Lithic Hypar: New Frontiers in Structural Stone Research

D. Malomo[1], V. Varano[2]

[1]DICEA, University of Rome, Italy
[2]LAMS,University of Rome, Italy

Abstract

The research proposed is based on the mechanical analysis of an innovative reinforced stone's structure, architecturally designed by Prof. Fallacara of the University of Bari (Italy): the headquarter's entrance portal of the offices of the French company SNBR (Société Nouvelle Batiment Régional) located in Troyes (France), the realization of which is planned for October 2015. The shape characterizing the work is the hyperbolic paraboloid, well known for many structural applications related to reinforced concrete shells. The main idea of this lithic reinterpretation of the hypar is to replace the reinforced concrete with pre-compressed stone: the stone is a symbol of these places, so it has been possible to join tradition and structural experimentation.

The hyperbolic paraboloid can be easily described in an analytic way, thanks to the COMSOL software that allows to simply define a parametric surface. The analytic description permits to directly calculate some geometric quantities that strongly characterize the structural behavior and the determination of the stresses on the surface through the structural mechanical model, modeling the hypar as a shell.

The hyperbolic paraboloid is one of the most famous ruled surfaces: it may be generated, in fact, as a geometric place of two families of straights called "generatrices". This feature is particularly important in this case, because of it allows an easier division into modules of stone and, above all, it allows to realize a post-stresses conditions through rectilinear steel bars in order to eliminate residual tractions, arranged along the generatrices.
This connection among geometry and structure allowed an easy modeling using the COMSOL software: the pre-compression has been modeled by the assignment of an uniform load on the whole paraboloid's edge, in the direction of the generatrices. The possibility of including parametric functions in COMSOL has been permitted to precisely determine the necessary pre-compression in order to eliminate the residual tensile stresses.

The results obtained by this modeling allow a fast and reliable valuation of some important physical quantities: the parameter value, that indicate the necessary pre-compression level, is of about 80kN/mt, i.e. about 4.4 ton for each steel bar. Moreover, it has been possible to verify that the uniform compression of the stone is permissible and there are no relative slidings among the ashlars, being the normal stresses (multiplied by the static friction value) much more than the

stresses related to the cut.

This analysis showed accurate and immediately utilizable data on the structural behavior of the work. The adopted modeling allows to examine in depth important technical issues: the possibility to describe the pre-compression in an analytic and geometric way and to foresee the behavior of stone allow to realize a prototype based on advanced and reliable studies and to reduce the number of mechanical test on physical models, influencing the work also in economic terms.

Reference

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Figures used in the abstract

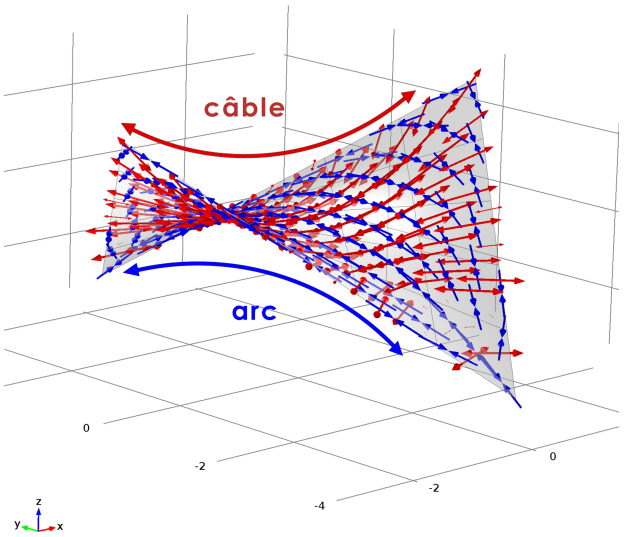

Figure 1: Structural behavior of the hypar

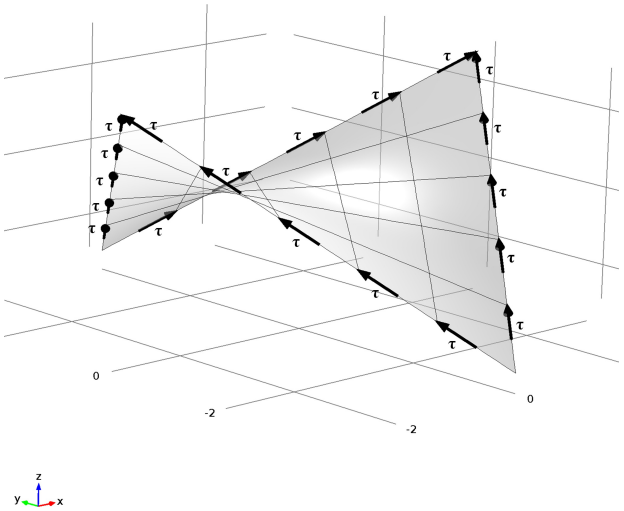

Figure 2: Shear stresses along the edges

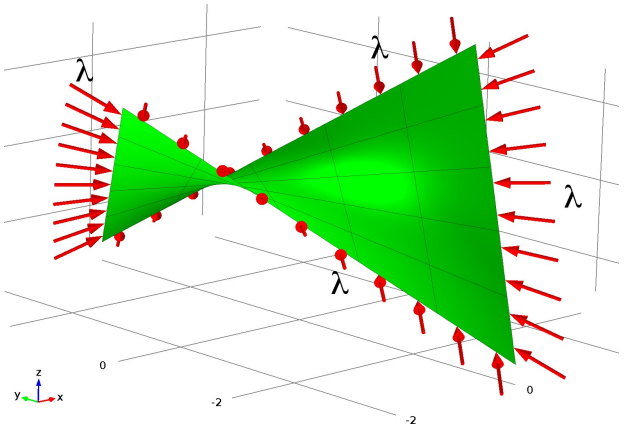

Figure 3: Model of post-tensioning

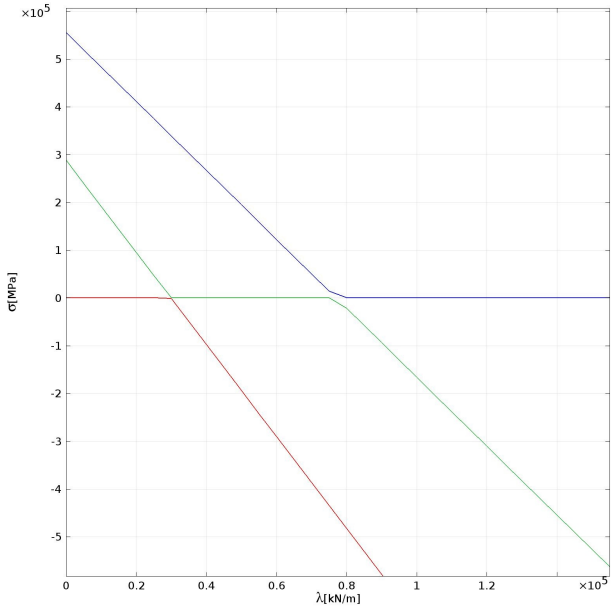

Figure 4: Determining the value of post-tensioning