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PRELIMINARY STUDY ON TEMPERATURE DIFFERENCE LOADING ON BRIDGES

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1. Introduction

Bridge structures are subjected to a complex environmental exposure that changes with time. The ambient air temperature, solar radiation,wind velocity, and humidity are the parameters most significant to changes in bridge temperatures. In current design practice,thermal effects in both simple span and continuous bridges are generally ignored. From field tests [1],there appear that temperature variations in bridges can cause thermal stresses that are comparable in magnitude to stressed induced by another loading (dead,live or earthquake load). Nowaday,since Japan have a tendency to introduce a Probability-Based design method into the design standards for highway bridges, then it is necessary to investigate the temperature difference loading effect more accurately. In this study, the probability of combined earthquake loading and temperature difference loading occurring in bridge structures is considered.

2. Temperature difference loading

This study attemps to consider the temperature difference loading occurring in bridges in Japan. Because of the limited data available, the estimation of occurrence rate of temperatures differential within the bridges is still difficult. The following is a summary of the available literature. In Ref.[2], it was suggested that a temperature difference of 20 ℃ could occur between three to five times/year,and one of 15 ℃ about 20 times/year for concrete bridges in New Zealand and at least five or six times a year for United Kingdom. For steel plate deck bridges, the study which was carried out by Kanai,et al.[3] have shown that the temperature differential within the deck reaching 15 ~ 20 ℃ would occur about three times/years. Since Japan lies on the same isotherm as United Kingdom,the same figures would probably be used. In this study it is assumed that nominal temperature difference will occur,on average,six times/year and exist for 1 hour.

3. Earthquake loading

In this study,earthquake which occurred within area around Tokyo and Osaka city are considered. The occurrence rate of earthquakes is obtained by determining from past data and collecting from the past researches. One example is a value obtained from the research of Yamada,et al.[4] which considered the earthquake occurred within a circular area with radius 300 km around Osaka city. From the 126 earthquake data,it was found that the occurrence rate of earthquakes is 9.75×10^{-3} /year and an average duration of strong ground motions is 1.4×10^{-6} year.

4. Method of analysis

First, it is necessary to define the 'danger period',Td ,within which the combination of the thermal and earthquake loads would yield potential damage condition. Suppose the severe thermal loading and earthquake loading exist on the bridge for time Tt and TQ. Fig. 1 shows that potential damage conditions would occur if the earthquake load occurs at any time within the period Td , where Td = Tt + TQ .

To compute the probability that the two loading conditions will occur simultaneously within a particular length of total time, and that,in this time,the average number of thermal risk periods will be nd.The total time the bridge is in danger is nd × Td.

If the earthquake loads are expected to occur at a rate of nQ / unit time,then, on average,the following number of simultaneous loading period will occur as nQ × nd × Td.

In this study,the thermal danger period is about 1 hour, and it can be seen that the chance of the earthquake load coinciding with a particular hour within a total time of 120 years is very small. Under such circumstances, the load combination occurring based on the Poisson distribution is assumed.

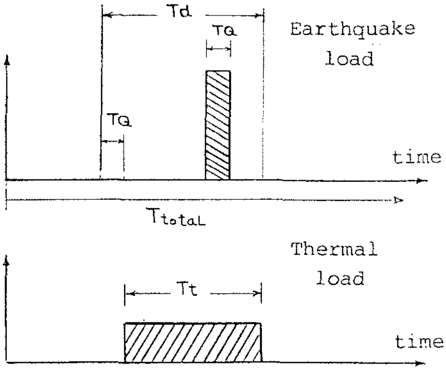

Fig.1 Definition of 'danger period' for probability analysis

$$P(x) = \frac{e^{-\mu}\mu^{x}}{x!}$$

where P(x) is the probability of x events occurring and μ is the average number of occurrence.

Thus,the probability of no events occurring is $P(0) = \frac{e^{-\mu}\mu^{0}}{0!}$. Hence,theprobability of an event occurring is

$$P = 1 - e^{-\mu}$$

or

$$P = 1 - e^{-[nQ\cdot nd(Tt + TQ)]}$$

5. Summary and Conclusions

In this study,the probability of combined earthquake loading and temperature difference loading occurring is considered by using simple probability method which the calculation results will be presented later. From the fact that there are few or no reports of damage to bridges caused by diurnal thermal loading especially when it is combined with earthquake loading,engineers still need to investigate its effect more clearly before they specify the rational load factors in the new design standards.

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