ANALYSIS OF A CABLE-STAYED BRIDGE UNDER EFFECT OF LATERAL STAY CABLE BREAKAGE

Waseda University Student Member ○Vu Hoang
Waseda University Fellow Osamu Kiyomiya
Waseda University Regular Member Tongxiang An

1. INTRODUCTION

Sudden cable loss events in cable stayed structures such as cable-stayed bridge, suspension bridge and extra-dosed bridge has been addressed and studied during last several decades. However, there is one extremely important cause of cable breakage was hardly mentioned in the past researches; it is collision of heavy mass vehicles into the cables; that causes significant lateral deformation to the cables system and affects the structural stability during the incident.

In this paper, structural dynamic numerical analyses were carried out to understand the behaviors of a two-plain cable-stayed bridge under effect of heavy weigh collision to the cables. Abrupt cable breakage was simulated by weight dropping tests, and then obtained impact force wave form was applied to the numerical model. Subsequently, the structural stability of the prototype bridge was confirmed.

2. METHODOLOGY

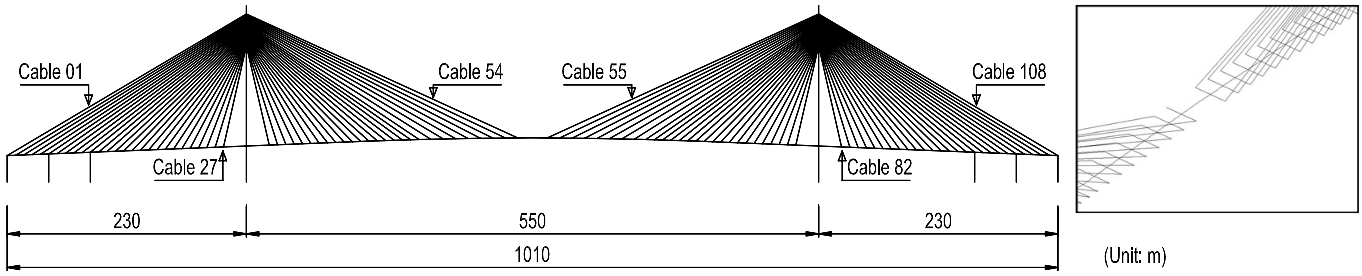


Fig. 1 Elevation view of the bridge

Fig. 1 shows the elevation view of the prototype model, a long span cable-stayed bridge with a total length of 1010 m. The main girder is tubular girder with 26 m wide and 2.7 m high, that can accommodate four traffic lanes. All of the cables were modeled as three dimensional truss elements with tensile axial force and nonlinear material property.

An experimental program on cable rupture due to collision was carried out (Fig. 2). A heavy weight was freely dropped onto a pre-tensioned PC steel wire with 2 m in length and 2 mm in diameter to completely break the sample. The geometric properties of the experimental specimens were determined respect to the rule of similarity. Strain gauges were attached at both ends of the specimen; longitudinal strains during the experimental were recorded. Fig. 3 shows a typical strain wave graph obtained from the experiment and it was used for numerical analysis. When the heavy weight was dropped onto the wire, the graph shows a sudden increase of strain and begins to fluctuate as the specimen was broken. Assuming that the relationship between strain and axial force is linear, the strain wave form can be simply transformed in to the axial force wave form using F=εEA relationship (F is axial force, ε is strain, E is elastic modulus and A is sectional area). To simulate the cable breakage scenario in cable-stayed bridge, the cable was completely removed from the model, and then the axial wave was applied to both anchorage positions. Because of the difference between the experimental specimen and the broken cable in the prototype bridge, the input wave was corrected according to the similarity law.

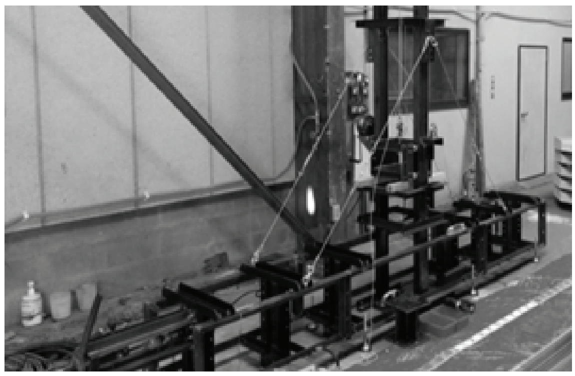


Fig. 2 Heavy weight dropping experiment

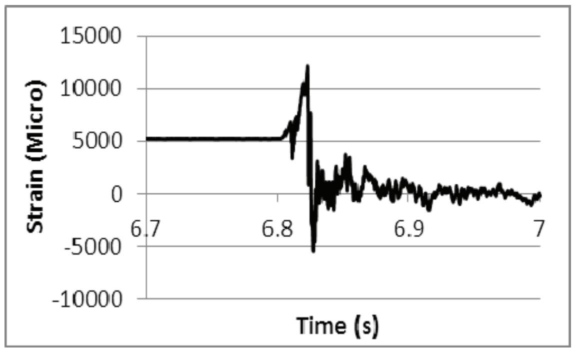
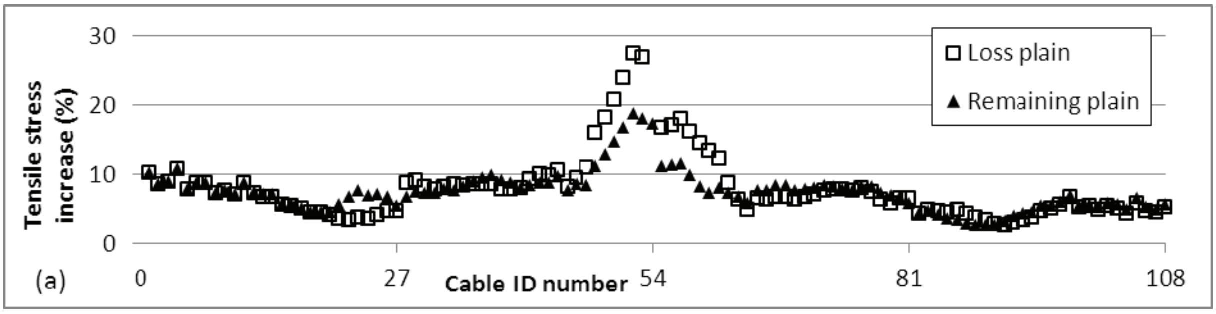


Fig. 3 Strain wave obtained from the experiment

Keywords: Cable-Stayed Bridge, Lateral Cable Breakage, Heavy Weight Dropping Experiment, Numerical Analysis
Contact address: Okubo 3-4-1, Shinjuku-ku, Tokyo, 169-8555, Japan, Tel: +81-3-5286-3852



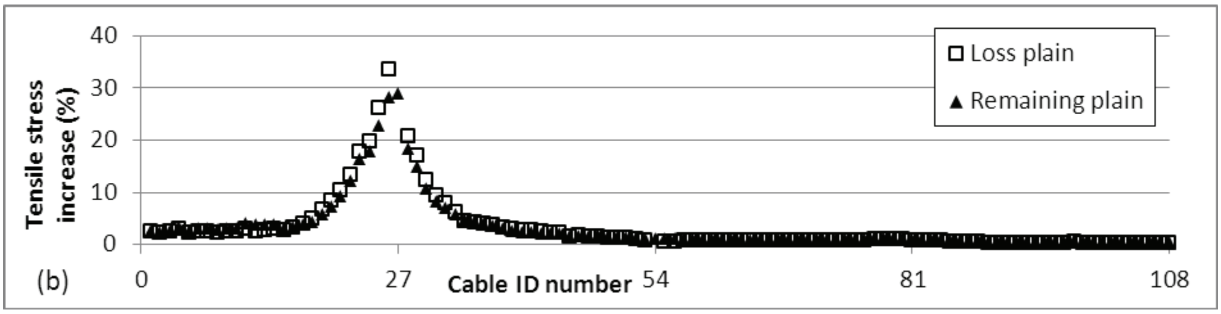


Fig. 4 Change in cables' tensile stress due to one cable loss
(a) Loss of cable 54, (b) Loss of cable 27

3. ANALYSIS RESULT

Fig. 4 represents the change in tensile stress of the cable system under the effect of losing one cable at position 54 and 27, compare with the initial stage, when the prototype bridge was unharmed with acting dead loads and live loads. The most significant responses are registered by nearby cables, in both the cable loss plain and opposite plain. As cable number 54 is the most extensive in the cable system, the Fig. 4.a clearly shows that the sudden rupture significantly affects all of the remaining cables. Particularly, there are four cables in the cable loss plain increasing more than 20% of tensile stress. When the cable at position 27 near the pylons is sudden rupture, the effect on nearby cable is even more significant as shown in Fig. 4.b. However, the further cables toward the abutments are minor affected.

Fig. 5 shows the maximum tensile stress appears in cable system if several adjacent cables are abruptly broken in any possible position. When four cables are rupture by heavy weight collision, the maximum tensile stress in the loss plain is over 1300 MPa, and that value in the remaining plain is around 1200 MPa. Considering that the ultimate tensile strength for stay cable in this structure is 1860 MPa, the cable system of this prototype bridge can maintain its stability even when such extreme incident occurs.

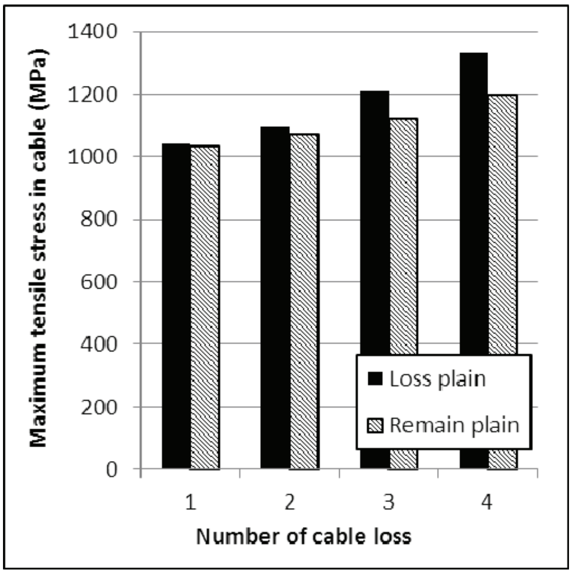


Fig. 5 Relationship between number of cables loss and maximum tensile stress in the remaining cables

4. CONCLUSIONS

This paper focus on one very important cause of cable loss event in cable-stayed bridge: the collision by a heavy weight to the cable system, which hadn't been seriously investigated up to now. An experiment was conducted and strain wave form obtained from this program was used as input data for numerical analysis of a prototype cable-stayed bridge. The calculation results showed that if one cable was abruptly broken, the adjacent cables could increase about 30% of tensile stresses and this value was significant. The maximum stress in cable system built up when the number of cables loss got bigger, but the remaining cables could maintain their stability even if 4 cables were broken at the same time.

REFERENCES

Hoang, V., Kiyomiya, O., and An, T.: Experimental Study on Impact Force Factor during Sudden Cable Loss in Cable-Stayed Bridges, IABSE Workshop, Helsinki, 2015.

American Association of State Highway and Transportation Officials: AASHTO LRFD Bridge Design Specifications, 2010.

Post-Tensioning Institute: Recommendations for Stay Cable Design, Testing and Installation 6th edition, 2012.