PROPOSING AN OPTIMAL CABLE CONFIGURATION FOR LALI CABLE-STAYED BRIDGE USING SEISMIC RISK ASSESSMENT

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Generally, in order to reduce the amount of calculations, engineers analyze and design the structures using simple force based methods such as quasi-static or spectral methods. On the other hand there are more accurate methods such as incremental dynamic analysis for research purposes. We also can use seismic risk assessment to study the damage due to probable earthquakes, instead of investigating force responses or displacement responses which are basis of simple design methods.

Changing the cable configuration in a cable-stayed bridge, firstly affects the period and damping of the structure (Kawashima et al., 1993), and secondly changes the forces in other components of the bridge which results in change of their required dimensions. Based on this, it can be concluded that a change in cable configuration will result in change in seismic risk, and a change in construction costs. So it is necessary to thoroughly investigate the common cable configurations in order to select the optimal option. It is notable that the common cable configurations are Harp, Fan and Semi Fan which are shown in the figure 1.

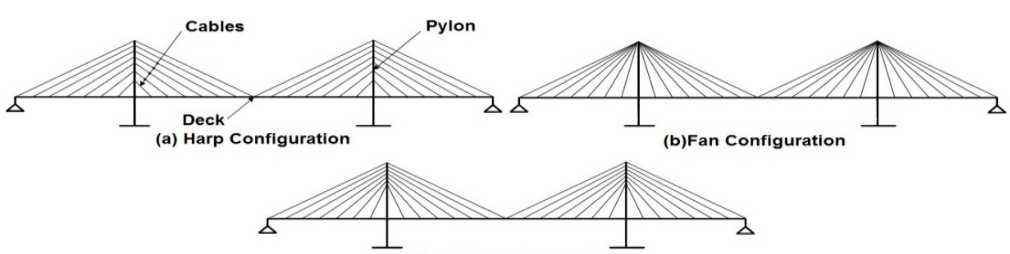

Figure 1. Three common types of cable configuration

In this paper, we will try to perform the "Conceptual Seismic Design" (Calvi et al., 2010) on a cable - stayed bridge with Semi Fan and two other configurations. So we will be able to relatively compare the dimensions and costs of three mentioned schemes. Also this paper uses a method based on energy dissipation for evaluating the damping ratio of structure from substructures (Kawashima et al., 1993).

Then, the loss due to probable earthquakes can be obtained for each scheme using the Seismic Risk Assessment process performed in two steps: Fragility Assessment and Loss Assessment (Akhoondzade Noghabi et al., 2014). The final results of the process will be obtained by combining the damage probability of the bridge system and loss ratio. This result will be reported based on Equation 1, as Total Loss Ratio (Tesfamariam and Goda, 2013).

$$Total\ Loss\ Ratio(IM = im) = \sum_{i=1}^{4}[P(DS_i|im) - P(DS_{i+1}|im)] \times LR_i \quad (1)$$

Where P is the probability function, DS_i is the ith damage state, im is the intensity measure of the earthquake and LR_i is the loss ratio in ith damage state.

In the end, by using the proposed Cost-Loss-Benefit (CLB) method and comparative - financial approach, the construction costs will be investigated simultaneously along with losses due to probable earthquakes. The CLB method will determine the optimal cable configuration by defining the Benefit Ratio (BR) as a profitability measure based on the equation 2.

$$BR_s = \left(\frac{C_{s=1}}{C_s}\right)^2 \times \left(\frac{EAL_{s=1}}{EAL_s}\right) \quad (2)$$

Where EAL represents the Expected Annual Loss (the area under each curve in figure 2), C is the construction cost, index s indicates the type of cable configuration, and index $s=1$ indicates the Lali bridge with Semi-Fan cable configuration.

The Total loss ratio resulted from the equation 1, is shown in figure2 against its annual frequency. Also the inputs and outputs of the CLB methods are given in table 1.

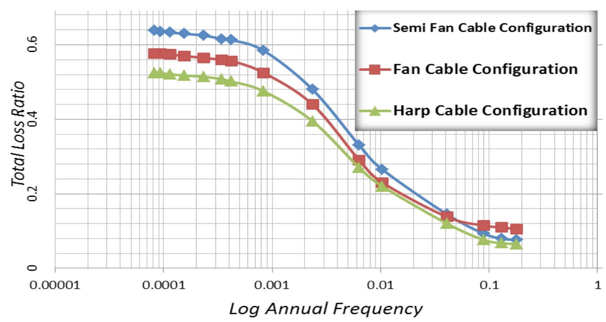

Figure 2. Total loss ratio curves of the Lali bridge system with three studied schemes

Table 1. The CLB data and results

Cable configuration	Material Volume Coefficient of Components			Bridge system	$\left(\frac{EAL_{s=1}}{EAL_s}\right)$	BR_s
	Pylons	Deck	Cables	$\left(\frac{C_{s=1}}{C_s}\right)$		
Semi Fan	1	1	1	1	1	1
Fan	1.03	0.85	0.93	0.91	1.3	1.08
Harp	1.02	0.74	0.79	0.77	1.4	0.83

Based on BR values which are considering the loss due to probable earthquakes along with construction costs, the fan cable configuration is suggested as the optimal cable configuration for Lali cable - stayed bridge. This result was achieved due to the BR value of fan type which is more than one. Expressing in more detail, using the fan type instead of Semi Fan type in Lali Bridge caused a 23 percent reduction of loss due to earthquake, whereas it only increased the construction cost by 10%.

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