POLYTECHNIC OF TORINO
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Honors theses

Numerical simulation of ancient masonry towers: The "Astesiano Tower" in Alba, Italy

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Towers of Alba

One possible approach to the study of the static behaviour of a structure is by means of a numerical model, which takes into account the geometrical and mechanical characteristics of the problem. This purpose is usually achieved using a structural software.
The object of the present study is a medieval masonry building called "Torre Astesiano" in Alba (Italy). The finite element code DIANA, produced by the Dutch TNO and the Delft Technical University, has been used for this purpose. The analyses have been carried out on the Silicon Graphics Origin 200 Server Castigliano at the Department of Structural Engineering and Geotechnics of the Politecnico di Torino.
To introduce the problem, the historical and architectural background of the town of Alba and its towers are initially described. According to ancient reporters, a big number of towers were in Alba, as much as to be defined the "town from the one hundred towers".

The Astesiano Tower is the third tower of Alba for height. It presents a crack pattern, which has being monitored for years. The geometry of the tower, including the present damage pattern, has being acquired by a survey.

Astesiano tower, crack pattern of the sud view

Furthermore, to explain the mechanical properties of the masonry a description of the mechanical behaviour of brittle materials is given. In particular, attention is paid to the factors that influence the compression strength, to the experimental investigations on the masonry, to the elastic theories, and finally to the causes of crushing in the real masonry.
The numerical method used for the analysis is called the “finite element method”. The structure is subdivided in several finite elements connected by nodes, where the state of stress and strain is calculated.
The solution of the problem gives the equilibrium configuration in the nodes. The displacement field is then obtained by interpolation between the nodes. The strain field is obtained by the derivation, and finally, the stress field is obtained from the constitutive equations. The approximation of the results depend on the number of nodes used to discretise the structure and on the assumed constitutive behaviour.
In order to take into account the exact position of the openings in the tower and the variation of the cross section of the wall at the various levels, the structure has been discretised with 1144 three-dimensional 20 nodes finite elements.

The various aspects concerning the model input, such as the generation of geometry, the constrains, the properties of the materials, the definition of the loads, are described in detail in the thesis.

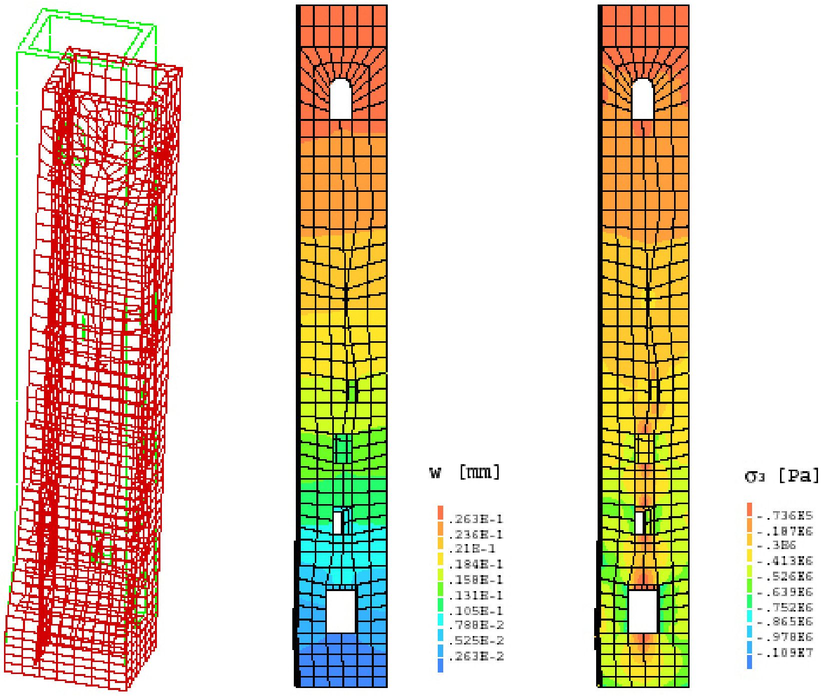

Diagram of the optained results

The numerical analysis has been carried out considering the dead loads and the wind thrust. Two configurations have been considered. The first configuration refers to the ideal situation of the undamaged structure. This situation could be achieved after the consolidation. The second configuration refers to the actual structure which presents a crack pattern in the South prospect.
In order to validate the model the results have been compared with data acquired during the not-destructive testing of the tower, in particular by means of flat-jack tests.
The two configurations show similar results as far as stress, strain and vertical displacemets are concerned. On the other hand, the horizontal displacements of the damaged configuration are much bigger than the undamaged ones.
The crack pattern, which is considered in the damaged configuration, definetly affects the horizontal deformation of the structure. This aspect must be carefully evaluated in case of a possible seismic event, although this kind of load has not been studied in the present thesis.

A few retrofitting alternatives are feasible on the present tower, for example: injections of binding mixtures, perforated steel rebars, the “cuci-scuci” methodology. My personal proposal is the “cuci-scuci” methodology, this choice is mainly suggested because the tower masonry morphology.

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