OPTIMAL SAFETY FACTOR OF MULTI-SPAN CONTINUOUS BRIDGES

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1. INTRODUCTION

Because of a few expansion joints and great resistance to seismic attack,there are recently many attempts to use multi-span continuous bridges. However,design of substructures in these bridges always requires larger section of piers which leads to uneconomic structures. Since these type of bridges are statically indeterminate structures,the failure of one element does not necessarily mean the collapse of the whole structure. But the current design code consideres factors of safety based on the initial(element) failure not the failure of the whole structure,leading to the use of high factors of safety in design of multi-span continuous bridges. To make the design of these bridges more economic,factors of safety for substructure design should be reinvestigated. This study can divide into two parts,which the first one is to investigate the reliability of multi-span continuous bridges designed by the current design code at structural element and system level and second one is to find how level of factors of safety (or allowable stress) for multi-span continuous bridges should be assigned. In this time,the results of first part and method used in second part will be presented.

2. RELIABILITY OF BRIDGES DESIGNED BY THE CURRENT DESIGN CODE

In this study,four types of multi-span continuous bridges selected for the investigation are shown in Figure 1,which superstructures are three,five,seven and nine span continuous box girder bridges with span length of 50 metre and substructures are reinforced concrete rigid-frame pier which its design is controlled by combination of dead,earthquake and temperature loads.

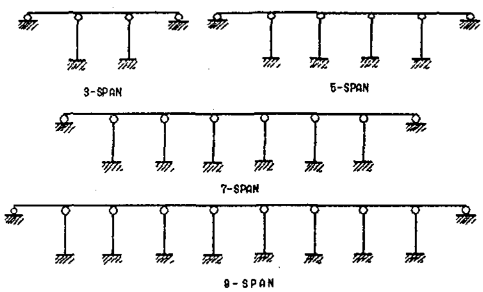

Figure 1

2.1 Actual Loads <u>Dead Load</u>: Dead load here,only the own weight of structure is considered and its distribution is assumed to be normal distribution. <u>Temperature Load</u>: This study considers two types of temperature effect. One is temperature variation effect on main girder supported with piers and other one on piers. The temperature effects on structural elements are assessed from variation in time of external air temperature. The distribution of maximum temperature differences are normal distribution. <u>Earthquake Load</u>: Actual earthquake load is modeled as Kh = Sa/g, where Sa = linear acceleration response spectrum and g = acceleration of gravity.The probability distribution of Sa is determined from earthquake data and assumed to be the extreme value distribution of the first kind for the convenience of the probabilitic analysis.

2.2 Element Reliability In the computing of element reliability,we consider the reliability of pier at the point where the maximum bending moment occurs. The Turkstra's rule of load combination is used to evaluate the failure probability of each elements. The capacity of the element expressed by the bending moment. The reliability analysis results of each types are shown in Figure 2. From the results,it is found that the current design code does not insure consistent level of safety. If we give the target failure probability of the elements as 10^{-3},it is found that the results here are too low. This can be concluded that the current design code use high factors of safety to minimize the failure of elements.

2.3 System Reliability Determining a reliability of structural system is complex because all the failure modes must be considered. Due to the difficulties of mode identification,mode combination ,etc.,this paper uses the method presented by Murotsu[2] in the analysis. Figure 3 shows the failure probability of each structure systems. It is found that failure probability of structure systems are too low when compares with of elements and types of structures with high degree of redundancy have low values of failure probability than with low degree.

3. COMPUTATION OF OPTIMAL FACTORS OF SAFETY

The general design format used in the allowable stress design can be written as follows:

$$R(f_c/\gamma_c, f_y/\gamma_s) \geqq S(\Sigma F_i) \quad (1)$$

where $R(\cdot)$ and $S(\cdot)$ are the resistance and load effect which are function of material strength and design value of load in the current design code,respectively. γ_c and γ_s are safety factors of concrete and steel reinforcement, respectively. For instance, the current design code,the safety factors of 2 and about 1.06 for concrete and steel(SD35) in combination of dead,earthquake and temperature loads. The results in section 2 is shown that it requires lower factors of safety to achieve the target failure probability if assumed as 10^{-3} and 10^{-7} for element and structure system. The steps for computing optimal factors of safety are represented below:

a) Select an appropriate load combination format.
b) Establish representative structures.
c) Assign initial values for all parameters (e.g. factors of safety,etc.).
d) Design each representative structures.
e) Determine the failure probability(limit state probability) of each representative structures based on actual loads.
f) Compute the objective function measuring the difference between the difference between the target limit state probability and the computed limit state probability as the following formula:

$$\Omega=\sum_{k=1}^{N}\left(\frac{\log P_i^{(k)}-\log P_i^{*}}{\log P_i^{*}}\right)^2 \quad (2)$$

g) Determine a new set of parameters along the direction of maximum descent with respect to the objective function.
h) Repeat Step c)-h) above until a set of parameters that minimize objective function is found.

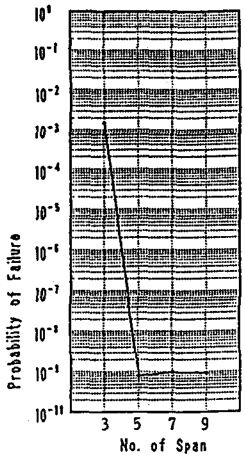

Figure 2

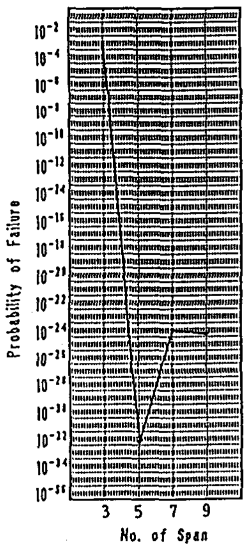

Figure 3

4. REFERENCES

1. Thoft-Christen,P.and Baker,M.,Structural Reliability Theory and Its Applications,Springer-Verlag,Berlin,1982.
2. Murotsu,Y.,Okada,H.,et al.,Automatic Generation of Stochastically Dominant Modes of Structural Failure in Frame Structure.,Bulletin of University of Osaka Prefecture,Series A,Vol.32,No.2,1983,pp.85-101.