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A Macro-Model for Nonlinear Dynamic Analysis of 3D RC Shear Walls and Comparison with the Finite Elements Method

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Abstract

Due to architectural limitations, in many cases the RC shear walls have to be extended in plan in different directions at one location making them a 3D configuration. Modeling and analysis of such walls is very challenging and only a few studies are available on them. In this research a number of 3D shear walls are considered with different shapes and heights. They are modeled for nonlinear dynamic analysis in Abaqus software using an exact moment-shear interaction model. A suit of appropriately selected and scaled ground motions are used for analysis. The envelope of the nonlinear force-displacement responses is used to develop a macro model of the same walls consisting of an elastic wall throughout in series with a nonlinear moment-rotation spring at the base in Opensees. It is shown that the developed model can predict the maximum responses with a very good accuracy in a much less time.

Keywords: 3D RC shear wall, macro model, nonlinear dynamic analysis.

1. Introduction

Architectural limitations along with other considerations make use of three dimensional (3D) concrete shear walls inevitable. Modeling and analysis of such walls require special remedies. The volume of research on this issue is relatively small. Such a modeling should result in a pattern able to predict the response parameters including the initial stiffness, yield point, strength and stiffness degradation, shape of the hysteretic curves and the dissipated energy[1].

Models proposed for analysis of shear walls can be categorized in three different groups consisting of refined (Micro) models, relatively refined (Meso) models and coarse (Macro)models. Although the refined models benefit from a superior accuracy, they require a large amount of time in analysis. This is the incentive of this paper to present a macro model for nonlinear analysis of shear walls in much less time and in a similar accuracy compared with the micro model. The walls are taken to be dominated by bending behavior. In the following, a description is given for the micro model used as a reference and the proposed macro model.

2. The reference micro model

In micro modeling of shear walls, use is made of the finite element method (FEM). The reinforced concrete wall is discretized using a large number of small concrete and steel elements connected at the nodal points. Number of elements is selected based on the required accuracy. Behavior of the two materials is introduced using simple constitutive relations. Different types of elements regarding their shapes and degrees of freedom have been developed by various researchers [2]. Among the elements able to be used for a 3D modeling is the one defined in SAP2000 [3]. This is a quadrilateral element having six degrees of freedom at each node. These 3D modelings are able to well predict the general as well as local behaviors of the shear walls including cracking of concrete, yielding of bars and crushing of concrete [4]. Ngo & Scordelis were among pioneers who applied the FEM to modeling of concrete elements [5]. While use of the finite element method for modeling of 3D shear walls is endorsed for its high accuracy, it needs a large computational time because of the necessity to solve a large number of concurrent equations and to integrate the 3D components of stresses. Therefore, use of the FEM for large walls is impractical [6]. The FEM is used in this research as a basis for comparison with the faster method proposed. The Abaqus software is used for the same purpose.