Codes & standards, CFD analyses, tunnel tests and structural checks for the two coal yard steel sheds of the power plant in Dubai, UAE

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SUMMARY
Since 1959 DEWA (Dubai Electricity & Water Autority) has been the only supplier of electricity and water in Dubai. At the end of 2013 DEWA's total installed generating capacity was 9,656 MW.
Based on the forecasted power demand, DEWA requires a new coal park power generation facility with an aggregate capacity of 1'200MW consisting of two units, with the first unit in commercial operation in March 2020.
This paper deals with CFD analyses and wind tunnel tests conducted to validate the pressure distributions defined in the design of the huge coal yard steel shed (2 hangars) for the coal power plant on the basis of ASCE 7-10.
The project of the hangars has been drafted by the Chinese company HEI (Harbin Electric International), the authors were tasked as third part checker by the Dubai Municipality with monitoring the project and proposing possible improvements.

Keywords: steel shed, CFD analyses, tunnel test.

1. INTRODUCTION

This paper discusses the CFD analyses and wind tunnel tests conducted to verify the accuracy of the pressure distributions considered in the executive design phase of the two twin storage hangars that make up the coal park serving the thermoelectric power plant of the new Dubai production facility located near the coast southwest of the city. The paper also discusses the remedial works on the steel structure planned following the tunnel tests.
The hangars, each 122m wide and 677m long, are placed side by side on the long side at a distance of 17m and positioned on the eastern edge of the area occupied by the thermoelectric power plant.
The steel structure of each of the two hangars consists of a series of arches spaced 12 m apart, constructed from a triangular-section truss structure, reinforced and pre-stressed along the intrados. The truss elements are tubular, while the tensioned element is made of spiral cable.
The arches are connected to each other by longitudinal lattice beams, and each of the four sections has four roof braces that stabilize the arches horizontally. The longitudinal beams, like the bracing elements, are also made of tubular elements.
The design review focused on several critical issues, including checking the accuracy of the wind pressure field.
Specifically, the design is based on the loads specified in the American standard ASCE 7-10, which, however, does not include shapes that sufficiently approximate the polycentric arch that characterizes the hangar cross-section, nor does it include a criterion for evaluating the interaction of the two bodies arranged very closely together with respect to their planimetric dimensions.

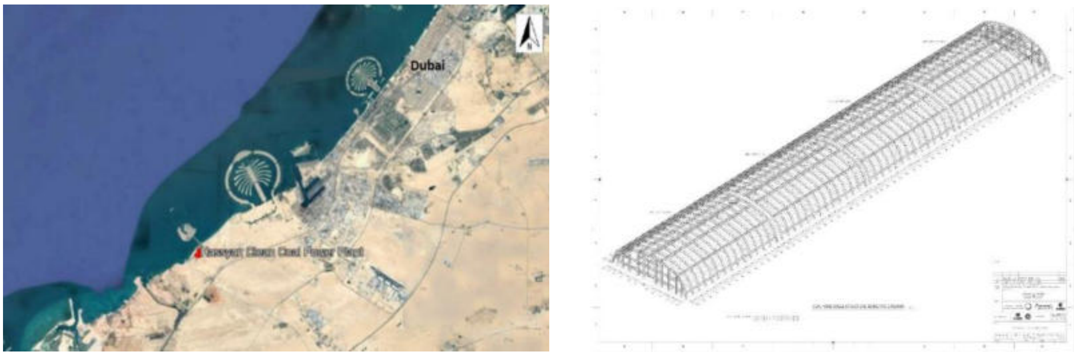

Figure 1. The coal park construction site southwest of the city and 3D view of a hangar

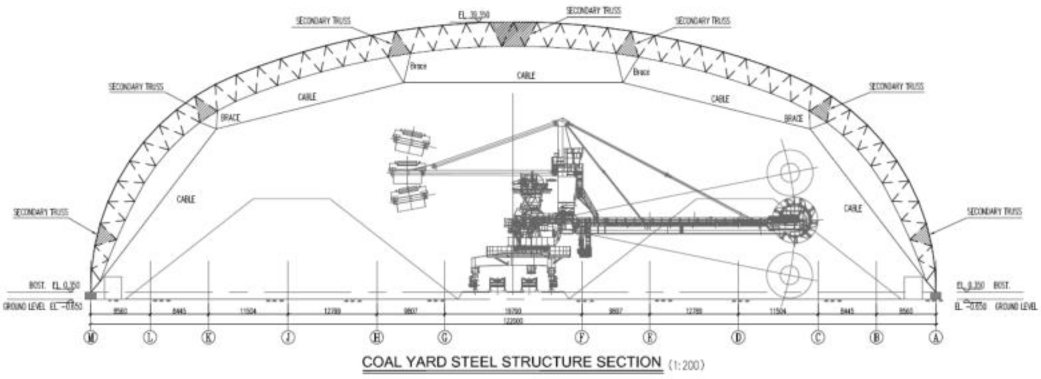

Figure 2. Cross-section of a hangar

A preliminary simplified CFD numerical analysis was then performed on a 2D model representing the hangar cross-section (concluded with the contribution of Prof. Luca Patruno), followed by wind tunnel tests on a scaled physical model, conducted by the German company Wacker Ingenieure.

The tests allowed us to define new design pressure distributions that are more in line with the specific case than those required by the standard to which the design refers.

2. METHODS

The wind loads on the structures are determined in the executive design of the hangars drawn up by the Chinese company HEI, according to the procedure established in the American standard ASCE 7-10, in accordance with the requests of the client, Dubai Municipality.

According to the standard, based on historical data from weather stations near the construction site obviously not harmonized in ASCE 7-10, the reference wind speed (measured with a 50-year return period, at 10 m above ground level, and a 3-second gust duration) is 162 km/h. Considering risk category III and a 1700-year return period, parameters established in agreement with DEWA, the reference speed value according to ASCE 7-10 becomes 219 km/h. Regarding the parameters characterizing the design wind action, some observations can be made:

1. The standard does not allow for explicit consideration of any aeroelastic interaction between the structure and the wind, except through the gust factor G_f;
2. The standard does not allow for any consideration of the interaction effects due to the proximity of the two hangars;
3. The shape factors are not precisely calibrated for the case of the geometry of polycentric arches.

3. RESULTS

Taking into account the uncertainties inherent in this calculation approach, a simplified CFD analysis was performed on a two-dimensional model representing the structure's cross-section. A sensitivity analysis was carried out aimed at evaluating the variations of G_f as a function of the variation of the parameters that influence its calculation.

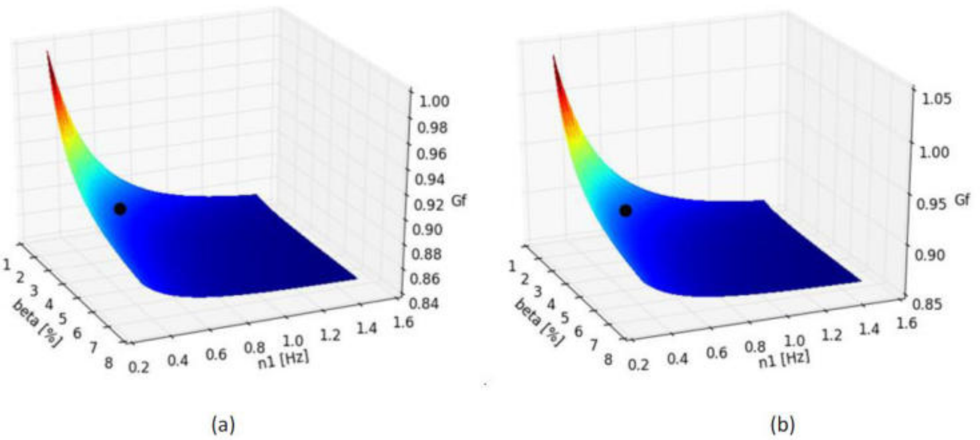

Figure 3. Variation of G_f as a function of the damping coefficient and the first natural frequency.

The wind tunnel tests were performed in accordance with the indications contained in ASCE 49-12, ASCE 7-10 and EN 1991-1-4, and the significant criteria for correct physical modelling were taken into account with regard to the geometric similarity of the model and the similarity of the incident wind flow.

Figure 4. The 1:500 scale model of the two hangars in the wind tunnel

One of the two hangars reproduced at 1:500 scale was equipped with 250 sensors measuring the pressure on the external surface.

4. DISCUSSION

The simplified CFD analysis on a two-dimensional model and the results of the wind tunnel tests highlighted show a pressure field distribution on the external surface of the hangars slightly different from that considered in the detailed design. In particular, the design pressure range identified through wind tunnel tests, although not globally more severe than that identified following the indications contained in ASCE 7-10, presents a greater imbalance as illustrated in comparative form in figure 5.

This more irregular distribution of pressures along the arch's development determines a secondary regime of flexural forces, more demanding for the structure than that considered by the HEI designers, which required the study of remedial works (works aimed at increasing tensile and compressive strength due to Eulerian buckling) on numerous elements of the lattice structure.

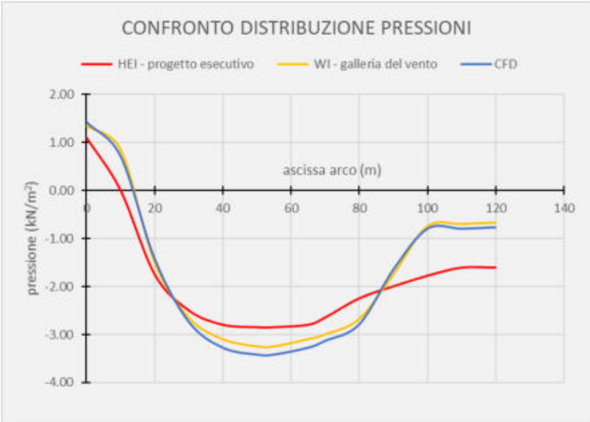

Figure 5. Comparison of pressure trends on the cross-section (kN/m^2)

5. CONCLUSIONS

An overview of the phenomena that lead to the definition of the loads acting on a structure exposed to wind action was presented. In this specific case, the two coal storage hangars of the new Dubai thermal power plant.

The sensitivity analysis of the gust factor G_f with respect to variations in the parameters that contribute to its definition did not reveal excessive variations for the structure under consideration but indicated, as expected, that the most critical parameter is the damping ratio.

The results obtained through CFD simulations showed good agreement with the loading scheme derived from the ASCE 7-10 guidelines for the isolated hangar and showed a reduction in overall pressures when the two hangars are considered together.

The wind tunnel tests confirmed the results obtained through CFD analyses regarding the pressure distribution and the interaction effects between the two coupled hangars.

However, both the CFD analyses and the physical model wind tunnel tests, while having returned an overall pressure field slightly less severe than that required by the American standard, show a greater imbalance. The greater asymmetry of the wind load identified by the tunnel measurements results in a stress state in some areas of the structure (typically the arch abutments) greater than that caused by the standard loads, which therefore do not always appear to be precautionary.

REFERENCES

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