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한국전산구조공학회 학술발표회 논문집

ANALYSIS OF MULTISTORY BUILDING STRUCTURES WITH FLEXIBLE FLOOR DIAPHRAGMS

바닥판의 면내 변형을 고려한 건축구조물의 해석

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ABSTRACT

An efficient model for three-dimensional analysis of multistory structures with flexible floor diaphragms is proposed in this paper. Three-dimensional analysis of a building structure using a finite element model requires tedious input data preparation, longer computation time, and larger computer memory.
The model proposed in this study is developed by assembling a series of two-dimensional resisting systems and is considered to overcome the shortcomings of a three-dimensional finite element model without deteriorating the accuracy of analysis results. Static and dynamic analysis results obtained using the proposed model are in excellent agreements to those obtained using three-dimensional finite element models in terms of displacements, periods, mode shapes.

INTRODUCTION

The assumption of rigid floor diaphragm is valid for most cases of simplified analyses of building structures. However, there are situations where the floor diaphragms can not be considered as rigid. The in-plane floor flexibility is particularly significant for buildings with a high aspect ratio of floors, with stiff end walls and with plans in the shape of the letters L, T, V, etc. Thus, the flexibility of floors is significant in the analysis of this type of building structures.

Shepherd and Donald [1] studied the effect of floor flexibility in two-story building using a lumped-mass approach. They insisted that the neglect of in-plane floor flexibility did not significantly change the dynamic properties. Blume and Jhaveri [2] have analysed a single-story building for several values of the roof aspect ratio using a lumped-mass approach and have shown that the effect of floor flexibility could be significant for buildings with stiff end walls. Ostrom and Hurt [3] wherein they modelled the floors by beams and the columns or walls by springs, with the resulting system solved approximately using the Rayleigh-Ritz technique.

The objective of this study is to develop an efficient model for the analysis of building structures. Since it is advantageous to have less degrees of freedom, especially for dynamic analysis, the proposed model is derived to have the minimal number of degrees of freedom need to avoid significant deterioration of the accuracy in analysis results.

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ANALYSIS METHOD

Analysis of a multistory building structure with flexible floor diaphragms can be performed using a three-dimensional finite element model which provides very accurate response predictions. However the use of finite element models is not very efficient in terms of computational time and memory size required. An effort was made in this study to develop an efficient model with much less degrees of freedom without significant deterioration of accuracy in the analysis results. A multistory building structure shown in Fig. 1 is considered as an assemblage of components such as two-dimensional resisting systems and floor systems as illustrated in Fig. 2.

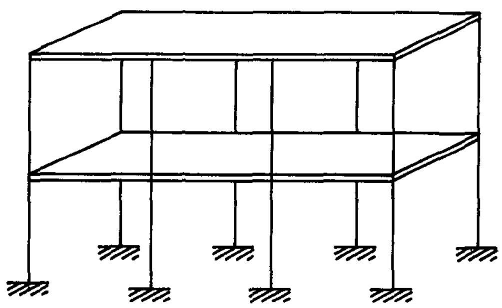


Fig. 1 A multistory building structure

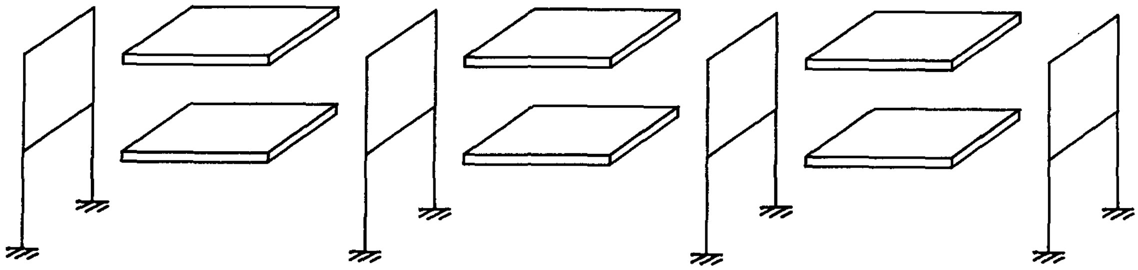


Fig. 2 A multistory building structure decomposed to two-dimensional resisting systems and floor systems.

A two-dimensional resisting system which can be a plane frame with or without stiffening elements such as shear walls or braces is reduced to a stick model with one degree of freedom per floor in horizontal direction as shown in Fig. 3. A finite element developed for analysis of frames with shear walls (W12 element) is used for a two-dimensional resisting system with shear walls [4].

Degrees of freedom for vertical displacement and rotation are eliminated using the story-by-story procedure of static condensation. A floor system which interconnects two adjacent two-dimensional resisting systems at each floor level is modelled as a stiff beam with flexural and shear deformations. Reduced stick models and stiff beams are assembled to obtain a simplified model for analysis of a multistory building structure with flexible floor diaphragms. The stiffness matrix of a simplified model is obtained by superposing condensed stiffness matrices of two-dimensional resisting systems and stiffness matrices of stiff beams. The assembled model and degrees of freedom are illustrates in Fig. 4. Lumped mass matrix is used for dynamic analysis of a simplified model.

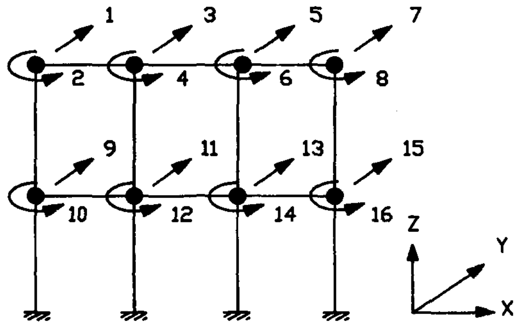


Fig. 4 Analysis model and degrees of freedom

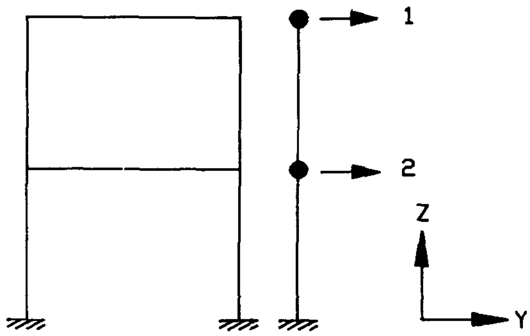


Fig. 3 Reduction of a plane frame

NUMERICAL EXAMPLE

A two-story building structure shown in Fig.1 is used as the prototype of example structures for assessment of the proposed model performance. The prototype is modified to obtain three A type example structures A1, A2, and A3 with different aspect ratio by varying the span in x direction to 6m, 12m, and 18m respectively to assess the performance of the proposed model for different floor aspect ratio. Interactions of floor systems and two-dimensional resisting systems are increased by adding shear walls at both ends of A type example structures to obtain B type example structures B1, B2, and B3 for assessment of the performance of the proposed model with increased floor deformations as shown in Fig. 6.

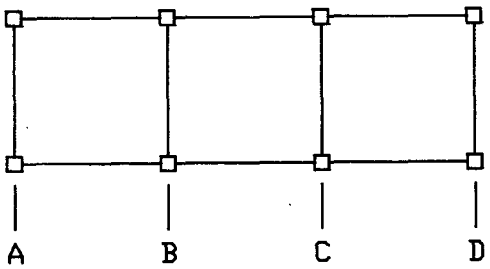


Fig. 5 Plan of A type structure

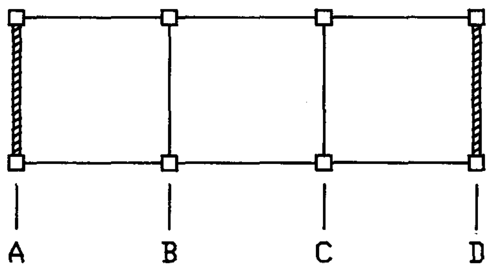


Fig. 6 Plan of B type structure

Static and dynamic analyses are performed for six example structures using the proposed model and three-dimensional finite element models. A computer code FF3D was developed for analysis of the proposed model and the computer code SAP IV was employed for analyses of finite element models. Analysis results obtained using FF3D are in excellent agreement with those obtained using SAP IV in terms of displacements, periods, and mode shapes for all of six example structures. Floor displacements for example structures A2 and B2 due to the static loading system illustrated in Fig. 7 are shown in Figs. 8 and 9 respectively. When floor deformation is significantly large, such as in the case of B2, slight disagreement between floor displacements predicted by the proposed model and three-dimensional finite element models is observed. Natural periods of structures 2A and 2B are listed in Tables 1 and 2 for the first three modes. Corresponding mode shapes are shown in Figs. 10 and 11. Solid lines in Figs. 8, 9, 10, and 11 represent values from three-dimensional finite element analysis while broken lines are used to plot those from the proposed model.

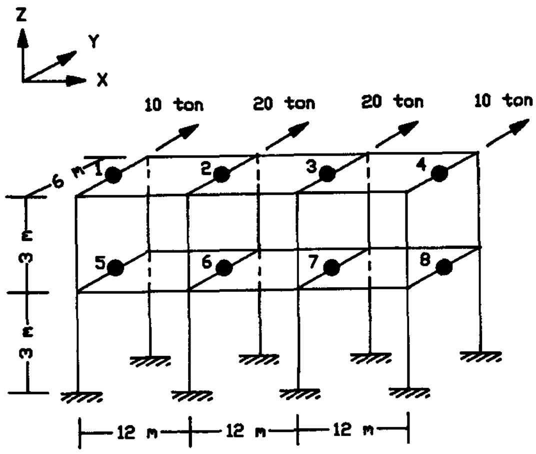


Fig. 7 Loading system used for static analysis

Table 1. Natural period of A2 structure

Mode	Period (sec)	
	FF3D	FEM
1	0.2494	0.2492
2	0.2208	0.2233
3	0.1036	0.1082

Table 2. Natural period of B2 structure

Mode	Period (sec)	
	FF3D	FEM
1	0.1588	0.1586
2	0.0735	0.0735
3	0.0552	0.0523

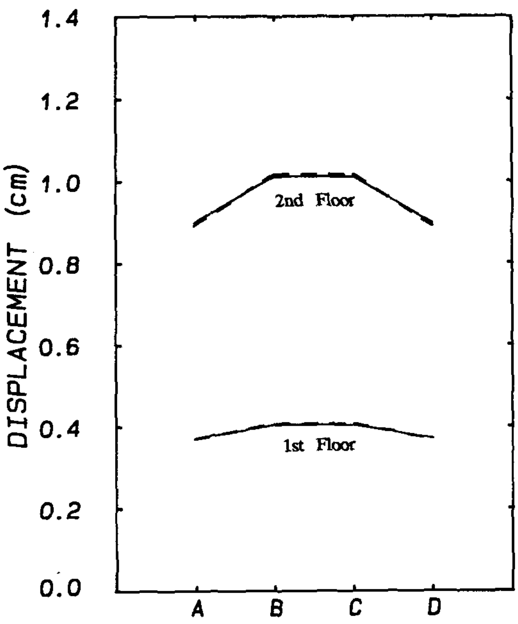


Fig. 8 Floor displacement of A2 structure

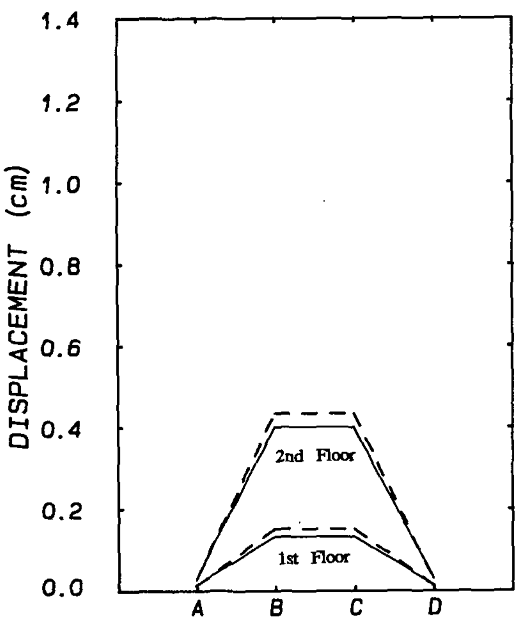
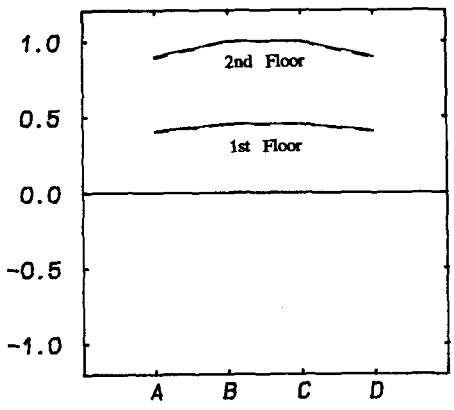
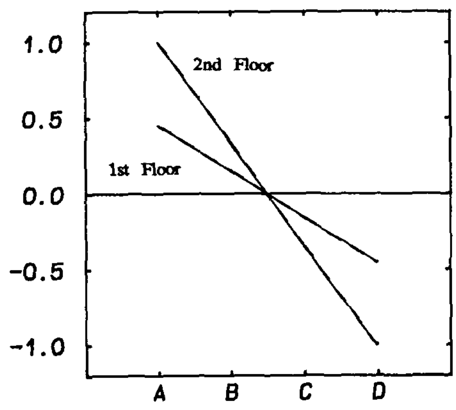


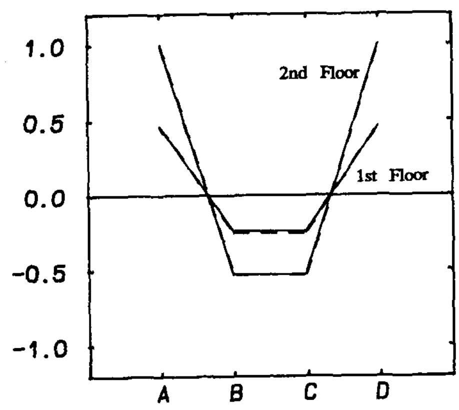
Fig. 9 Floor displacement of B2 structure



a) First mode shape

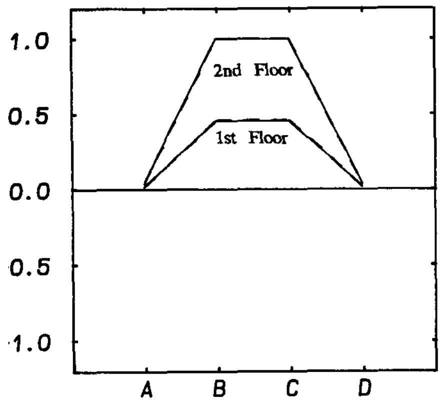


b) Second mode shape

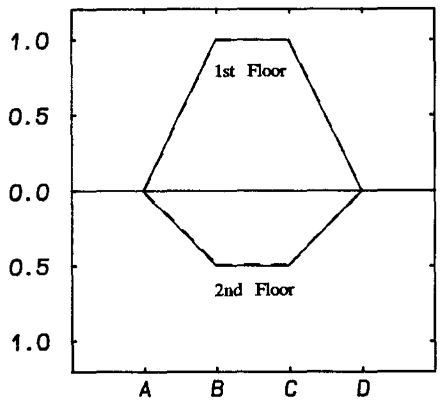


c) Third mode shape

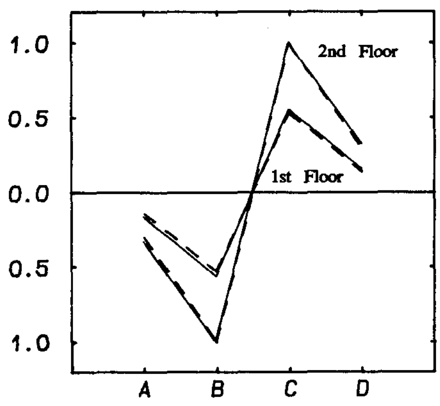
Fig. 10 Mode shapes for A2 structure



a) First mode shape



b) Second mode shape



c) Third mode shape

Fig. 11 Mode shapes for B2 structure

CONCLUSION

Following conclusions are drawn from comparison of analysis results obtained using the proposed model and finite element models for six example structures. of multistory buildings can be performed even on a personal computer.

1. The simplified model proposed in this study can be used as an efficient tool for the approximate analysis of multistory building structures with flexible floor diaphragms.

2. The use of the proposed model is so efficient in terms of computational time and memory size that three-dimensional analysis

3. The use of the proposed model for response spectrum analysis or time history analysis is expected to provide dynamic response prediction with excellent agreement to those by finite element models based on the accuracy of periods and mode shapes.

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