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SYSTEM REDUCTION IN SPACE FOR DYNAMIC FINITE ELEMENT ANALYSIS OF BEAM-COLUMNS ASSEMBLIES AGAINST EARTHQUAKES

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True behaviour of structural systems is nonlinear and dynamic. For the analysis, a conventional approach is to discretize in space (by finite elements) the partial differential equations describing the behaviour, and then integrate in time the resulting ordinary initial value problem. Despite advances in finite elements and time integration, computational effort is still an important concern. Every new day, along with improvements in CPU, RAM, and hardware, the size and complicatedness of structural systems increase. Accordingly, new improvements are being suggested for efficient analysis, in order to prevent or lessen the excessive computational effort. This is a main purpose of reduction methods (Besselink et al., 2013). The main attention in this paper is on reduction in space and simplifying models to be analyzed with less number of the degrees of freedom. The structures are limited to structural systems consisted of beam-columns, the discretization in space is considered by simple two-node beam-column element, and the method for dynamic analysis is time history analysis using a time integration method. In 2008, a technique was proposed for reducing the time history analysis against digitized excitations (Soroushian, 2008). The reduction obviously differs from the objective here, i.e. reduction in space. However, in view of the mathematical basis of the technique (Soroushian, 2008) and the successful past experiences (Table 1) (Garakaninezhad & Moghadas, 2015; and Zarabimaensh, 2017), the technique is recently adapted to finite element static analysis of assemblies of beam-columns (Farahani et al., 2017). The results were successful with computational effort reductions more than the original application, i.e. time history analysis.

This paper presents another step forward, towards reduction of finite element models of assemblies of beam-columns in dynamic analysis against earthquake excitations. The assumptions are:

1. The masses associated with beam-columns, though continuous with respect to the beam-columns longitudinal axes, are represented in a digitized format.
2. The digitization step is constant throughout each beam-column.
3. The dynamic analysis method is time history analysis using a time integration method.

The reduction takes place by replacing the digitized mass with another mass digitized in larger steps. The consequence is smaller number of beam-column elements, and accordingly, smaller mass stiffness and damping matrices. Consequently, the run time, the in-core memory, and the computational effort decrease. Because of the convergence-based formulation defining the new record (Soroushian, 2008), the accuracy is being preserved. Several examples, including a simple three member element, a multi-storey irregular building structure, and an underground tunnel (simplified model) are studied. The first is introduced in Figure 1, and led to considerable reduction of computational effort (see Table 2) with negligible change of accuracy. Similar results are obtained for the other two examples, not reported here for the sake of brevity. In view of the studied examples and the mathematical basis of the technique (Soroushian, 2008), we can consider the adaptation of the technique successful, provided the above-mentioned assumptions are valid. Furthermore, a practical application of the adapted technique is seismic analysis of lengthy underground structural systems. Finally, study on more improvement in the provided additional efficiency, broader application area for the technique (Soroushian, 2008), and combination of reductions in time and space can be addressed as the perspective of the future.

Table 1. Performance of the technique (Soroushian, 2008) in application to several time history analyses.

System	Details	Computational Effort Reduction (%)	Change of accuracy (%)
Residential buildings	About 200 buildings structures with linear/ nonlinear behavior and regularity/irregularity in plan/height subjected to different earthquakes	50-90	< 7
Power station, Cooling tower, Space structure, Silo, Bridge	Special structure, considering linear/nonlinear behavior and different near-field/far-filed earthquakes and different integration schemes, and multi-support excitation	>50	
Milad telecommunication tower	Considering linear/nonlinear behavior and near-field/far-filed earthquakes and different integration schemes	50-70	

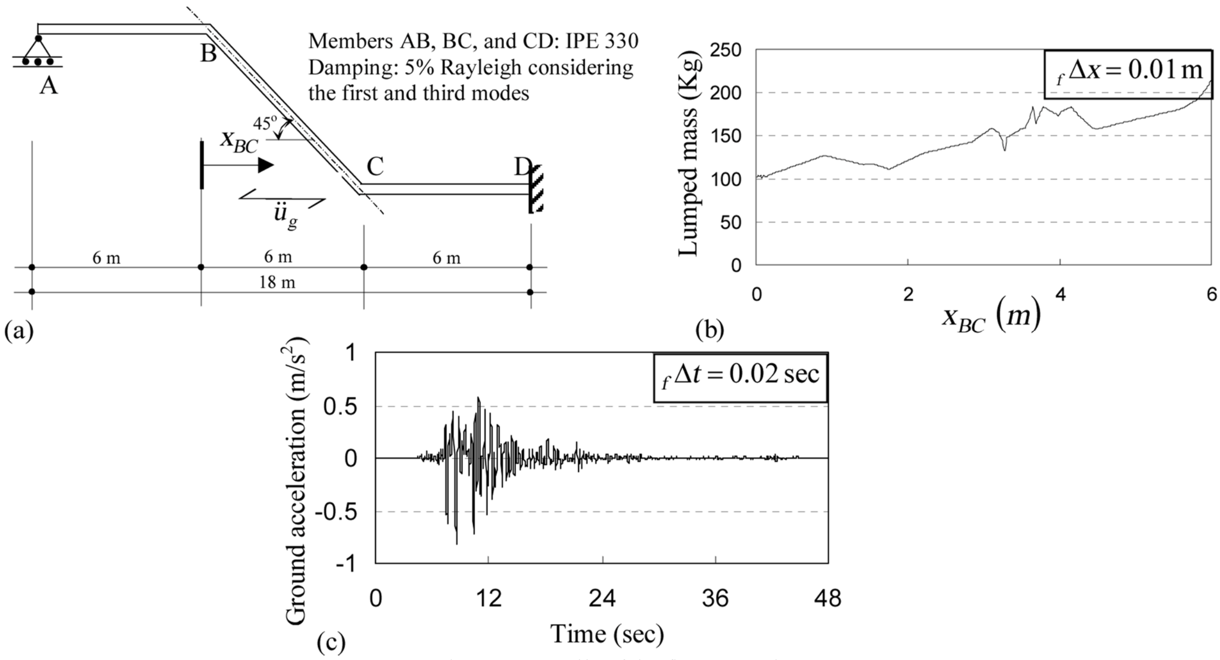

Figure 1. Details of the first example.

Table 2. Run-time and in-core storage for time history analysis of the first example.

Length of beam-column element (m)	0.01 (original analysis)	0.025	0.05	0.08
Run time (minutes)	28' 6"	10' 50"	5' 2"	3' 8"
Reduction in the in-core memory (%)	0	> 93	> 96	> 98

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