Modified Bouc-Wen model with damage and flexibility increase for the dynamic analysis of masonry walls

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Abstract. The purpose of the following study is to present a force-based macroelement for the static and dynamic analysis of the in-plane response of masonry panels. The nonlinear behaviour of masonry is described by a constitutive model based on the Bouc-Wen hysteretic formulation modified with the introduction of damage and flexibility increase by means of two scalar variables that regulate the rate and type of degradation. Damage is considered as a reduction of the hysteretic force, while flexibility increase is modelled through an enlargement of the elastic displacement, both depending on the dissipated energy. The aim is to give a more accurate representation of the strength and stiffness decay these walls undergo when subjected to cyclic loadings and to better represent the loading and unloading branches of the response curves. To investigate the effect of the degradation in the dynamic field, the behaviour of both a slender and a squat wall is analysed under harmonic excitations.

Introduction

A large part of the architectural heritage throughout the world is built using traditional materials. Among these, masonry is the most widely spread, and is still nowadays largely studied. Its fascinating and complex behaviour, due to the coupling bricks or blocks with mortar, together with the high uncertainty caused by the failure mechanisms occurring during cyclic and dynamic actions, has deserved the application of numerous formulations to reproduce its mechanical response. The Bouc-Wen hysteresis [1] has proved to be a reliable tool for the representation of the cyclic response of masonry, especially when modifications are introduced to account for the onset and propagation of damage [2,3].

The formulation already presented in [2] is here enhanced with the introduction of flexibility increase, depending on the dissipated energy and a scalar variable that regulates the rate of the stiffness degradation, for a more accurate description of the stiffness and strength decay observed in experimental tests.

The proposed macroelement, originally formulated in [3], uses the modified Bouc-Wen law to model the nonlinearity of masonry in a shear link and two lumped flexural hinges that are in series with an elastic beam element. Pinching and the high initial stiffness that characterize slender panels are also taken into account by the flexural hinges thanks to the introduction of a nonlinear elastic and an elastic negative device, respectively. Regarding the dynamic formulation, the lumped mass matrix and classical Rayleigh damping are implemented consistently with the equilibrated force-based approach adopted for the formulation of the macroelement.

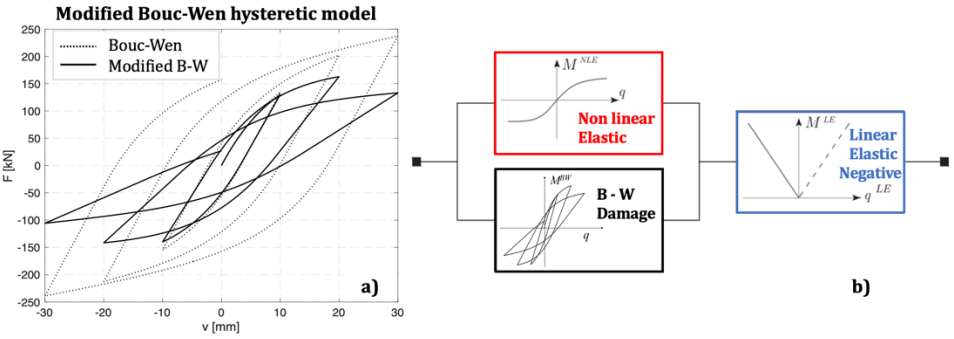

Figure 1: Modified Bouc-Wen model with damage and flexibility increase a); structure of the flexural hinge of the macroelement b).

Results and Discussion

Both the static and dynamic behaviour of masonry walls are investigated, considering two different geometric configurations, namely a slender and a squat panel. A good agreement of the static response compared to experimental results presented in literature is highlighted. Moreover, the impact of damage and damage with flexibility increase is investigated with respect to the classical Bouc-Wen model and the elastic case, with the aim of examining the performance of the model in the dynamic field, specially focusing on the influence of damage mechanisms on the dynamic characteristics of the structural response.

References

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