Cover page

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Sense-making on design and control of complex structural systems for bridges

Franco Bontempi, Luciano Catallo, Luca Sgambi*

ABSTRACT

This paper deal with analysis and design of the long suspension bridge. In particular the design of transversal and longitudinal devices is developed. The seismic analysis, developed under 400 earthquake simulations, shows the dynamical behavior of the bridge.

INTRODUCTION AND GEOMETRICAL DESCRIPTION

The subject of this study is a long suspension bridge having the main span of 3300 m (see the Figure 1). The total length of the deck, 60 m wide, is 3666 m (including side spans). The deck is formed by three box sections, outer ones for the roadway and the central one for the railway. The roadway deck is composed of three lanes for each carriageway (two driving lanes and one emergency lane), each 3.75 m wide, while the railway section is composed of two tracks [1], [2]. The height of the two towers is 383 m and the height of the deck in the middle of the bridge is 77 m in order to provide a minimum vertical clearance for navigation of 60 m – with the most unfavorable static load conditions – over a width of 600 m. The bridge suspension system relies on two pairs of steel cables, each with a diameter of 1.24 m and a total length, between the anchor blocks, of 5300 m. In the tower zones transversal and longitudinal devices are present. These devices join the towers with the bridge deck (Figure 2) and they working only in compression.

The regions near the towers are critical zones because, under transversal loads, the horizontal curvature (and therefore the momentum) increase considerably. To govern this local effect, the devices has designed with a proper gap (the Figure 2 show a typical constitutive law used in the analyses).

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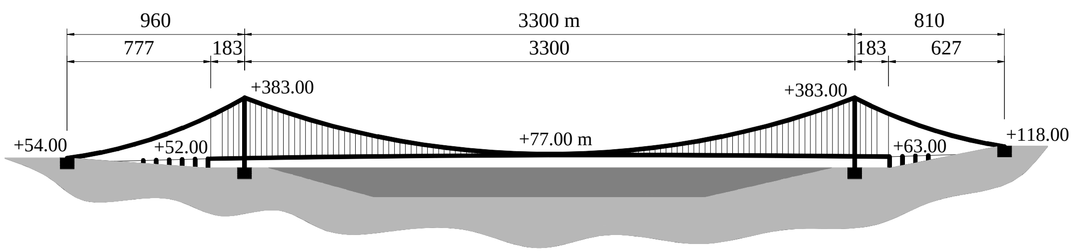

Figure 1. Longitudinal view of the long span suspension bridge.

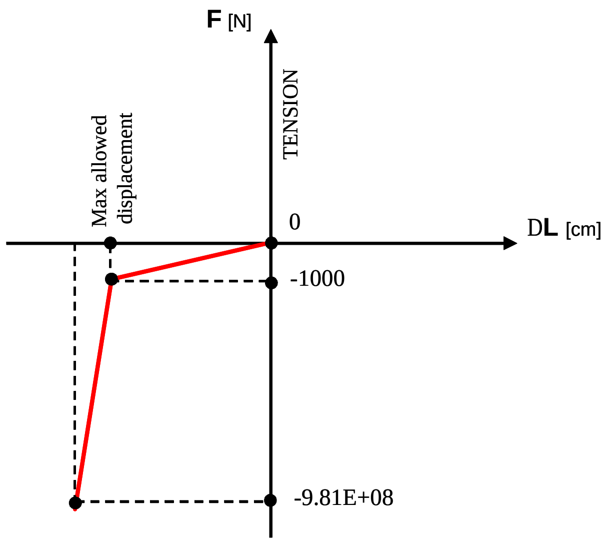

Figure 2: Force-displacements (F-? L) law of the slack.

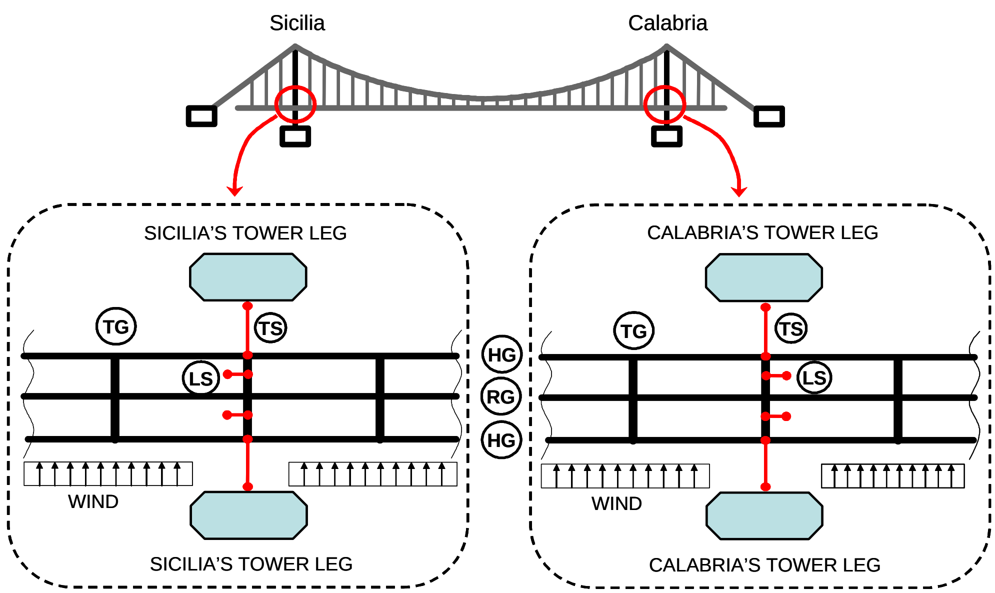

Figure 3: Both transversal slack (TS) and longitudinal slack (LS) arrangement along the suspension bridge. (HG: Highway box girder; RG: Railway box girder; TG: Transverse box girder.)

DEFINITION OF DEVICES

The slack was designed considering the bridge response under static loads. The loads considered, in this preliminary design phase, were: the temperature gradient, the static component of the transversal wind and the worst live load combination regard to the longitudinal displacement. Figure 4 shows the transversal displacement of the bridge deck under the most severe static wind load considered. It is evident the modest influence of the gap presence on the global bridge response. Figure 5 and Figure 6 represent the bridge response in terms of horizontal curvature. From these figures appear clearly a zone near the tower which the presence of the gap play an important role. In these zones the local curvature decreases of 20 – 40% if the gap is present in the transversal devices. From these considerations the longitudinal and the transversal gaps was fixed to: 0.6 m (Longitudinal gap) and 0.3 m (Transversal gap).

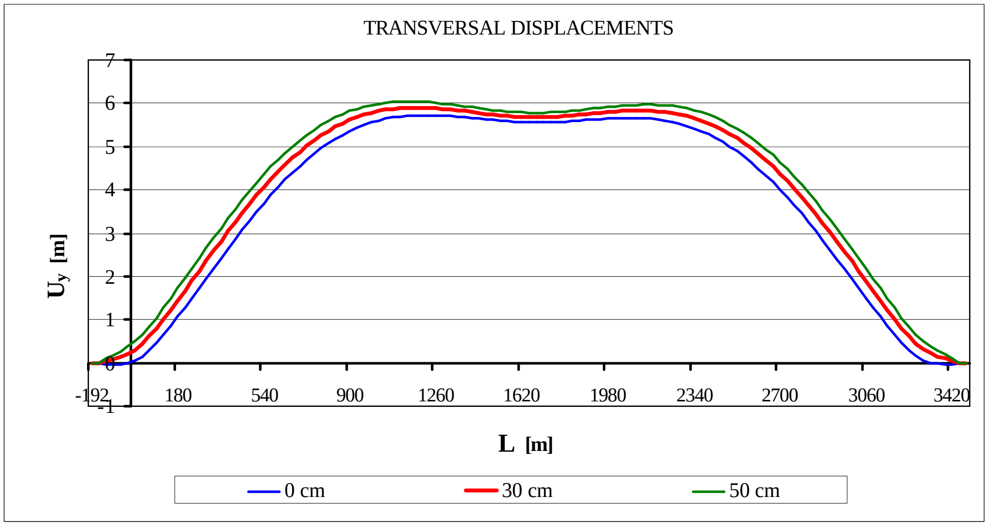

Figure 4: Transversal displacement of the deck.

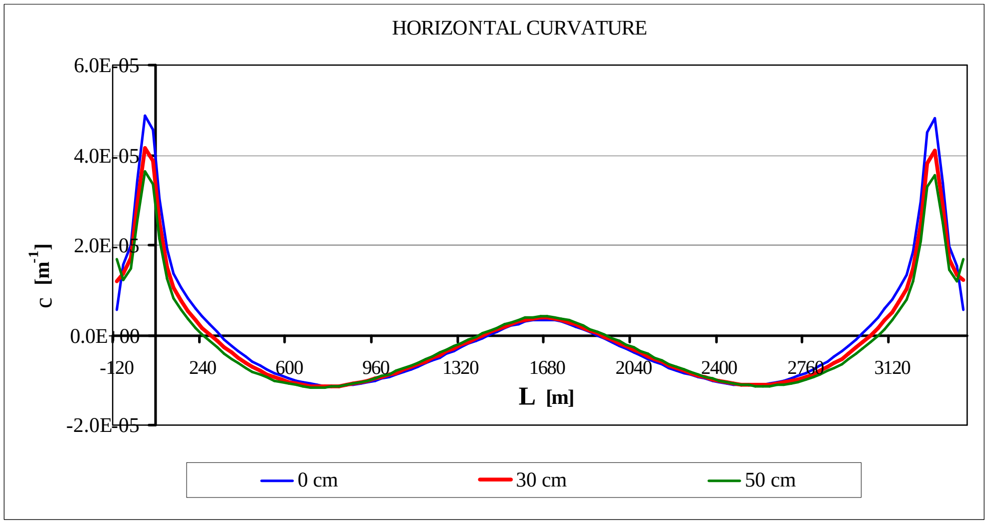

Figure 5: Horizontal curvature of the deck.

In order to analyze the behavior of the long span suspension bridge, specifically regarding the stress state evaluation, the model of the bridge deck close to the towers (Figure 6 and Figure 7) is refined using two-dimensional finite elements working according to the shell theory [3], [4].

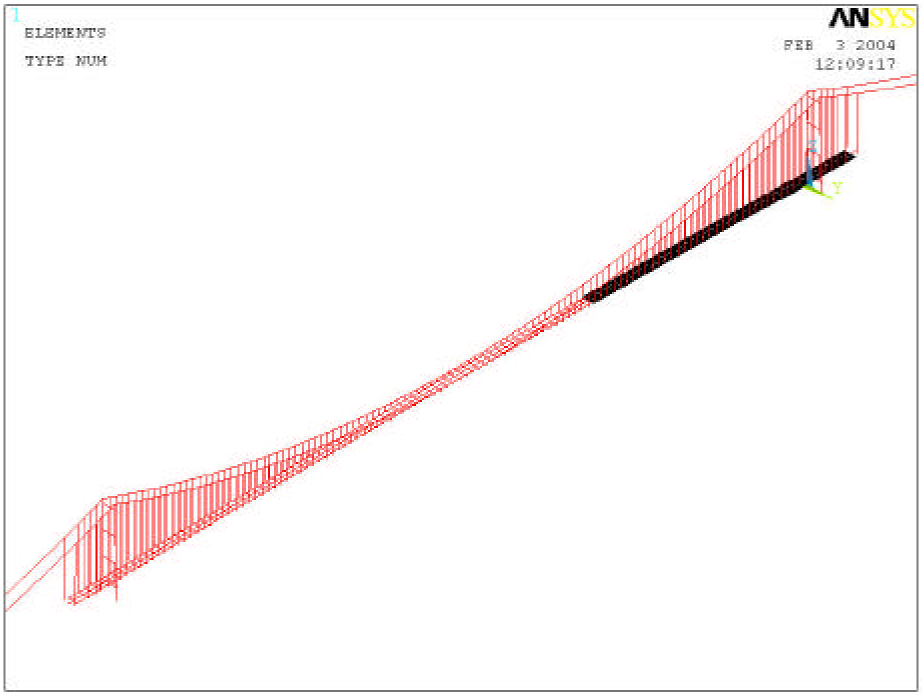

Figure 6: Sub-Structuring model of the bridge.

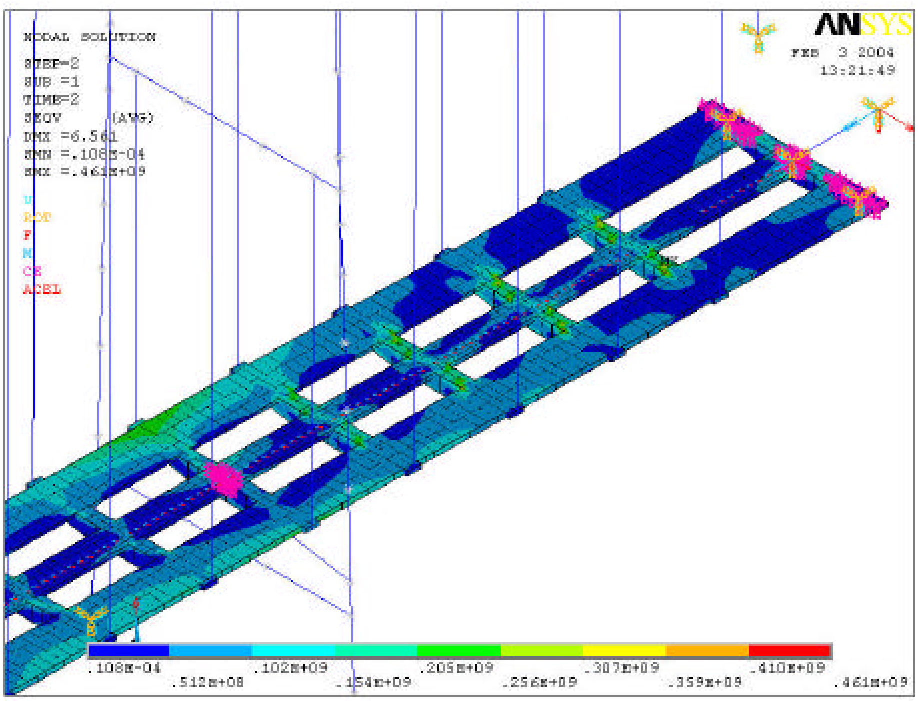

Figure 7: Tension contours in the shell elements near the Calabria's tower.

THE EARTHQUAKE SIMULATIONS

The earthquake analysis was developed considering an asynchronous seismic action. The seismic input was modeled like a time history displacement applied at the restraint point of the numerical model. In order to consider the asynchronies of the seismic input, four different time history was utilized for the four zones identified in Figure 8. Different time histories were used along the three Cartesian directions in order to consider the randomness of the earthquake principal direction. All the seismic actions were considered not correlated.

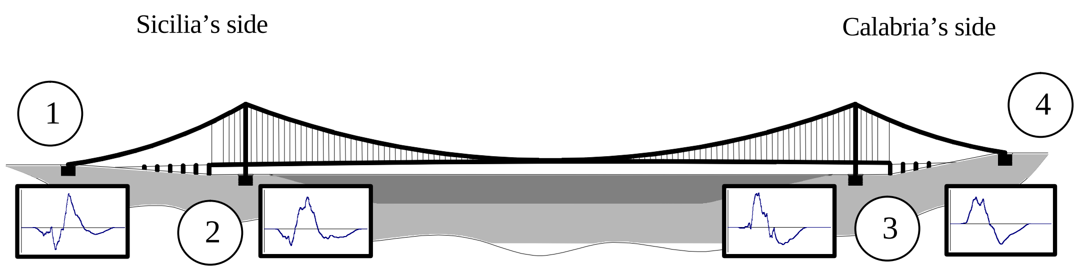

Figure 8: Horizontal curvature of the deck.

Io order to give statistical significance at the analyses, 400 different earthquake simulations was developed. All the time histories considered are spectrum compatibles with the response spectrum resulting from the Italian Regulations. In the Figure 9 and Figure 10 some results are presented such as Gaussian Curves.

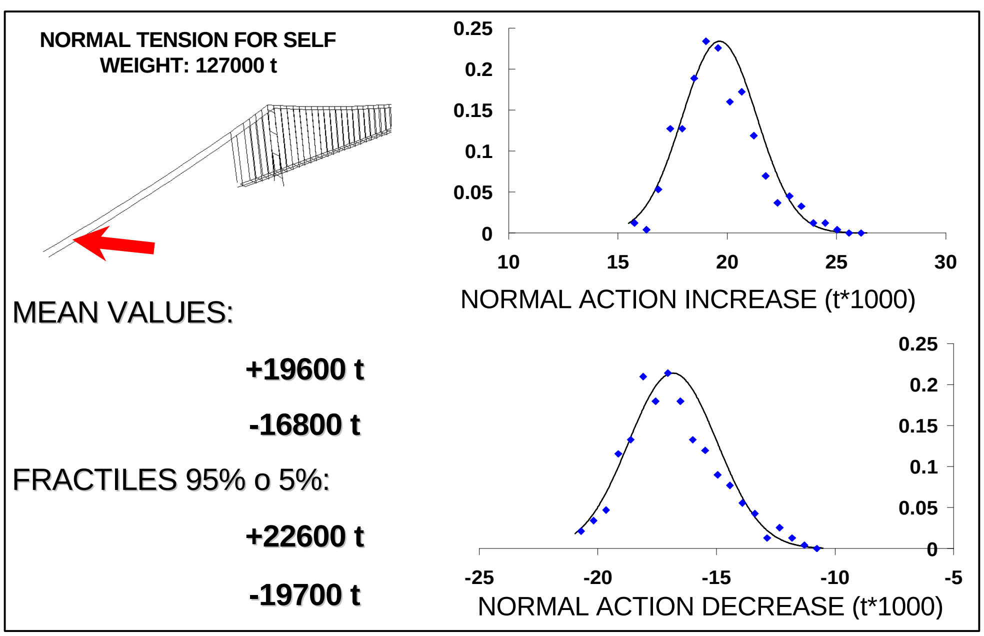

Figure 9: Gaussian curves of the cable normal tension.

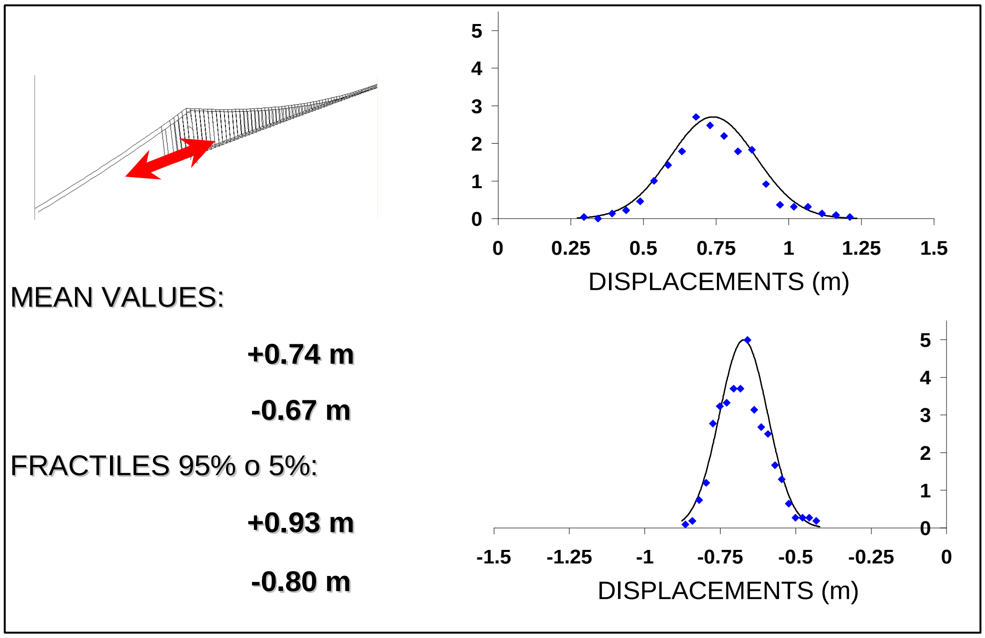

Figure 10: Gaussian curves of the longitudinal displacement.

CONCLUSIONS

In this paper some analyses about the Messina Strait Bridge are presented. The design problem of the transversal and longitudinal slack is developed. The behavior of the bridge under seismic action is investigated using 400 earthquake simulation in order to give statistical significance at the results.

ACKNOWLEDGED

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