Proposal of a Steel and a Hybrid Stress-Ribbon Bridges and Their Aerodynamic Stability

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1. Introduction

In a previous paper, two of the authors proposed a stress-ribbon pedestrian bridge of light steel construction and it was found 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 lighter steel and a hybrid stress-ribbon bridges as a collaboration between two countries. The results are briefly introduced below.

2. The previously proposed and an improved lighter steel bridges

Figure 1(a) shows the previously proposed steel structure. It is composed of inner cables, a pair of circular steel pipes, cross beams, a concrete slab and a decoration panel. The pipes work as the edge girders. The most important idea of this proposal 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. Much lighter is the improved design presented in Fig. 1(b). The heavy concrete slab is replaced with a lighter steel open grating partially covered with a hard rubber plate. Moreover the bottom decoration panel is removed. It can be easily understand the deck weight of the improved structure could be reduced to above a half of the previously proposed structure, i.e., 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 required 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 enables W to reduce remarkably. However, f/L should be also reduced in order that this type of structure, as the second phase of this study, may be applicable to roadway bridges because the bridge design code in Japan provides 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. Proposed hybrid bridge

The alternative proposed hybrid structure shown in Fig. 2 is a good solution for the above mentioned problem. The original structure in Fig. 1(a) is a conventional concrete stress-ribbon bridge. But the central portion of the deck is replaced with the improved lighter steel stress-ribbon, Fig. 1(b) and 2(b). Moreover, about a half of the 'inner cables' inside the steel deck are stretched outside, over the concrete decks, Fig. 2(c). The concrete decks close to the abutments are lowered to the same level of the steel deck ends and suspended by the 'outer cables'.

The dead load difference between the proposed hybrid and the conventional concrete structures, and corresponding cable and deck shapes are schematically drawn in Fig. 3. When the central portion of the concrete deck is replaced with the improved lighter steel deck, the sag decreases and the cable shape changes from the curve denoted by a broken line to that denoted by both the solid line at the central portion and the dotted lines close to the abutments. Then, the concrete decks on both sides are lowered as denoted by solid lines, and suspended by the outer cables which are supported by newly installed low concrete towers. In cases where much smaller sag is required, pre-tension force can be introduced in the hangers. One can easily understand that the introduction of the outer cable system enables remarkable reduction of the sag. The concrete decks could be replaced with the steel decks.

5. Aerodynamic stability

It has been shown in the studies of concrete stress-ribbon pedestrian bridges that the half-circular edge modification, similar to a half-circular fairing as shown in Fig. 2(c), is quite effective for both increasing the critical flutter speed and suppressing vortex excitation [2,3]. Based on these studies, similar cross-sectional configuration is formed for the steel structure shown in Fig. 1(a) by attaching the bottom decoration panel.

However, in the study of the Nagashima Suspension Bridge, which is a steel pedestrian bridge with a main span length of 160 m and has a similar deck to that shown in Fig. 1(b), the deck was found to be quite aerodynamically stable [4]. The stability depends on the width of the open gratings. But roughly speaking, its non-dimensional critical flutter speed is around 10 and the aerodynamic exciting force for vortex excitation

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is small, in the range of allowable value. Since the generalized mass of the hybrid bridge is larger than that of the improved lighter steel bridge, the former is expected to be more aerodynamically stable than the latter.

6. Concluding remarks

The proposed hybrid stress-ribbon bridge is expected to have highly aerodynamic stability. Since this type of structure enables the reduction of 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 and 6.

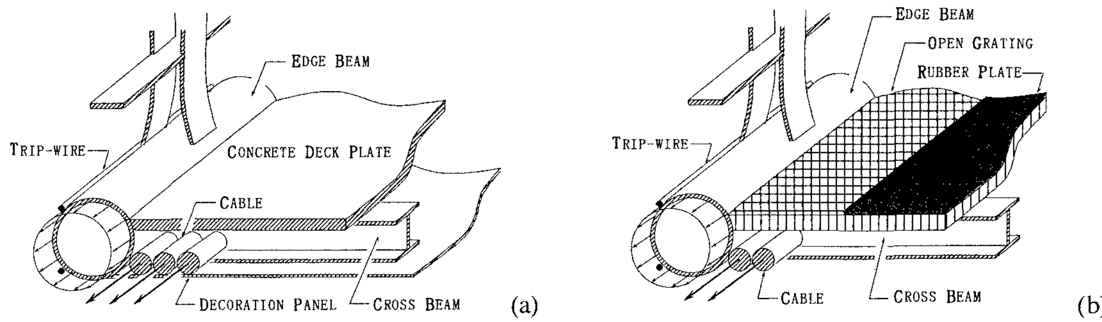

Fig. 1 Cross-sections of the previously proposed steel structure (a) and an improved lighter steel one (b).

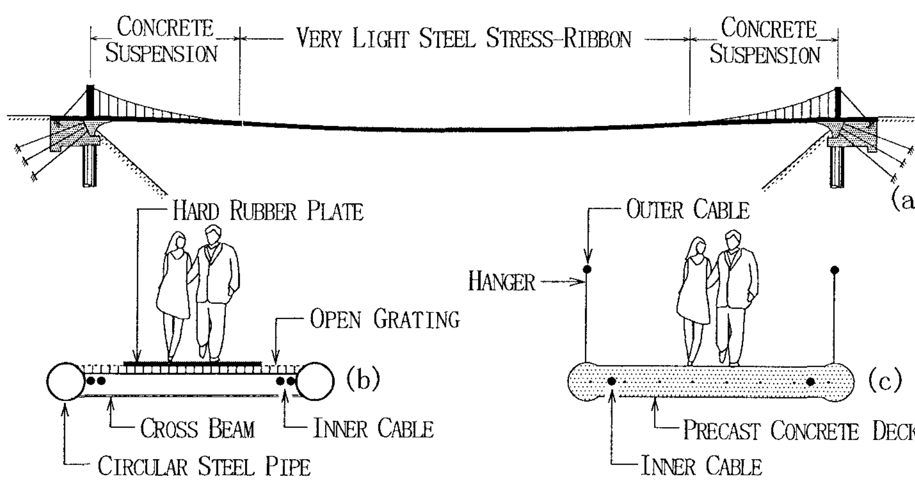

Fig. 2 Outline of the proposed hybrid stress-ribbon pedestrian bridge.

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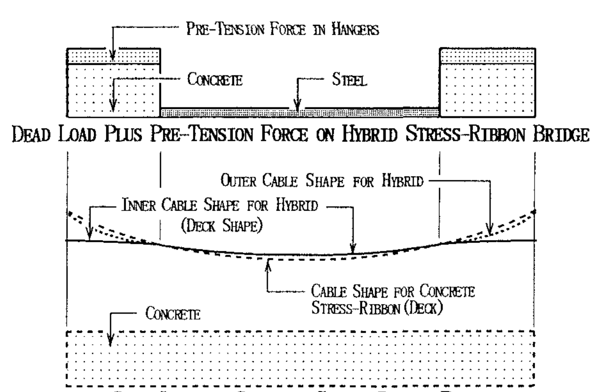

Fig. 3 Dead load difference between the hybrid and the conventional concrete bridges.