The Macau Eiffel Tower – Recreating the 19th Century Elegance

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Summary

The Macau Eiffel Tower is a faithful replica of the Paris Eiffel Tower constructed, next to the Venetian Hotel on the famous Cotai Strip in Taipa, Macau. The Macau Eiffel Tower forms a part of the hotel development and will complement the new hotel, acting both as a landmark feature and a tourist observatory tower. This paper presents the challenges encountered and the engineering solutions provided from the structural design phase through to the construction phase and how effective project management has brought successful collaboration between the project teams to deliver the recreation of the Eiffel Tower in Macau.

Keywords: Eiffel Tower; steel construction; steel design; slender structure; wind engineering; footfall vibrations; 3D drafting; temporary works design.

1. Introduction

The Macau Eiffel Tower (referred to as the Tower hereafter) is required to be a faithful replica of the Paris Eiffel Tower to a 48% scale of the original Paris Eiffel Tower. The Tower is located at the east of Parcel 1 Lot 3 and connected to the main development by a pedestrian link bridge, which is a new development on the Cotai Strip by The Venetian Cotai Limited. The full height of the Tower is 155m. Many decorative features on the original Paris Eiffel Tower such as cornice scrolls, balustrades, gussets plates, lattices, staircases, mesh screens at observation decks have been aesthetically replicated to simulate what is present on the original Eiffel Tower.

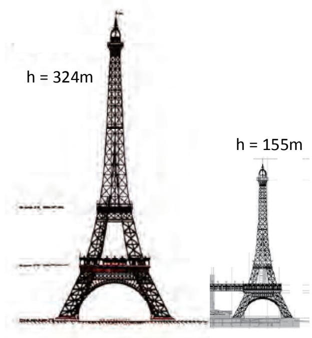

Fig. 1: Comparison of Paris Eiffel Tower (left) and Macau Eiffel Tower (right).

During the initial design stage, all specifications were thoroughly reviewed and interpreted to ensure correct assumptions and constraints are applied in the detail design.

A comparison of the Paris Eiffel Tower and the Macau Eiffel Tower is shown in Fig. 1. Apart from the height difference, the central lift shaft of the Macau Eiffel Tower has a central lift shaft from level P07 deck (about a third of height of the Tower) to the top of the tower. The Macau Eiffel Tower also has a pedestrian link bridge connecting the Tower to the adjacent casino podium which is not present in the Paris Eiffel Tower.

2. Design and Construction Challenges

The design analysis model was developed based on an agreed wireframe model between all working parties including the architect, structural engineer and mechanical services engineer etc. Typical member elements e.g. column shape, lattice member, gusset plate and truss detailing and connection design were developed and submitted for the architect's review and approval to ensure that the structural design replicates the Paris Eiffel Tower as closely as possible.

Macau is affected by typhoons and the critical wind loading for the Tower arises from a direct hit from typhoons. The determination of wind loads for the Tower was carried out utilising the framework of the Equivalent Static Wind Loads (ESWL) approach developed for towers of this nature. A series of studies were also performed to investigate the wind-induced dynamic response at the top observation deck of the Tower under various wind speeds and its impact to human comfort resulting from potential vibrations.

Fig. 2: Analysis model

For design of the link bridge, an acceleration based vibration assessment method that accounts for crowds walking loading was adopted. The vibration response was determined through superposition of responses from various contributing vibration modes. The assessment shows that the vertical vibration is within acceptable human comfort levels.

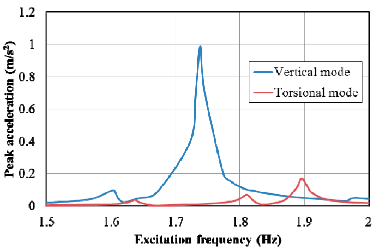

Fig. 3: Dynamic response of link bridge.

Drafting of the Tower has been carried out using the 3D drafting software Revit, which allowed the designer to visualise connections in 3D space and hence detect any probable issues during the design stage and to avoid amendment at the shop drawing preparation or fabrication stage.

One of the challenges faced during the construction phase was delivery of the oversized steel items from Shanghai to Macau by sea freight. The Macau port is not large and the sea water is shallow. Shallow hull vessels were therefore required, which also limited delivery capacity. Consequently, the size of delivery racks was carefully considered to maximize the delivery capacity. Up to 25% of the overall fabrication cost can be made up of delivery cost and therefore delivery of materials must be carefully planned.

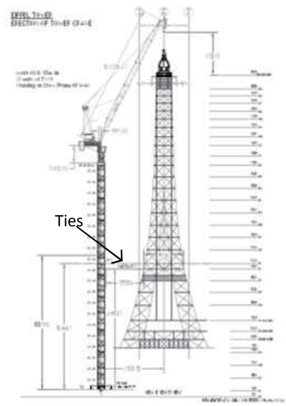

Fig. 4: Tower crane tied to the Eiffel Tower (Eiffel Tower legs not shown).

Fig. 5: Crane base frame with twin trusses.

A tower crane was required to facilitate erection of the Tower and was required to be tied to the Tower at level P11. The Tower is a slender structure and cannot provide full lateral rigidity to support a tower crane as compared to a stiff concrete building. It was important that the tie of tower crane would not overstress the permanent structural members of the Tower. The tower crane selection was a complicated process which required a full collaboration between the construction manager, the Tower design engineer and the tower crane manufacturer, to avoid large lateral loads being transferred to the Tower. A shorter crane mast with a level-luffing jib crane was selected to limit the lateral forces. The level-luffing jib crane could reach the top of the Tower with a maximum of 28 tons hoisting capacity. This large hoisting capacity facilitated the use of modular construction method for a fast and safe installation.

The design of the steel base to support the luffing jib crane was a challenge to the construction and design team. 280 tons of kentledges were added to the base of the crane to ensure no tensile reactions at the base support. A proprietary cross beam was used to extend the reaction arms and transfer the tower crane base moment effectively as push-pull forces. The push-pull forces were transferred down to the concrete basement structure through a specially designed crane base frame made of trusses that were sourced from existing materials present on site.

The collaborative effort of the construction and designer teams has brought success to the implementation and delivery in recreating this monumental landmark structure in Macau.