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INTRODUCTION OF DYNAMIC ANALYSIS OF A CABLE STAYED BRIDGE SUBJECTED TO THE BLAST LOADINGS

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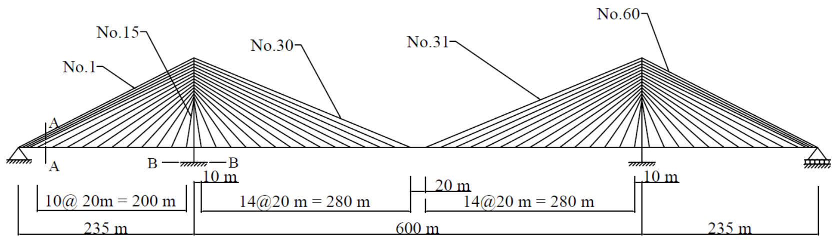
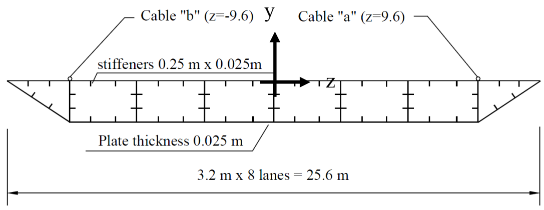
1. INTRODUCTION

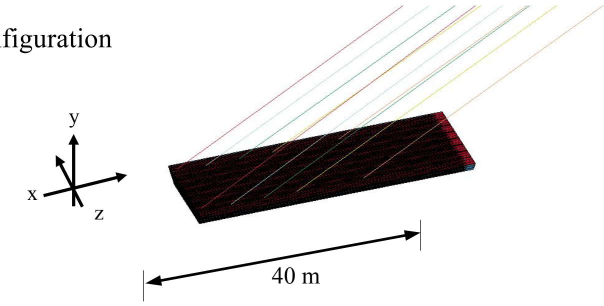
Recently, blast loadings are one of the most critical aspects must be considered when a bridge is designed (Hao and Tang 2010). After 911, terrorist attacks have been one of the most concerned situations for iconic civilian structures like bridges. If the bridge is attacked by terrorist, the structure might be fully collapsed, although it is rare case. However, even some minor damages would create the bridge closure for repairs, which affects to economy significantly (Mahoney 2007). Therefore, bridge damages due to blast loadings have to be studied. In this study, these two analysis are introduced: 1) the dynamic analysis of the entire bridge model with sudden loss of cable and, 2) the local damages on the steel deck analysed by using LS-DYNA (2007).

2. Bridges model



(a) Bridge configuration





(b) Cross section (A-A) of deck (c) Numerical deck model

Figure 1. Bridge configuration and deck cross sectional area

2.1 Geometry

The dimensions of the bridge and geometry of the deck for the bridge considered in this paper are shown in Figure 1. Figure 1a shows a whole image of a cable-stayed bridge under consideration, which has a total length of 1070 m with 600 m long middle span. This bridge is supported by a total of 120 cables. this model is designed according to Australian Standard (AS5100.2, 2004b). The bridge deck is 25.6 m wide (8 standard traffic lanes according to AS5100.2 (2004) and 2 m deep and made of a multi-cell steel box girder which is depicted in Figure 1b. As shown in Figure 1a, cable no.5 to cable no.55 are regularly spaced (20 m apart) along the deck. Regarding the back stays no. 1-4 and 57-60, a 5 m and 10 m spacing along the deck were considered. These bridge model and the deck model were developed by the commercial software called ANSYS and LS-DYNA, respectively. A detailed 3D deck model shown in Figure 1c is modelled by shell element using LS-Dyna. This part model is 40m length from the pin-support (see Figure 1a) including a total 10 cables.

2.2 Material properties, modelling and analysis

Table 1. Material and geometrical properties of the deck, towers and cables.

Structural component	E (MPa)	σ_y (Mpa)	σ_u (Mpa)	E_{sh} (MPa)	A (m^2)	I (m^4)	$\varepsilon_{i\text{-}PT}$
Box Girder	200	350	420	500	1.91	1.36	-
Cable	200	1860	1860	-	0.0327	-	0.0033

E is the modulus of elasticity, σ_y and σ_u denote the yield and ultimate strength and E_{sh} is the hardening modulus of steel.

The modulus of elasticity, E, the yield stress of steel, σ_y , deck second moment of area, I, as well as cross sectional area as well as cable size are given in Table 1.

2.3 Loads for design

The loads considered for blast analysis assessment of this bridge deck are gravity loads including the self-weight of the structure (Dead) plus the surfacing asphalt (Superimposed Dead) and the traffic load (S1600) according to AS5100.2 (2004). Applied post-tensioning forces in the cables were calculated according to AS5100.2(2004) provisions for ultimate and serviceability design requirements as well as allowable mid-span deflection due to traffic loads.

Keywords: blast loading, sudden loss of cable, cable stayed bridge
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3. PROGRESSIVE RESPONSE OF THE CABLE STAYED BRIDGE BY SUDDEN LOSS OF CABLE

The dynamic responses of the entire bridge model subjected to sudden loss of cable was carried out in this study to find out the most significant cable loss scenario (Aoki et.al. 2012). For dynamic analysis, the unconditionally stable Newmark constant acceleration method is used for time integration. The cables are removed over an integration time step, , which is short enough compared with the 1st natural period of the bridge to warrant the adequacy of dynamic analysis for alternate load path (ALP) method. Two scenarios were considered, 1) loss of cable no.1 and 2) loss of cable no.30. The maximum deflection at the mid span, and drift on top of the left tower and maximum σxx stress on top and bottom deck are shown in Table 2. According to these results, two things are found. First one is loss of cable no.1 is more critical than the cable no.30. Second one is the entire bridge collapse is hardly occurred by losing a cable.

Table2: Summary of maximum responses

Scenario (FE model)	Deflection in deck (m)		Max. drift on top of the left tower (m)	Max. σ_{xx} stress in deck (MPa)	
	Mid span	Max. @ x (m)		Top of deck	Bottom of deck
Cable no.1 loss	1.81	2.04 @ 485	0.69	137	233
Cable no.30 loss	1.83	1.86 @ 530	0.16	55	185

4.BLAST LOAD ANALYSIS AND SUDDEN LOSS OF CABLE

4.1 Scenario considered for Blast load analysis

In this study, the deck model around the pin support (see figure 1C) is selected since the cables are spaced closely around the pin-support as well as these cables are most critical cables regarding to the previous study. The charges of TNT as 27 tonnes is adopted, which are the equivalent maximum explosive capacity of a semi-trailer, respectively (Mahoney, 2007). When the blast load analysis is carried out by the LS-dyna software, there are several conditions which can be considered such as formulation type, Cowper-Symonds and so on. In this study only basic analysis is shown. For example, formulation type is fully integrated and Cowper-Symonds are not considered.

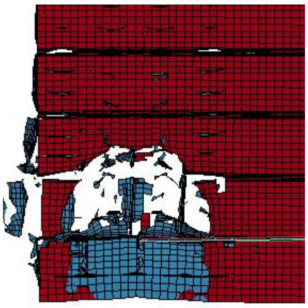

Figure 2: Damaged area

4.2 Results and Discussions

The damaged areas due to 27tonnes blast loads around the pin-support predicted by LS-DYNA model are shown in Figure 2. It is noted that red element is the surface of the deck, blue element is the bottom of the deck. When both surface and bottom deck element were eliminated, the white area can be seen in the figures. According to the Figure2, the damage area is larger than 10m × 10 m including three cables near detonation center were snapped due to the damage of the anchorage zones. The total number of eliminated shell element was 2393.

5.CONCLUSIONS

A numerical study of the idealized cable-stayed bridge and local deck model subjected to loss of cable and blast loadings were carried out in this paper. With regard to the numerical studies undertaken this paper, the following conclusions may be drawn;

- The loss of cable no.1 (around the pin supported area) brought more significant effect than the loss of cable no.30.
- The entire bridge collapse is hardly be occurred by losing one cable, thus analysis of local damage is more important.
- By 27tonne is larger than 10m × 10 m with three cables snapped.

The blast load due to terrorist attacks has to be considered in Japan, since there will be an iconic international event coming soon (such as Olympic and word expo). It is important to define the potential damage area and analyses the possible damage by the blast loadings, which will help to protect the structure in the future.

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