I －B 33

Proposal of a Steel and a Hybrid Stress-Ribbon Bridges for Their Application to Roadway Bridges

Takeshi YOSHIMURA*, Yoji MIZUTA M. JSCE, Kyushu Sangyo Univ.
Won-Ho KANG, Kwang-Kyu CHOI Dong-A Univ., Korea
Soon-Duck KWON Korea Highway Corporation, Korea
Keitaro KONUMA M. JSCE, New Structural Eng., Inc.

1. Introduction

In a previous paper, the authors proposed a stress-ribbon pedestrian bridge of light steel construction and it was found that the deck weight could be reduced to one-fourth of the conventional concrete stress-ribbon bridges [1]. Further study has been made to propose an improved, much lighter steel and a hybrid stress-ribbon bridges for their application to roadway bridges as a collaboration between Japan and Korea. The results are briefly introduced below.

2. Previously proposed and improved, much lighter steel bridges

The authors showed that the half-circular edge modification for concrete stress-ribbon bridges is quite effective for increasing their aerodynamic stability [2]. Based on this study, similar cross-sectional configuration is formed for the previously proposed steel structure shown in Fig. 1(a) [1]. The bridge is composed of inner cables, a pair of circular steel pipes, cross beams, a concrete slab and a decoration panel. The most important idea of this proposal following the study by Wheen & Wilson [3] is that the pipes are also pre-stressed by pre-tension force in themselves, and therefore, partially play an important role in suspending the deck weight and the loads.

However, in the study of the Nagashima Storage Dam Bridge [4], which has a similar deck to that shown in Fig. 1(b), the deck was found to be quite aerodynamically stable. Although the stability depends on the width of the open gratings, its non-dimensional critical flutter speed is high enough and the aerodynamic exciting force for vortex excitation is small, in the range of allowable value. This valuable experience is applied to the improved design presented in Fig. 1(b). The heavy concrete slab in Fig. 1(a) is replaced with a lighter steel open grating partially covered with a hard rubber plate. Moreover, the steel pipe diameter of 40 cm in Fig. 1(a) is reduced to 20 cm and the bottom decoration panel is removed. It can be easily understand that the deck weight of the improved structure could be reduced to about half of the previously proposed structure, i.e., up to about one-tenth of the conventional concrete structures.

3. Application of the structure to roadway bridges

To reduce the horizontal component of extremely large tensile force in the inner cables, H_w, it is necessary to reduce the total deck weight, $W=wL$, as well as to 'increase' the sag ratio, f/L, as H_w is proportional to both W and the inverse of f/L. Application of the improved steel structure introduced above allows for a reduction in W remarkably. However, f/L should also be 'reduced' in order that this type of structure may be applicable to roadway bridges since the bridge design code in Japan stipulates that their maximum gradient should be 5 %, much smaller than that of 12 % for pedestrian bridges. Therefore, alternative structures should be invented for this application .

4. Proposal of hybrid structures applicable to roadway bridges

The alternative proposed hybrid structure shown in Fig. 2 provides a good solution for the problem mentioned above. The original structure in Fig. 2(a) is a conventional concrete stress-ribbon bridge. However, the central portion of the deck is replaced with improved, much lighter steel stress-ribbon, Figs. 1(b) and 2(b). Moreover, about a half of the 'inner cables' inside the steel deck are stretched outside at the steel deck ends and lifted up over the concrete decks close to the abutments. These 'outer cables' are supported by newly installed low concrete towers for increase in their sag remarkably yielding a remarkable reduction in H_W. The concrete decks are suspended by the outer cables and lifted up horizontally by introducing the pre-tension force in the hangers. Therefore, the partial introduction of the outer cable system with the low towers allows for a 'reduction' in the deck sag as well as an 'increase' in the sag of about half of the cables remarkably. In this 'stress-ribbon suspension bridge', the side concrete decks could be replaced with the same central steel deck, and another full-steel hybrid structure can be invented.

5. Non-linear cable deflection analyzed by proposed method

A sample result of *w-f* curve for a stress-ribbon cable analyzed by a proposed method is presented in Fig. 3 denoted by a solid line [5]. *p(live load)-f* curves, after connection of the deck segments to each other, for an actual bridge and the previously proposed steel and the improved lighter steel bridges are denoted by dotted lines in the figure. *EA* together with *EI* effects on the reduction in the deflection can be seen in the

---

Key words: stress-ribbon bridge, roadway bridge, hybrid structure, composite structure, aerodynamic stability
*Corresponding author. Address: Higashi-Ku, Fukuoka, Japan 813-8503 E-mail: takeshi@ip.kyusan-u.ac.jp

figure. More important is that the lighter structures give larger deflection due to the same live load, i.e., the lighter structures are more flexible. Therefore, the hybrid bridge with concrete side decks may be better than the full-steel bridges as moderate stiffness is generally required for every structure in civil engineering.

6. Concluding remarks

The proposed hybrid stress-ribbon bridge is expected to have highly aerodynamic stability. Since this type of structure enables the reduction in both the deck weight and the sag, there is a feasibility that this type could be applicable to roadway bridges. For further details on this study, refer Ref. 5.

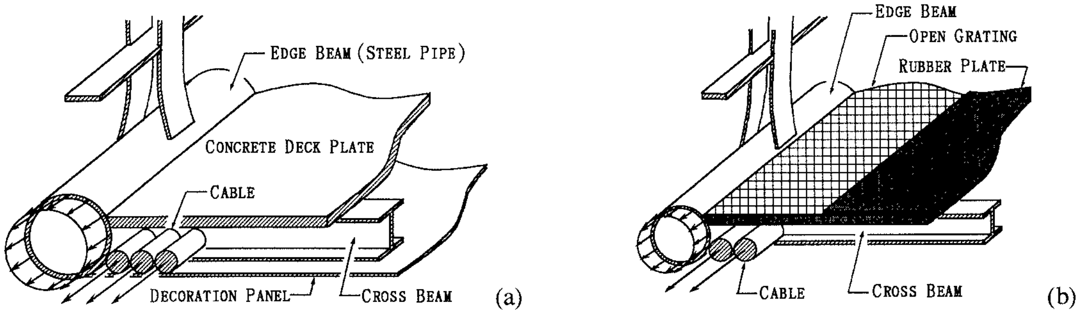

Fig. 1 Cross-sections of the previously proposed steel structure (a) and an improved lighter steel one (b).

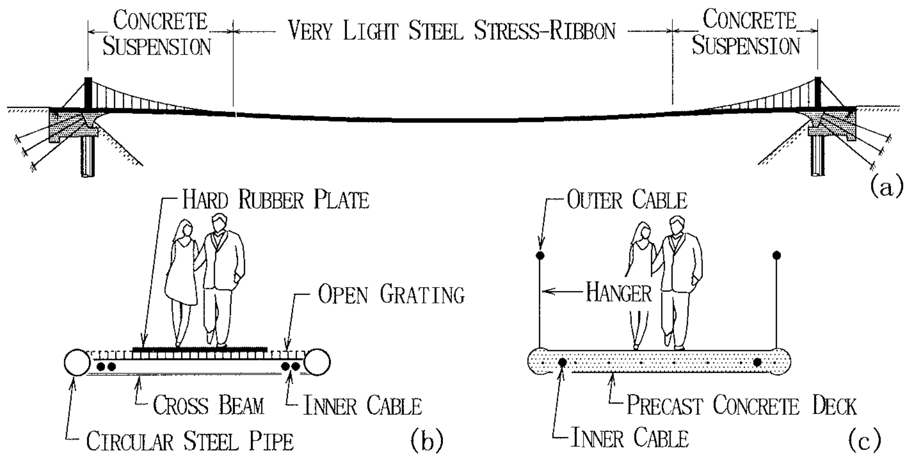

Fig. 2 Outline of the proposed hybrid stress-ribbon bridge.

References

1. Mizuta, Y. et al.: Proposal of a steel stress-ribbon bridge and its mechanical characteristics, J. Structural Eng., Vol. 43A, 1997.
2. Yoshimura, T. et al.: Half-circular and half-elliptic edge modifications for increasing aerodynamic stability of stress-ribbon pedestrian bridges, J. Wind Eng. and Industrial Aerodynamics, Vol. 69-71, 1997.
3. Wheen, R.J. & A. J. Wilson: The stress-ribbon bridge concept in steel, The Structural Engineer, Vol. 55, No. 5, 1977.
4. Yoshimura, T. et al.: Aerodynamic stability of the Nagashima Storage Dam Suspension Bridge, Prep. JSCE Seibu Branch Annual Conf., 1998.
5. Yoshimura, T. et al.: Proposal of steel and hybrid stress-ribbon bridges for their application to roadway bridges, Proc. IABSE Symp. on Long-Span and High-Rise Structures, Kobe Japan, to be published.

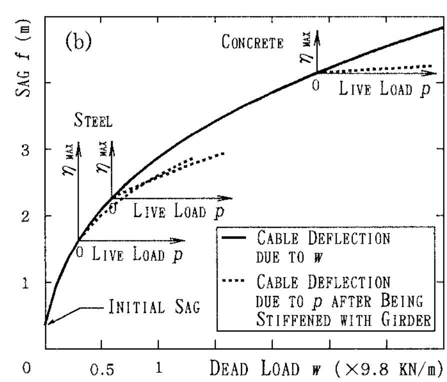

Fig. 3 Cable sag change due to dead and live loads before and after connecting deck segments to each other.