New Approach on the Safety Factor of Cable in Long-span Bridges

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Summary

Super long-span bridge R&D centre in Korea has investigated and developed the design guideline for cable supported bridges in accordance with Limit State Design concepts. Recently suspension and cable stayed bridges have become longer in span and huge tonnages of steel are required for cables. A significant part of the force in the cables of long span cable supported bridges arises from dead load. It is therefore obvious that significant cost savings can be obtained in cables and cable anchorages together with related savings in pylons and construction time by adopting the reasonable safety of cables.

Keywords: suspension, cable stayed bridge: high strength cable; reliability based; reliability index; safety factor; partial factor; serviceability limit state; ultimate limit state.

1. Introduction

Usually long span cable supported bridge (LSCSB) is unique in its scale, boundary condition and public needs. And it also requires longer life cycle while the maintenance work should be minimized due to the difficulties of access and repair

In the allowable stress design method, it is not possible to quantify the reliabilities of both bridge components and the entire bridge system. Recently suspension and cable stayed bridges have become longer in span and huge tonnages of steel are required for cables. A significant part of the force in the cables of long span cable supported bridges arises from dead load. It is therefore obvious that significant cost savings can be obtained in cables and cable anchorages together with related savings in pylons and construction time by adopting the reasonable safety of cables

2. Target reliability, β_T

Regarding the uniqueness of long span bridges compared to the ordinary bridges in terms of the size and the importance of the bridge, it is highly required to provide the reasonable process how to set the target reliability index for the design of LSCSB.

The safety factor for the design of the cable component is getting decreased recently. This is partly due to the increase in main span length which increases the weight proportion in the load. As the dead load is more accurate than the variable loads to estimate, it reduces the uncertainty and increases the safety level. Also, considering the accumulation of the construction experience and the development of the technology in the field of analysis, design, construction and material, the target safety level is lowering in these days. 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.

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3. Target reliability indices and resistance factors

3.1 Main cable of suspension bridge

The stress of main cable may be considered to be composed of uniform axial stress from axial cable force, bending flexure of the cable, transverse stresses at saddles and cable clamps, and uneven axial stress due to built-in construction inaccuracies or temperature variation across main cable section.

For the reliability based evaluation, various resistance factors are allowed in accordance with the ratio of Permanent load to Variable load (Table 1). From Table 1, it can be noted that the reliability indices of main cables are much higher than those of stiffening girder. One of reasons of this kind of high indices is caused by the small standard deviation of resistance of parallel wire cables determined for the specified tensile strength.

Table 1: Reliability Based Resistance Factor for Suspension Bridge

β_T	PL:VL	ϕ_{mem}	S.F.	β_T	PL:VL	ϕ_{mem}	S.F.	β_T	PL:VL	ϕ_{mem}	S.F.
10	95 : 05	0.66	1.94	11	95 : 05	0.62	2.07	12	95 : 05	0.58	2.21
	90 : 10	0.67	1.95		90 : 10	0.63	2.09		90 : 10	0.58	2.25
	85 : 15	0.64	2.07		85 : 15	0.58	2.28		85 : 15	0.52	2.54
	80 : 20	0.59	2.27		80 : 20	0.53	2.55		80 : 20	0.47	2.89

Usually spiral rope, strand rope and PWS are used for hanger elements in suspension bridges. The cross section area of the hanger has been determined based on the safety factor of 3.0 with respect to the breaking strength for CFRC rope and 2.5 for PWS. But considering its function and importance, it is reasonable to adjust the number to the same level of stay cables in cable stayed bridges. Also, in some long span suspension bridges, the partial factor for PWS hanger was adopted as 1.67. So, the resistance factor for hanger in suspension bridge is recommended to be the values of the stay cables.

3.2 Stay cables of cable stayed bridge

Similar to suspension bridge, for the reliability based evaluation, various resistance factors are possible in accordance with the possible ratio of Permanent load to Variable load and corresponding target reliability index as shown in Table 2.

Table 2: Resistance factors for cable stayed bridge

β_T	PL:VL	ϕ_{mem}	S.F.	β_T	PL:VL	ϕ_{mem}	S.F.	β_T	PL:VL	ϕ_{mem}	S.F.
7	85 : 15	0.78	1.77	8	85 : 15	0.72	1.91	9	85 : 15	0.66	2.08
	80 : 20	0.78	1.80		80 : 20	0.71	1.98		80 : 20	0.64	2.20
	75 : 25	0.76	1.88		75 : 25	0.68	2.10		75 : 25	0.60	2.37
	70 : 30	0.74	1.98		70 : 30	0.65	2.25		70 : 30	0.57	2.57

In conclusion of investigations, safety factors of several suspension bridges and cable stayed bridges in Korea were analysed and compared to some of international major bridges. In conclusion, the allowed resistance factor for suspension bridge is in the range of 0.47~0.66, and 0.57~0.78 for cable stayed bridge as shown in Table 3 and Table 4.