Aerostatic and Aerodynamic Study of Melak Cable Stayed Bridge

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Summary

This paper presents the result of aerostatic and aerodynamic study as well as the wind tunnel test carried out on the model of Melak Bridge. The bridge is designed as a cable stayed concrete bridge, located in Kalimantan island of Indonesia, with 340 meters of mid span, 14.20 meters wide for 2 lanes of traffic, and total length of 680 meters. Due to narrow width of the bridge, its aerodynamic behavior under wind loads was carefully studied, including a wind tunnel test using a rigid section model that was mounted elastically on a dynamic test frames simulating the dynamic characteristics of the bridge. Then the model was tested and studied in both turbulent and smooth flow conditions representing of those at the bridge site, in order to be able to determine the aerodynamic response characteristics and any tendency to flutter and vortex shedding instability.

Keywords: cable stayed bridge, aerostatic, aerodynamic, wind tunnel, flutter instability.

1. Introduction

Melak Bridge is located in Kutai Barat, East Kalimantan, Indonesia, which is designed as a double-pylon cable stayed bridge with mid span of 340m and side span of 170m (Fig. 1.1 & 1.2). The bridge deck represents an open cross section with twin side girders of partially prestressed concrete having 14.20m wide and 2.40m high. The pylons have a slightly curved A-shape with about 108m high.

Fig. 1.1: Melak Bridge (Artist Impression)

In accordance with requirement of the Indonesian Concrete Bridge Design Code SNI T-12-2004 for special bridge category (e.g. cable stayed bridge, suspension bridge, etc), the service life time of this bridge should be determined for at least 100 years [1].

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In the design process, an aerodynamic study was carried out by PT. Partono Fondas Engineering Consultant [2], in order to ensure the bridge safety under wind loads during construction state and service state. This study was performed in cooperation with the State Key Laboratory for Disaster Reduction in Civil Engineering (SLDRCE) of Tongji University in Shanghai, China, particularly to undertake the wind tunnel test and study on the wind-resistant performance of this bridge [3].

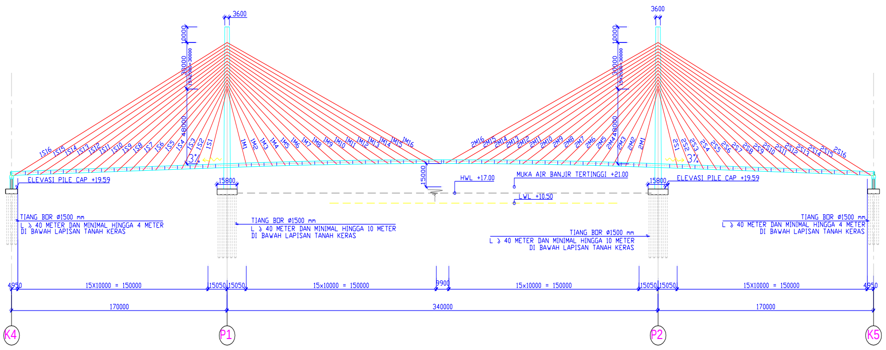

Fig. 1.2: General configuration of the bridge structure

2. Purpose of Study

Purposes of this study are:

- To proof that the aerodynamic stability of the bridge under wind loading is satisfactory, by performing a section model of the bridge deck that is mounted elastically on a dynamic test frame, simulating the characteristics of the completed bridge and/or during construction state.
- Should the stability and response characteristics proven not to be satisfactory, modifications to the aerodynamic cross section could be made for further testing.
- Determination of the response under design wind speeds and permits the assessment of aerodynamic loads. Analytical techniques would be used incorporating the results of the model tests using dynamic analysis on the bridge prototype to define the wind loading of the structure.
- Assess the aerodynamic derivatives, i.e. the so-called “flutter coefficients”.

Due to limited number of pages in this paper, discussion will be limited around the flutter stability problem.

3. Concluding Remarks

Based on the dynamic analysis, aerostatic analysis and the aerodynamic study including the section model wind tunnel test on the wind-resistant performance of Melak Bridge, we may draw the following major conclusions:

(1) The results of dynamic analysis shows that the natural frequencies of the fundamental vertical bending and torsion modes of the service state are 0.227Hz and 0.792Hz respectively, that means the ratio of torsional frequency to vertical bending frequency is 3.49, which gives a good indication of torsional stability.

(2) The aerostatic analysis on the completed bridge state shows V_{td} = 313m/s that largely satisfies the aerostatic torsional stability requirement of being > $2V_d$.

(3) The wind tunnel tests demonstrate that the critical flutter-induced wind speed is 106m/s with considering the structural damping ratio of 1% in service state and 123m/s in the longest cantilever state with wind attack angles of -3°. If the structural damping ratio is set to above 1%, the corresponding flutter-induced wind speed can still be increased. Those values are largely higher than the site limit wind speed for flutter checking (56m/s and 47m/s respectively). Therefore, the Melak Bridge is proven to be stable enough against flutter for both service state and the construction states under wind attack angles between -3° and 3°.