joint are now more frequently used even in members of the floor system which are directly subjected to wheel loads.

The concept and procedure of fatigue design of highway bridges shall be described below.

2. Members requiring fatigue design

The ratio of dead load to the entire load is quite high in highway bridges. The stress range to which the main member shall be subjected during the service life of the bridge is small.

According to the results of stress measurements made on several bridges in service, the live load stresses in steel main girder as well as in cord and diagonal members of truss bridges are 320 kg/cm^2 or less. These data of stress are obtained from the bridges on national highways of high traffic volume with high percentage of heavy vehicles. From this, no consideration to fatigue of the main member of highway bridges seems to be needed because of the small stress range.

Because of the technical difficulties involved in actual measurement of stresses in slabs and floor system, there are little available data of stress measured for these members. But as any simple design calculation shows the ratio of the dead load stress to the entire stress is in general small compared with the live load stress. This means that the stress range in slab and floor system is far greater than those in the case of main member. As a result, the effect of fatigue can not be ignored here.

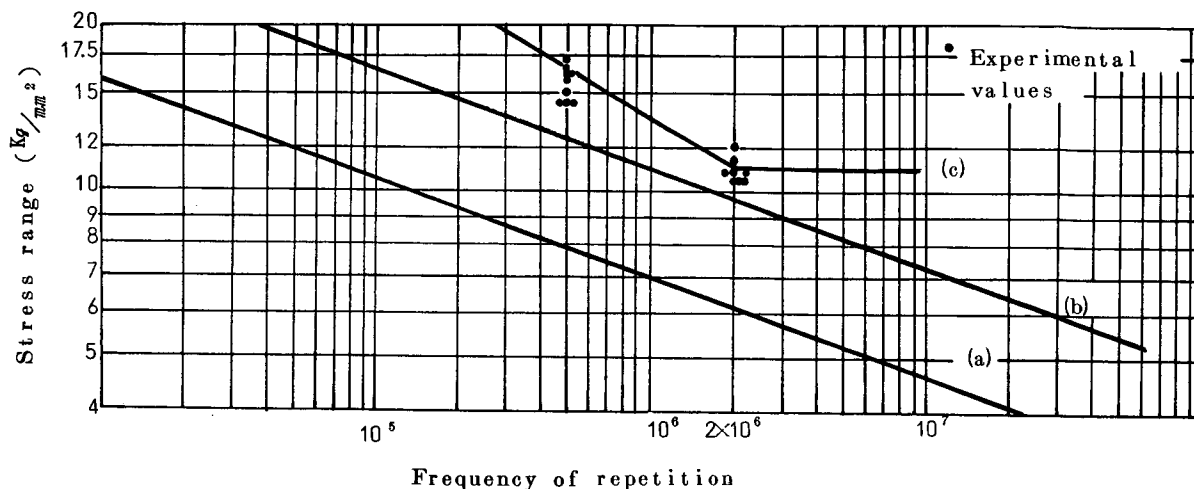
3. Assumptions made in fatigue design

As to the fatigue fracture, it is now widely accepted that the fatigue life of a structure depends only on the stress range and not on the effect of mean stress.

Now let S_r denote the stress range and N the frequency of repeated loads at which fatigue crack starts. S_r and N are related as

$$\log S_r = A - K \log N \dots\dots\dots (1)$$

where A is a constant, K is a slope of the S-N line. Namely, when the ordinate and abscissa are graduated in log., we have a linear relation between the stress range and the frequency of loads for fatigue crack (see Fig. 1).



- (a) Crack initiating S-N diagram for transverse fillet welds with interrupted loaded plate.
- (b) Crack initiating S-N diagram for transverse fillet welds with continuous loaded plate.
- (c) Fracture S-N diagram for transverse fillet welds with continuous loaded plate.

Fig. 1 S-N Diagram for SM 41

The values for A and K can be determined from results of fatigue tests and depend on the types of materials and joints used. However, as far as the initiation of fatigue cracks is concerned, K may be taken as 0.18 without involving much error. Now it is said that the strength in fatigue fracture obtained by general fatigue test at the frequency of 2×10^6 can be regarded as equivalent to the strength in the fatigue crack initiation at the frequency of 10^6 .

Strictly this linear relation is realized, when the repeated loads (stress range) are constant. But working stresses in actual structures are random. In the case of random loads, it is assumed that the modified Miner's theory is applicable in estimating the fatigue damage effect. In the modified Miner's theory, the fracture is assumed to initiate at $\frac{n_i}{N_i} = 1$.

Here n_i is the total frequencies of loading at the stress range S_i , N_i is the frequency of loading when fracture is observed for the stress range S_i to which the structure is subjected. In deriving this relation, it is specifically assumed that the fatigue damage on one cycle of stress range S_i is $1/N_i$.

Now if the total frequencies of repeated loads applied is N_t , $P(S_r)$ is the probability of the stress range S_r and $N(S_r)$ is the fracture frequency at the stress range S_r , we have the following relation.

$$\int \frac{N_t \cdot P(S_r)}{N(S_r)} \cdot dS_r = 1 \dots\dots\dots (2)$$

From equations (1) and (2), we have the following relation;

$$\frac{N_{eq}}{N_t} = \int P(S_r) \cdot \left(\frac{S_r}{S_b}\right)^{1/K} \cdot dS_r \dots\dots\dots (3)$$

where S_b is called as the basic stress range and is equivalent to the stress due to specified live load, and N_{eq} is called as an equivalent fracture frequency of repetition of the basic stress range.

4. Range and frequency of repeated stresses applied

(1) Life of bridges

The first item to be determined in fatigue design of bridges is the expected life of the bridge. Now, there is no settled view to the life of highway bridge in any country. A survey result on the life of highway bridges in Japan shows that the life of most bridges is 30 - 40 years. The reason of reconstruction of bridge is not due to structural defects of bridges but rather to resolve the inadequacy of bridges for the increasing traffic volume or to improve the road alignment. This particular situation implies that unnecessarily long life is not much meaningful.

The Ministry of Construction recommends a expected service life of 50 years for bridges. The life of 50 years is widely accepted in Japan.

(2) Traffic volume

Let $N(Y)$ (Y being the year) be the daily traffic volume per lane. The total traffic volume on the bridge during the service life, N_{ta} , can be expressed as

$$N_{ta} = \int 365 \cdot N(Y) \, dY$$

In practice, it is extremely difficult to estimate $N(Y)$ accurately at the design stage of bridges. The maximum hourly traffic volume per lane is 2500 vehicles however, because of considerable differences in the volume depending on the time bands of the day, 20,000 vehicles seems to be a maximum daily traffic volume per lane.

To determine $N(Y)$ at the time of design, some suitable values below 20,000 will be selected for the class of roads concerned.

(3) Equivalent frequency of repetition of the specified load

The Ministry of Construction conducts an annual survey on the traffic load. All data measured at many observation sites spread all over Japan from 1970 to 1973 are shown in Fig. 2. This is therefore considered as an average wheel load distribution in Japan.

The equivalent frequency of repetition of the T-load which is the specified truck load in the highway bridge design (see Fig. 3), can be obtained as follows.

According to the steel highway bridge design specification, the weight of rear wheel of T-load is 8 ton. Now regarding this 8 ton as a basic wheel load, the equivalent frequency of repetition of 8 ton can now be obtained. Assuming the validity of the modified Miner's theory in this case, equation (3) can be rewritten as

$$\frac{N_{eq}}{N_t} = \int_{T_{min}}^{T_{max}} P(T) \cdot \left(\frac{T}{8}\right)^{1/K} \cdot dT \dots\dots\dots (4)$$

where N_{eq} : equivalent frequency of repetition

T : wheel load

$P(T)$: probability for applied wheel load

K : slope for S-N curve (K is taken as 0.18, see Fig. 1)

This equation shows clearly that fatigue crack initiation depends strongly on the magnitude of wheel load. For example, the relation between T and $(T/8)^{1/K}$ is illustrated in Fig. 4.

This relation shows that the fatigue damage due to one loading of 12 ton, which is 1.5 times of the basic wheel load, is equivalent to that due to

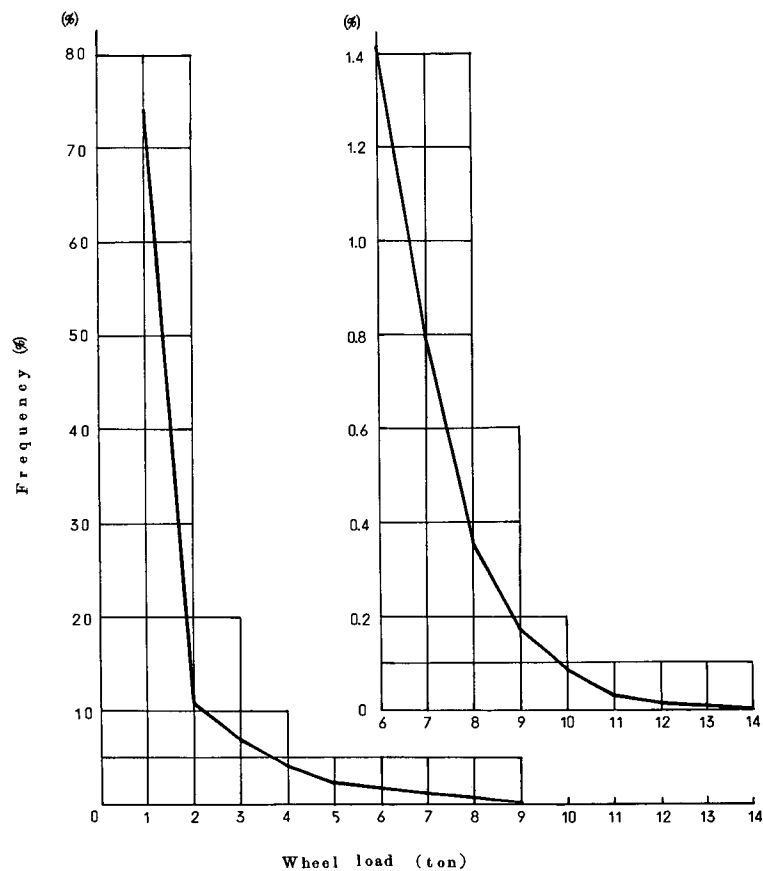
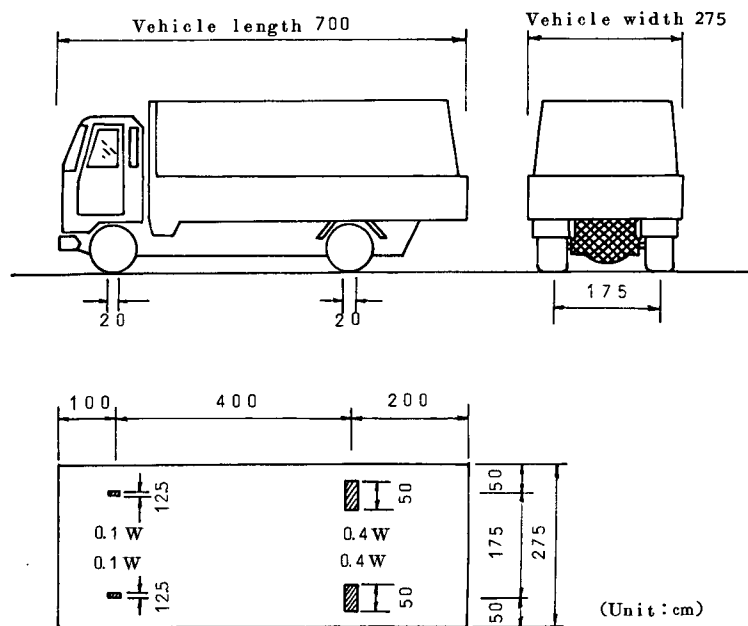


Fig. 2 Actual wheel load frequency distribution



Total weight W (t)	Front wheel load 0.1W (kg)	Rear wheel load 0.4W (kg)	Front wheel width b_1 (cm)	Rear wheel width b_2 (cm)	wheel contacting length a (cm)
20	2,000	8,000	125	50	20

Fig. 3 T-load

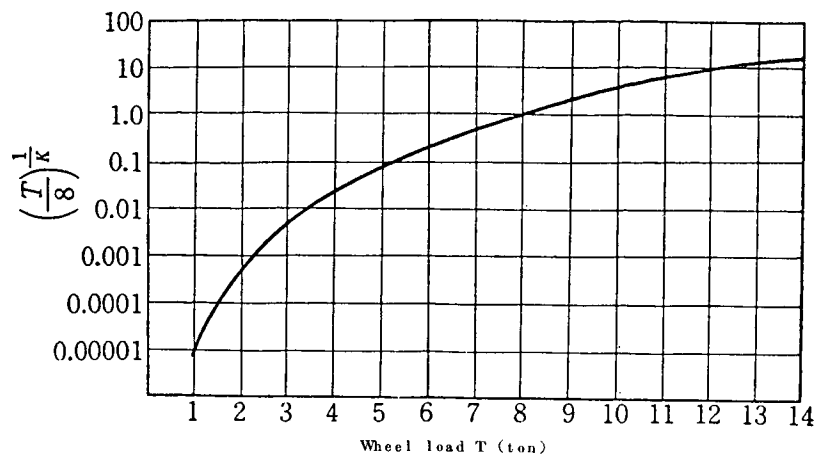


Fig. 4 Accumulated fatigue damage rate due to wheel load (on the basis of 8 ton loading with $K=0.18$)

9.5 loadings of the basic 8 ton. The equivalent frequency of repetition is calculated from equation (4), in which $P(T)$ is obtained by using the actually measured data of frequency distribution of wheel loads (shown in Fig. 2).

Now let us consider some member of a bridge. Obviously, the effect of a live load on the particular member, depends greatly on its loading position. In design calculations, we place always the specified load at the position whereby the member under consideration is subjected to the largest stress. Now knowing the probability of loading position of basic load on actual bridge and the subsequent stress in member, the effect of repeated load, on a particular member, due to the entire traffic volume can be evaluated by computing the equivalent frequency of repetition of basic loads placed at the loading position of design calculation. Now if the basic load is assumed to be a T-load and frequency distribution of vehicles are known for each passage position, the correction factor C_1 to be multiplied the equivalent frequency of repetition N_{eq} can be obtained from the following equation.

$$C_1 = \int \left(\frac{R(x)}{R_0} \right)^{1/K} \cdot P(x) \cdot dx \dots \dots \dots (5)$$

where C_1 : the correction factor multiplying N_{eq}
 R_0 : stress in the member due to the basic load applied at a basic loading position considered in the design calculation

$R(x)$: stress in the member due to the basic load applied at arbitrary loading position x

$P(x)$: probability of the stress $R(x)$

K : slope of S-N diagram

The equivalent frequency of repetition taking the effect of passage position of vehicles can be found as $C_1 \cdot N_{eq}$.

By examining the results surveyed on major highway, it is found that the frequency distribution of heavy vehicles for the rear wheel's passage position forms a normal distribution curve with standard deviation of 31.5 cm for 2 lanes highway and 45.5 cm for 4 lanes highway having 3.5 m lane width (see Fig. 5). The relation between $R(x)$ and $P(x)$ of equation (5) can now be determined based on measured data of passage position of vehicles.

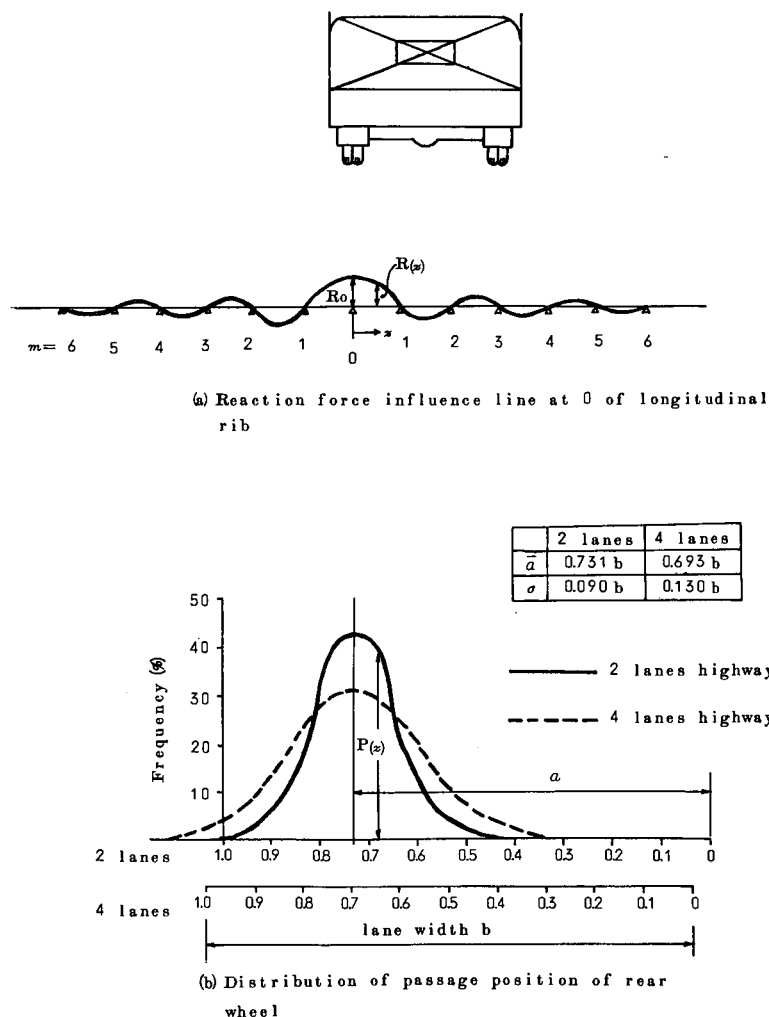


Fig. 5 Influence line of longitudinal rib and passage position of wheel load

5. Proposal of allowable stresses for fatigue design of steel plate decks

Tensile strengths, yield points and ordinary allowable stresses of various grades of Japanese structural steel are indicated in Table 1. For each grade of steel, we proposed the allowable stresses for the design of steel plate decks. Table 2 indicates our proposal. We set the allowable stresses for each effect due to the action as a part of main girder, due to the action as floor deck and due to combined action of these. The allowable stresses for the action as floor decks were given based on numerous fatigue tests, which were carried out to obtain the fatigue strengths at the crack initiation at 2×10^6 cycles.

When the number of repetition is not 2×10^6 cycles, the allowable stresses must be modified according to the number of repetition. The modification can be done using the following equation;

$$\sigma_{eq} = \sigma_f \left(\frac{2 \times 10^6}{C_1 N_{eq}} \right)^K$$

where, σ_{eq} : modified allowable stresses for the action as floor decks

σ_f : allowable stresses for the action as floor decks specified in Table 2

$C_1 N_{eq}$: equivalent frequency of repetition, this can be obtained using the method given in the previous sections.

Figure 6 shows the relationships between bridge service life, traffic volume per day per lane and equivalent frequency of repetition obtained from the method given in the previous sections. When the bridge life and the traffic volume to be considered in the design are given, the equivalent frequency of repetition for the longitudinal ribs can easily be obtained from Figure 6.

Figure 7 shows the relationships between modification factor $(2 \times 10^6 / C_1 N_{eq})^K$ in the above equation and equivalent frequency of repetition $C_1 N_{eq}$. Using this figure and Equivalent frequency of repetition $C_1 N_{eq}$ which could be obtained above, we can get the modification factor easily. And finally we get the modified allowable stresses for the action as floor decks by the above equation.

Table 1 Specific values of strength and allowable stresses for the tested steel

grade of steel	tensile strength σ_u (kg/cm ²)	yield point σ_y (kg/cm ²)	allowable stresses for the combined action as apart of main girder and bridge deck σ (kg/cm ²)	allowable stress σ_a (kg/cm ²)	$\frac{\sigma_u}{\sigma_y}$	$\frac{\sigma_u}{\sigma}$	$\frac{\sigma_u}{\sigma_a}$	$\frac{\sigma_y}{\sigma}$	$\frac{\sigma_y}{\sigma_a}$	$\frac{\sigma}{\sigma_a}$
SS 41 SM 41 SMA 41	4100	2400	2000	1400	1.71	2.05	2.93	1.20	1.71	1.43
SM 50	5000	3200	2700	1900	1.56	1.85	2.63	1.19	1.68	1.42
SM 50 Y SMA 50 SM 53	5000 5300	3600	3000	2100	1.39 1.47	1.67 1.77	2.38 2.52	1.20	1.71	1.43
SM 58 SMA 58	5800	4600	3700	2600	1.26	1.56	2.23	1.24	1.77	1.42

Table 2 Proposed allowable stress for steel plate deck

Type of allowable stress Grade of steel	allowable stresses for the action as apart of main girder (kg/cm ²)	allowable stresses for the action of bridge deck (kg/cm ²)				allowable stresses for the combined action as apart of main girder and bridge deck (kg/cm ²)
		base metal	butt weld finished smooth by grinding	transverse fillet weld on continuous loaded plates	continuous longitudinal fillet weld	
SS 41, SM 41 SMA 41	1400	1400	1400	900	1100	2000
SM 50	1900	1600	1600	900	1100	2700
SM50Y, SM53 SMA 50	2100	1600	1600	900	1100	3000
SM 58 SMA 58	2600	1600	1600	900	1100	3700

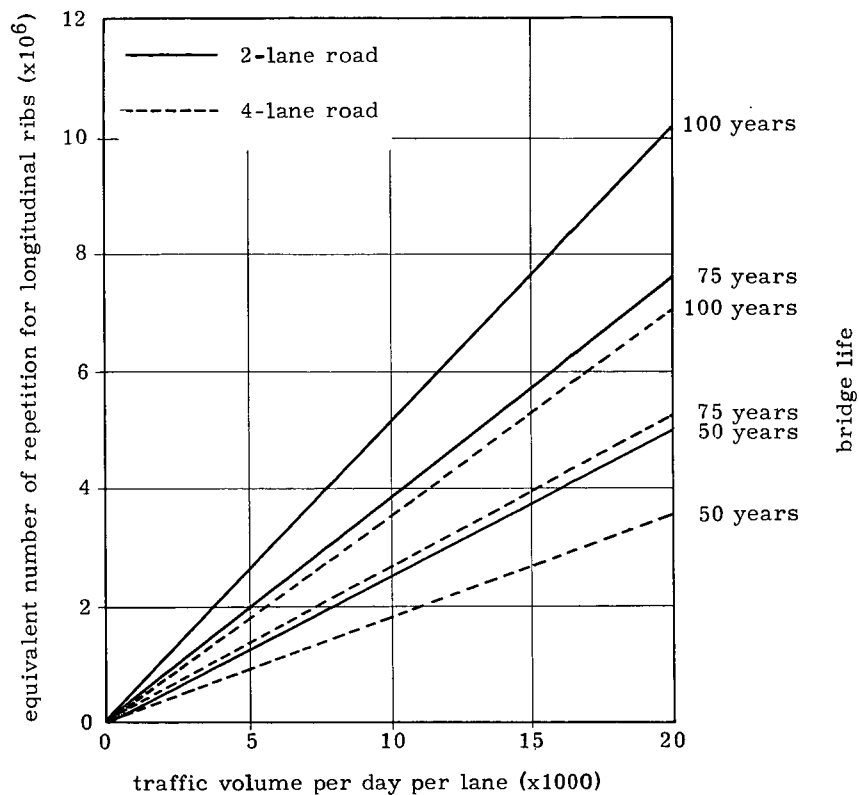


Fig. 6 Relationship between traffic volume, bridge life and equivalent number of repetition

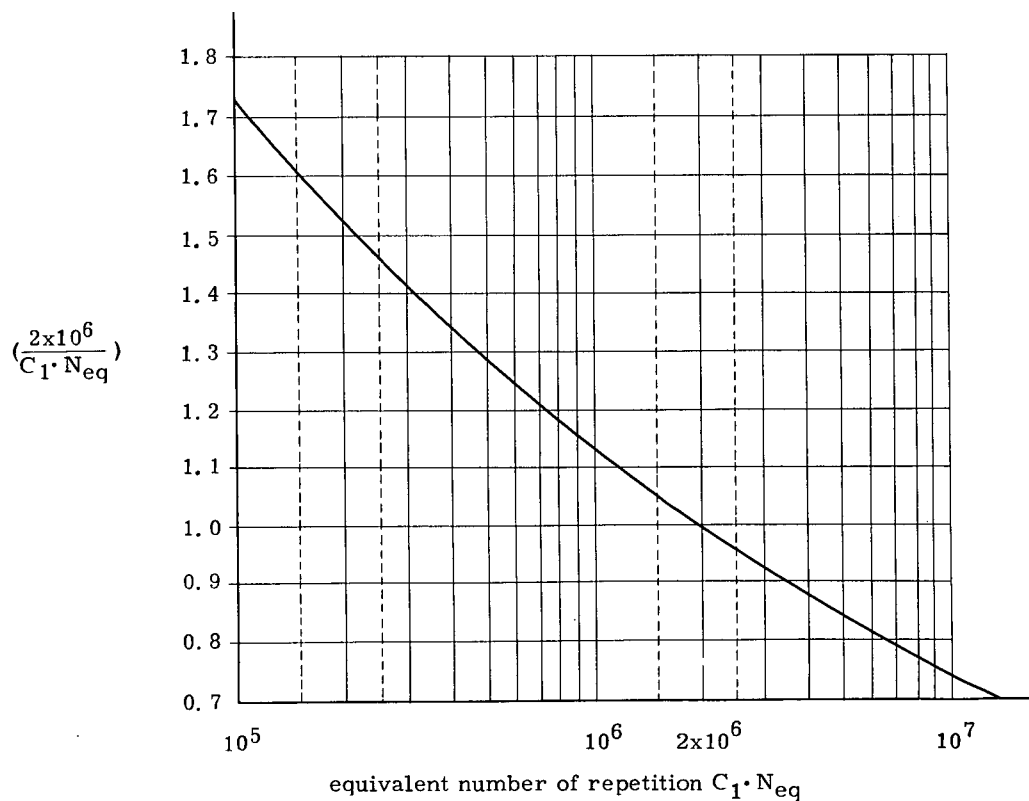


Fig. 7 Relationship between equivalent number of repetition $C_1 \cdot N_{eq}$ and $\left(\frac{2 \times 10^6}{C_1 \cdot N_{eq}} \right)$

6. Conclusion

In this paper, the authors have presented a basic concept on the fatigue design for steel plate deck bridge briefly.

Fatigue design of steel plate decks must be made taking into account the magnitude and the frequency of repetition of working stresses. The probabilistic distribution of the magnitude of stresses can be derived from the probabilistic distribution of the weight of vehicles and their passage positions observed in the survey on the major highway.

The fatigue effect due to passing vehicles on a bridge with arbitrary weight, frequency of repetition and passage position can be substituted by the effect due to specified vehicles with the equivalent frequency and the basic passage position considered in design calculation. By inducing the concept of equivalent frequency, fatigue design of steel plate decks can be considerably simplified for practical use.

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建設省土木研究所橋梁研究室
FATIGUE DESIGN OF STEEL PLATE DECK
BRIDGES

キーワード：橋梁, 鋼床版, 疲労設計

Key words: Bridge, Steel Plate Deck, Fatigue Design

要 旨：この報文は1974年6月24～26日に米国スタンフォード大学で開かれた米国土木学会主催の「工学における確率的手法」に関する特別会議に提出されたものである。この論文は、鋼床版橋の疲労強度を取扱っており、疲労寿命の推定方法および疲労を考慮した許容応力度を提案している。

Synopsis: The paper was presented to the ASCE Specialty Conference on Probabilistic Methods in Engineering held at Stanford University in U.S.A. on June 24-26, 1974. In this paper, fatigue strength of steel plate deck bridges is dealt with and recommendation has been made to the method for estimation of fatigue life and to the allowable stresses for fatigue design.

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