

# FRAME-ELEMENTS CONSTITUTIVE LAW FOR NONLINEAR STATIC AND DYNAMIC ANALYSES OF MASONRY BUILDINGS

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Equivalent frame method (EFM) is widely used for the nonlinear static and dynamic analyses in the engineering applications for seismic assessment and design verification of masonry buildings due to its efficiency in the performance prediction and high computational ease. The available large data base on the nonlinear response of masonry elements makes EFM as a suitable choice for the analysis and an ideal option when large building stock and/or parametric sensitivity analyses are under consideration. The available constitutive laws for masonry elements, generally recommended, are investigated in the prediction of seismic displacement demand on the buildings using nonlinear time history analysis (NLTHA) against the analytical prediction using secant vibration period and overdamped spectrum with the bias in the prediction being quantified. The investigation is performed on two to five storey masonry buildings of Pakistan using six different available frame elements constitutive laws. The investigation shows that the bi-linear constitutive law, Takeda type rule, with Emori type of unloading give relatively more consistent results. The effect of different spectral reduction factors, recommended by Euro Code 8, is also investigated.

*Keywords:* Equivalent frame method, constitutive law, seismic assessment, masonry buildings, Pakistan.

## 1. Introduction

The paper presents the investigation of frame-elements force-displacement constitutive laws for nonlinear static and dynamic analyses of masonry buildings using macro-element approach particularly EFM within the context of seismic assessment and design verification of masonry buildings. The investigation is performed using nonlinear dynamic time history analyses (NLTHA) of structural models using real accelerograms in light of the analytical prediction through secant vibration period of the system and overdamped seismic displacement spectrum with the dispersion in the error being quantified.

The displacement-demand on the system is used as the key parameter in the

investigation process due to its direct correlation with the structural expected performance level for a given seismic demand (Priestley *et al.* 2007). The investigation aim at the identification of a conceptual and consistent force-displacement constitutive law for nonlinear static and dynamic analyses of masonry buildings.

## 2. Nonlinear Static and Dynamic Seismic Analyses of Masonry Buildings (SD-SAM)

### 2.1. Equivalent frame method

In this method the masonry buildings are idealized as an equivalent frame with beams and columns, with material nonlinearity considered through the use of lumped