Investigation of Design Loads and Load Combinations for Limit State Design of Long Span Cable-Supported Bridge

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Summary

For the design of long span cable supported bridge (LSCSB), the reliability based limit state design manual is under development. Statistical and probabilistic definition of the design loads and the load factors in the load combination are examined in relation to the design period and the safety level. For the purpose of investigating the reliability level of the design load combinations in the ultimate limit state and the extreme event limit state, the definitions of the variable loads are reviewed in terms of the design period and exceedance probability. An example of cable-stayed bridge is presented to show the reliability indexes of design load combinations of earthquake load.

Keywords: long-span cable-supported bridge; design life; reliability index; earthquake load; cable-stayed bridge; pylon.

1. Differentiation of target reliability

One of the most important matters in the design codes for bridge structures may be the criteria relating to the safety level of the design. In the ongoing project in Korea for the writing of the draft of the design manual for LSCSB, it is decided that the safety level needs to be determined in terms of probabilistic and statistical manner. Through the research so far, by considering the relative importance of the bridge structures, the target reliability indexes are differentiated in order to obtain rational and economical design.

Table 1 : Target reliability for Design Life

Structural Component		Based on 1-year Time Period		Target Reliability Based on Design Life				
		Target Reliability	Probability of Failure	20 year	30 year	50 year	100 year	200 year
Replaceable Components	Stay cable & Hanger Rope	9.09	4.74×10^{-20}	8.76	8.72	8.66	8.58	8.50
	Other Components (20 year)	4.66	1.58×10^{-6}	4.00	3.90	3.78	3.60	3.42
	Other Components (30 year)	4.74	1.05×10^{-6}	4.10	4.00	3.88	3.71	3.53
	Other Components (50 year)	4.85	6.32×10^{-7}	4.21	4.12	4.00	3.83	3.66
Repairable & Permanent Component	Main Cable	12.43	8.88×10^{-36}	12.19	12.16	12.11	12.06	12.00
	Other Components	5.11	1.58×10^{-7}	4.52	4.43	4.32	4.16	4.00

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The target reliability index of 4.0 is basically applied to all members of LSCSB and the reduced design lives for the replaceable components are applied. The design lives of the replaceable components are 20, 30 and 50 years depending on components. Table 1 shows the target reliability index converted to 1 year time period. The corresponding reliabilities for 1 year are 4.66, 4.74 and 4.85 for the design lives of 20, 30 and 50 years, respectively. These values of reliability are similar to 4.75 of the ordinary bridge. The target reliability index of the cable component in the limit state design has been determined corresponding to the safety factor in the allowable stress design. The draft of the design manual is based on the safety factor of 2.2 for suspension bridge and the corresponding reliability index of 12. Also, the basic safety factor is 2.0 for cable-stayed bridge and the corresponding reliability index is 8.5.

2. Safety level of design manual

In the writing of the design manual of LSCSB, it is required to determine the target reliability index and the appropriate safety factors. The safety factors are calibrated using the statistical properties of the loads and resistances. For the calibration process, it is very important to define the design loads in statistical manner. Especially, the variable loads which depend on time such as live load, wind load and earthquake load are defined based on statistics and probability. In this paper the intermediate results of the ongoing research for the determination of the statistical properties of the design earthquake load are presented and applied for the analysis of the reliability of the example LSCSB design. The optimized results which use the generalized extreme value distribution method for the design life of 50 years, 100 years and 200 years are shown in Figure. 1.

An example LSCSB designed by the prototype bridge design team are used for the reliability calculation of the application of design load combination of the proposed design manual. Six different sections of the pylon are checked in the design. The moment in the transverse direction is studied and the results are shown in Figure 2. The reliability index of the example bridge pylon is denoted as R_{real} and is between 2.50 and 2.84. The reliability index with the minimum required strength required by the design load combination of the design manual is denoted as R_{min} and is between 2.34 and 2.61.

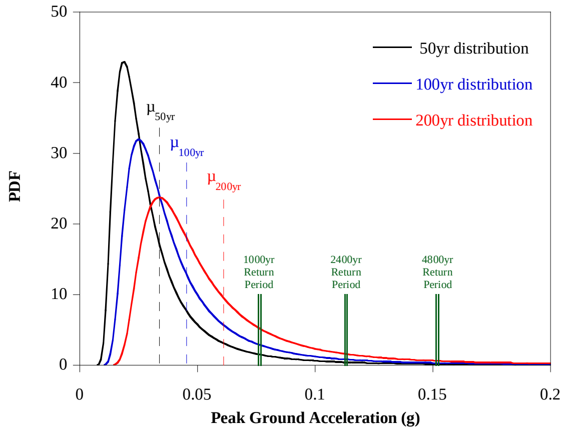

Fig. 1: PDF for PGA of Design Earthquake in Korea

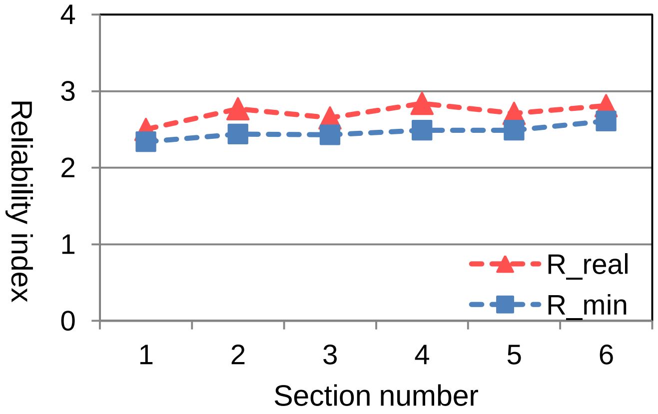

Fig. 2: Reliability analysis of an example cable stayed bridge

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