The 2020 World Congress on
Advances in Civil, Environmental, & Materials Research (ACEM20)
25-28, August, 2020, GECE, Seoul, Korea

A review on cable-stayed bridges pylons configurations

*Pauline Lin Li Lam[1)] and Thomas Kang[2)]

[1), 2)] *Department of Architecture & Architectural Engineering, Seoul National University, Seoul, Korea*
[2)] *tkang@snu.ac.kr*

ABSTRACT

For the construction of a cable-stayed bridge, the design of its concrete pylons is as important as the one of its cables. Being compressive members, concrete is their preferred used material. To understand the influence of the pylon's configuration on the structural behavior of cable-stayed bridges, a review on finite element analysis is conducted. Up to now, parametric studies – considering different static and dynamic solicitations – have been carried out to get a better understanding of the influence of the shape of pylons. The choice of pylons shapes is principally based on cost efficiency and the results from finite element models of bridges with different configurations, made on the software SAP2000.

1. INTRODUCTION

For the past decades, cable-stayed bridges have been preferred over other types of bridges for their higher structural properties – like longer span length for lower cost – and aesthetics. Concrete is also preferred for its economy for similar stiffness conditions and its adaptability to more complex forms of pylon. The typical cable-stayed bridge structure is composed of a deck, pylons erected around the middle of the span, cables and girders that provide additional support. The most common cable arrangement encountered is the fan system due to its efficiency and the degree of freedom regarding geometrical adaptation – usually applied as a semi-fan system to allow more room for individual stay-cable anchors. Thus, the studies led to consider this cable system – keeping all the parameters unchanged except for the pylon shapes.

2. PYLONS PARAMETERS

2.1 Pylon height

Pylons are tower structures subjected to high compression and bending moment – the most important loads applied are the axial force originating from the

[1)] Graduate Student
[2)] Professor

cable's layout attached to it and the deck's self-weight. Their purpose is to support this cable system and to transfer the vertical forces to the foundations. As a result, the pylons can be treated as a part of the cable system as shown in Gimsing (2012).

To optimize the superstructure of a cable-stayed bridge, the variation in the quantities of the pylons – weight of pylon legs – must be considered. In a fan system, the total force from the cable system is acting only at the pylon top (concentration of the cables at the top), and Eq. (1), Eq. (2) and Eq. (3) can then be obtained from Fig.1. An effective stress f_{pld} that carries the vertical force from the cable system to the foundations can then be calculated.

$$N_{pl}(\xi) + dN_{pl}(\xi) = N_{pl}(\xi) + \frac{\gamma_{pl}}{f_{pld}} N_{pl}(\xi) d\xi \tag{1}$$

$$N_{pl}(\xi) = N_{pt} \exp\left(\frac{\gamma_{pl}}{f_{pld}} \xi\right) \tag{2}$$

$$Q_{pl} = N_{pb} - N_{pt} = N_{pt}\left[exp\left(\frac{\gamma_{pl}}{f_{pld}} h_{pl}\right) - 1\right] \tag{3}$$

Where $N_{pl}(\xi)$ is the normal force at ξ, N_{pt} is the maximum normal force at the top of the pylon, Q_{pl} is the quantity of the pylon, γ_{pl} is the density of the pylon (weight per unit volume), and h_{pl} is the height of the pylon (top to ground level).

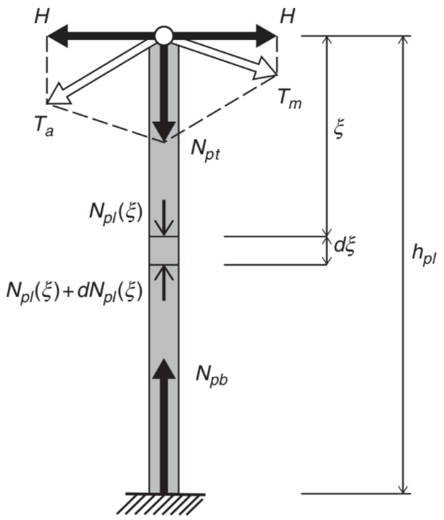

Fig. 1 Vertical forces acting on a pylon

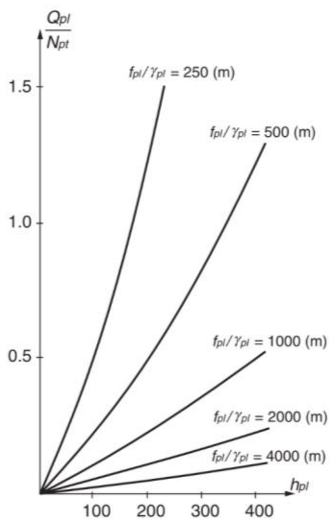

Fig. 2 $\frac{Q_{pl}}{N_{pl}}$ according to h_{pl} for different $\frac{f_{pld}}{\gamma_{pl}}$

From Eq. (3), Fig. 2 can be plotted for different values of $\frac{f_{pld}}{\gamma_{pl}}$. For concrete pylons, this ratio is between 250 m and 500 m, and the optimum pylon height is found for $\frac{Q_{pl}}{N_{pl}} > 1$ – when the weight of the pylon legs is larger than the maximum normal force applied by the cable layout at the top of the pylon (for a given cable system) – that is, $0.17 < \frac{h_{opt}}{l_m} < 0.25$ for concrete decks, where h_{opt} is the optimum pylon height and l_m is the main span length.

2.2 Pylon shape

There are multiple pylon shapes, and typical ones include single pylons of A-shaped, H-shaped, inverted V- or Y-shaped ones and even diamond and pyramid shaped ones. They behave differently for a same cable layout and same loads.

A linear static analysis can give us a first idea of the structural behavior of one pylon shape under its own weight as shown in Hararwala (2017). The study is based on the bridge at the river Ravi in Jammu Kashmir, India.

After this, a dynamic analysis under earthquake load – led by Shah (2010) – allows us to obtain the seismic response according to pylon shapes. The bridge considered is the Quincy bay view cable stayed bridge situated at river Mississippi, the United States. Then the Bhuj earthquake time history was applied in longitudinal and lateral directions of the bridge. In this case, soil conditions must be considered since concrete self-weight is higher than that of steel, inducing higher seismic forces.

The studies being led on cable-stayed bridges with different dimensions, we consider the tendency of the results and not their values to compare them in this paper review. The maximum deflection at the pylon top and the maximum bending moment for rectangular concrete pylons according to the shape of pylons are displayed in Fig. (3) and Fig. (4) – results from static analysis and dynamic analysis, respectively.

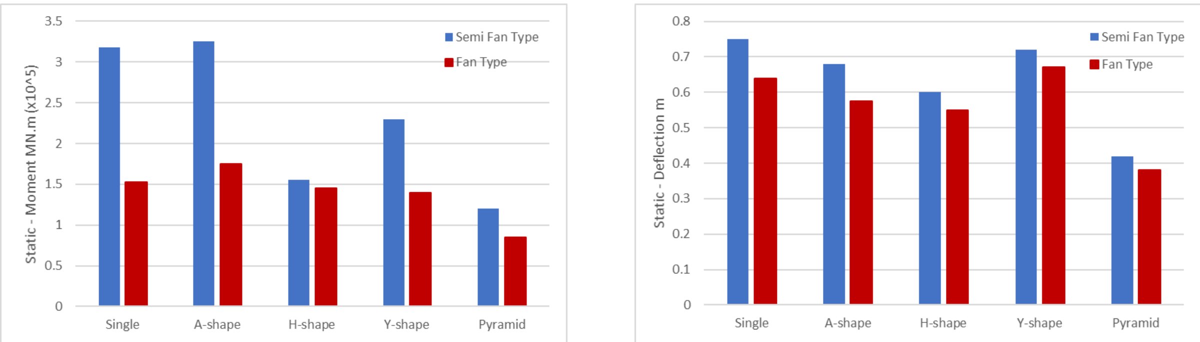

Fig. 3 Static analysis results under self-load

Thus, we observe that the pylon shape has great influence on the structural behavior of the bridge. In general, for the fan cable system, pyramid shape pylons seem to have better structural properties to resist the different loads considered. Especially, the generally smaller maximum bending moment during seismic analysis is important since this parameter plays a crucial role in the seismic design of cable-stayed bridges to reduce the damages in case of earthquake. The same may apply to the wind design against the hurricane or typhoon-induced gust and its corresponding resonant vibration.

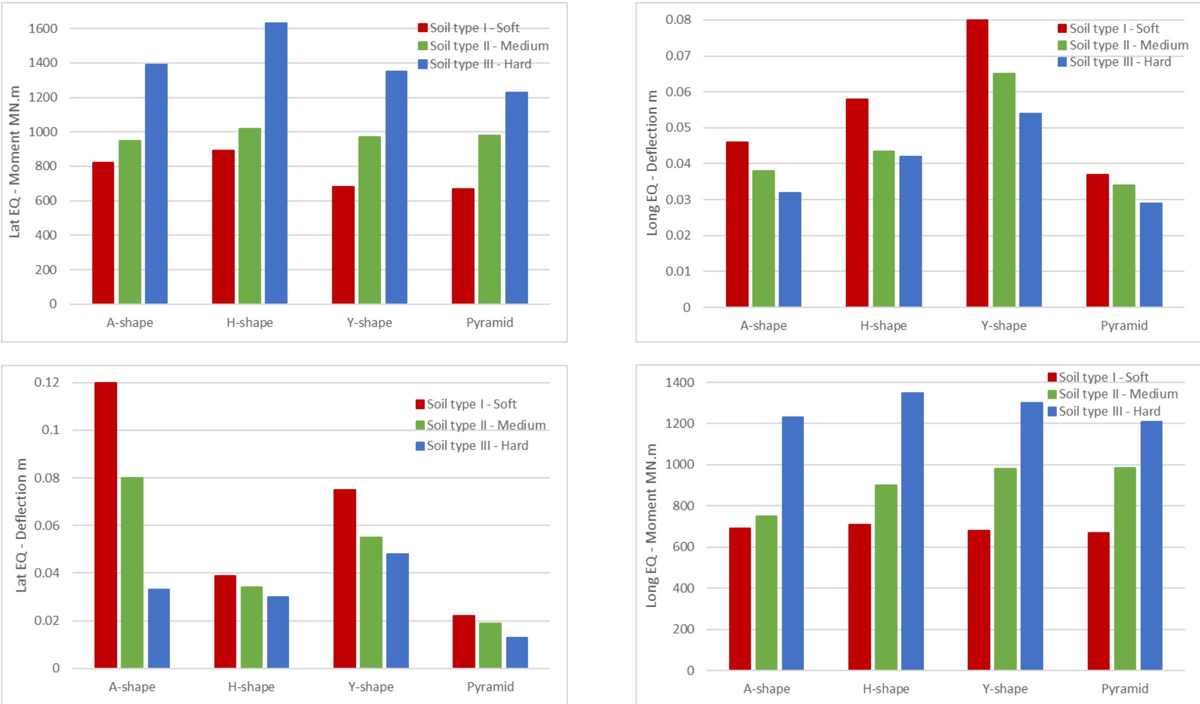

Fig. 4 Dynamic analysis results for Bhuj earthquake – in longitudinal direction (left) and in transverse direction (right)

More exhaustive results can be found in the respective papers by Hararwala (2017) and Shah (2010).

3. CONCLUSIONS

A review study on cable-stayed bridges pylons configurations is conducted. The analyses in this study are only valid for rectangular cross-section pylons and fan or semi-fan cable layouts – not all the pylon shapes are considered. That is why, from these analyses, one cannot settle on one optimal pylon shape for one load combination. More exhaustive experiments and analyses should be conducted to complete the studies. For example, considering more pylon shapes, different earthquake acceleration or wind speed time-histories, or various materials used for pylons (not only concrete) would be needed. Finally, to apply it to real construction projects, cost analyses should also be carried out. Because such cable-stayed bridges are commonly built in the coastal hurricane or typhoon-prone regions, detailed vibration studies along with wind tunnel testing or computational fluid dynamics (CFD) modeling would be important. Due to the time and budget limitations, the latter may be a feasible option for parametric studies of pylons configurations such as shape, dimension, and other factors affecting the wind-pylon interaction.

REFERENCES

Gimsing, N. J. and Georgakis, C. T. (2012), *Cable supported bridges: Concept and design, 3rd Edition*, John Wiley & Sons.

Hararwala, H. and Maru, S. (2017), “Comparison between the behaviour of the different shapes of pylon in the linear static analysis of cable stayed bridge using SAP2000”, *International Journal of Bridge Engineering*, **5**(2), 81-102.

Shah, S. G., Desai. J. A. and Solanki, C. H. (2010), “Effect of pylon shape on seismic response of cable stayed bridge with soil structure interaction”, *International Journal of Civil and Structural Engineering*, **1**(3), 667-682.