Soil Dynamics and Earthquake Engineering 114 (2018) 548–554

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

journal homepage: www.elsevier.com/locate/soildyn

Optimum design of dynamic modal control algorithm using non-linear structural mathematical modeling

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ARTICLE INFO

Keywords:
Structural systems
Dynamics
Control algorithm
Full mathematical implementation
Non-linear response

ABSTRACT

The paper falls within the framework of dynamic control of existing structures exhibiting non-linear behaviour. On the basis of some previous research developed by the authors, it specifically focuses on the analytical setup and development of a control algorithm for mitigating in an improved way the response of non-linear spatial structures, made of masonry. The presented setup does not involve the gross simplifications of the structural model behaviour that are usually adopted in these cases; on the contrary it proposes a more appropriate full mathematical formulation, which is, nevertheless, made still manageable for numerical purposes and significantly more reliable than alternative approaches.

1. Introduction

For masonry structures, the proneness to disease or collapse is usually related to the activation of cracking mechanisms rather than to local failure ought to crushing in compression of masonry [1–6]; this feature requires that fracturing is regarded as an intrinsic pattern for the stress-strain relationships of the material model (see e.g. [7,8] and, in terms of fracture mechanics [9,10]). The poor tensile resistance, usually decaying in time, of the material, coupled to the skill of developing fractures pushes towards the adoption of non-linear mechanical models of the No-Tension (NT) type, where suitable extensions of the energy principle may be successfully developed.

According to this mechanical hypothesis, numerical investigation may be performed by implementing the full mathematical problem representing the case under exam in order to achieve some reliable forecasts about the behaviour of the construction.

In most cases, when one aims at investigating the seismic performance of buildings sustained by planar vertical walls supporting one or more floors, push-over analyses on simplified models (see e.g. the POR software [11]) are performed rather than full analyses implementing the more complex problem related to the more appropriate material modeling [12], even when dynamic control is to be adopted (for some literature on control theory in civil and seismic engineering [13] refer to e.g. [14–32]).

Actually, masonry walls subject to seismic-type actions show an overall ductility, with an holonomic behaviour, and, consequently, the control algorithm aimed at mitigating dynamic effects should be designed by considering the non-linear structural response. To this regard, one should also emphasize that control of masonry constructions is not so often addressed in literature.

In the paper, within the framework of control of nonlinear systems (see e.g. [33,34]), the problem is treated through the development of an algorithm where the non-linear pattern is included into the design procedure, with the purpose to ensure that the control device produces a benefit also after entering the non-linear phase, as explained in Section 4. Full analytic implementation is developed of the box-behaviour structure, without making recourse to simplified models, thus ensuring the possibility of reproducing the original geometry and capturing the real behaviour of the masonry material. Static or dynamic analyses of the 3D NT building are then involved in the proposed approach, where full non-linear analyses are developed and relevant calculus codes compiled.

2. General setup

In the following one refers to a spatial building with perimeter and internal masonry walls and a rigid floor slab, to be dynamically controlled with respect to incoming ground actions.

The rigid generalized displacement coordinates are identified in the two floor plane translations $u(t)$ and $v(t)$ along the x and y axes in the floor plane, and in the rotation $\phi(t)$ around the z axis, orthogonal to the same floor. The implementation of the full NT mathematical

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https://doi.org/10.1016/j.soildyn.2018.07.033
Received 28 March 2018; Received in revised form 9 July 2018; Accepted 22 July 2018

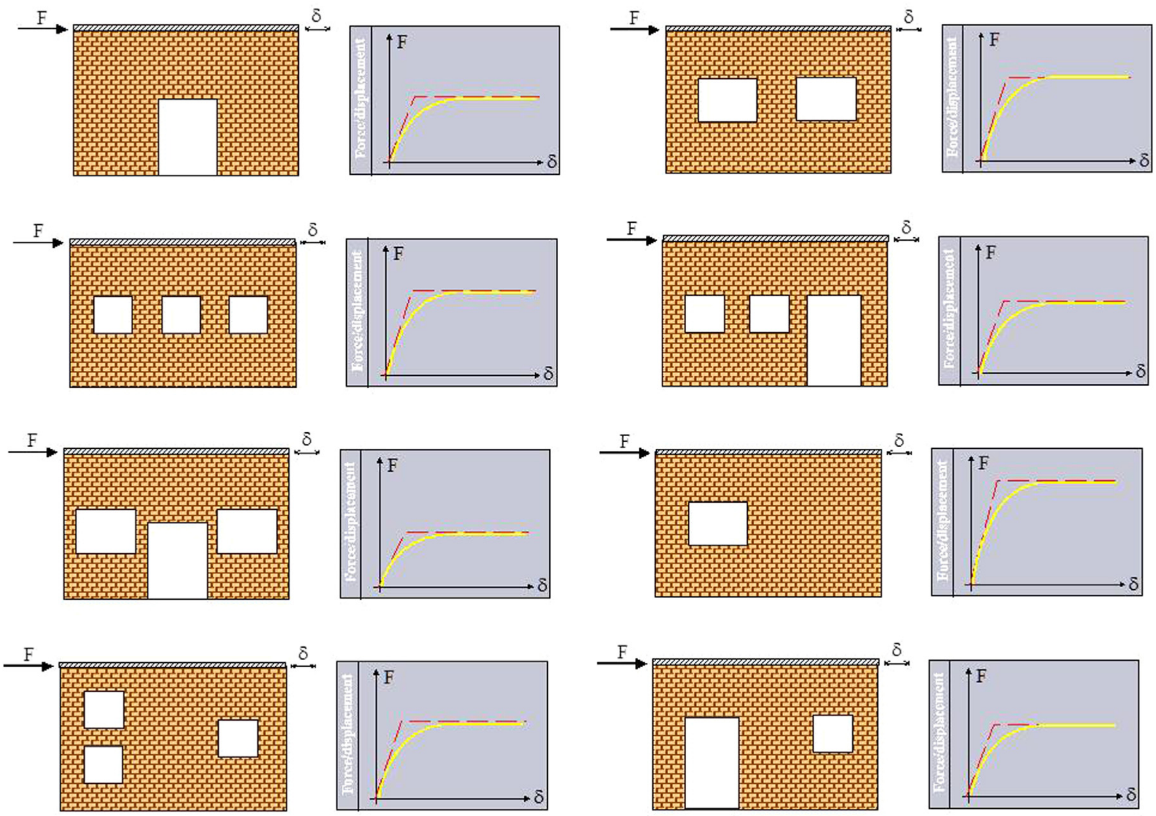

Fig. 1. Push-over diagrams for masonry panels modelled according to the NT assumption.

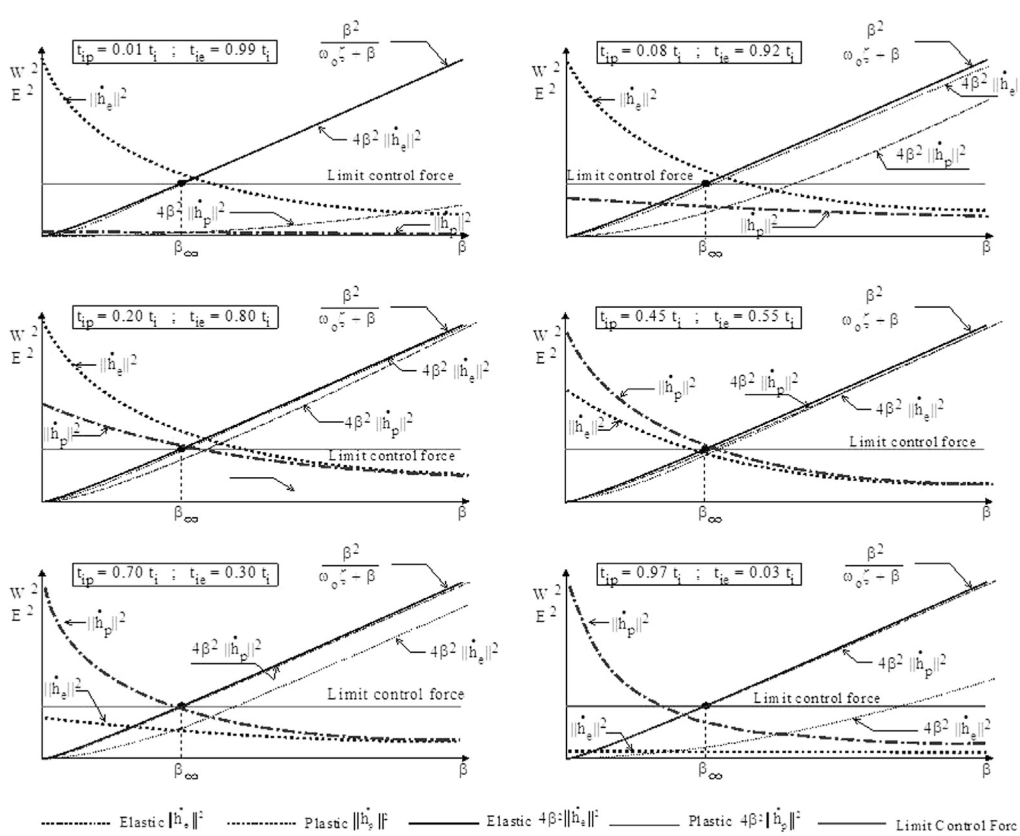

Fig. 2. Linear and non linear response energy operators (E^2) and control force operators (W^2) depending on the impulsive response energy in the linear and non-linear phase with feedback parameter β.