Multidomain Symmetric Galerkin BEM for non-linear analysis of masonries in-plane loaded

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Summary: The preservation of the historical and monumental buildings, but also of the considerable heritage of old constructions made by traditional techniques, is one of the actual problems of the structural mechanics. The level of knowledge of their structural behavior in presence of external actions is made through calculus methods and simple procedures in order to allow a reading of the material suffering degree and as a consequence of the related safety.

In this paper an elastic analysis of walls, also in presence of geometrical nonlinearity consisting in the contact/detachment phenomenon among stone blocks. The wall having any shape and zone-wise variable physical characteristics is loaded in its plane. For these structures some interventions of structural strengthening have as aim to improve the wall behavior by reducing the stress concentration, so to have a better safety in comparison with its initial value.

General aspects in the use of SGBEM in the masonries analysis

Among the more considerable aspects within the protection of the masonry buildings, and in particular of the historical and monumental patrimony, there is the identifying of the static instability causes found in the walls. The difficulties in studying these structural systems depend on several elements, as the complexity of structural behavior and the uncertainties in the physical-mechanical characterization of the materials.

At same time, the choice of the interventions in order to guarantee the safety wanted, respectful of the rules of the restoration, is full of dangers. Often the architect or engineer uses empiric rules, also supported by rough structural schematizations, attaining to solutions often not answering to the necessary safety of the building.

As a consequence the use of the calculus code supported by appropriate computational methodologies is necessary to make numerical simulations which, once known the external actions, have the aim:

- to identify the possible causes of the instabilities through the solution of an inverse problem;
- to perform interventions on masonry panels, having feature of prevention towards possible static instabilities;
- to establish what, among the technical solutions of intervention to be activated, is this more appropriate, by making a comparison among different solutions of reinforcement.

The aim is to increase the safety conditions of the masonry buildings through the improving the stiffness of each wall panel in order to reach a global structural response with a more uniform field of the stress state.

In this paper the analysis is performed in the hypotheses that the actions (boundary and body forces, displacements of the constraint) act in the plane of each panel. It can be made through numerical simulations using analysis methodologies able to perform the necessary checks within reduced calculus times.

The usual calculus codes employed to analyze the masonries have as theoretical basis the Finite Element Method (FEM). But this method shows several drawbacks meanly connected to the discretization employed in the walls, usually foreseeing the use of elements having the same geometry.

The present paper suggests an innovative analysis based on the use of a multidomain strategy within the symmetric Galerkin formulation of the Boundary Element Method (SGBEM).

Within the SGBEM, in this paper, a strategy which uses the displacement method, proposed by Panzeca et al. [1, 2], is utilized. The latter method shows symmetry of the algebraic operators and is characterized as follows:
a) the subdivision of each masonry panel by substructures having any shape and dimension and different physical properties;
b) the boundary distinction of each substructure into constrained, free and interface with other substructures;
c) the writing of a characteristic elasticity equation for each substructure connecting weighted tractions evaluated on the interface boundary to nodal displacements of the same interface and to the load vector;
d) the use of the equation system through the writing of the compatibility strong form at the interface nodes and through the related weak form involving weighted (or generalized) tractions at the interface boundary elements,
e) the computation in closed form of all the double integrals making up the equation system coefficients, having hypersingular, singular or regular kernels [3],
f) permit the transformation of the domain integrals into boundary ones. The reader can refer to Panzeca et al. [4].
The discretization of the panel into substructures can be made through its subdivision into macrozones characterized by a homogenization of the physical parameters of the stone-mortar system and single elements constituting the panel as stone blocks and mortar layers, possibly considered separately.
The simultaneous use of the two different levels of discretization, one more sparse in macrozones and another more dense, is characteristic of the potenziality of the method. The presence of substructures having big or small dimensions does not involve numerical instabilities because all the coefficients of the equation system were computed in closed form.
The analysis of the masonry is made by using the Karnak.sGbem code [5]. This program allows to evaluate the response of the structural system subjected to all the possible static actions, whether volumetric or surface loads, but also to volumetric and linear distortions and to displacements imposed in the constraints.
Besides, it is possible to make a nonlinear analysis of cohesive detachment, so reproducing the evolution of the probable disconnectedness between stones through a strategy developed by some authors [6].

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