Evaluation and comparing the behavior of concrete horizontal diaphragms in linear behavior of concrete by numerical method

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Abstract: One of the most important assumptions which is being used in analysis and design of buildings against lateral forces is the rigid-floor assumption. Lateral rigidity of diaphragms depends on several factors such as: type of the structure, dimensions of structure, rigidity and location of lateral load bearing elements, stiffness of frames, type and thickness of floors, number of stories and etc. so, we should give more and more importance to this assumption. In this study, in order to investigate how concrete slabs behave, a lot of models in two cases of rigid-floor and flexible-floor in linear limitations are analyzed and compared.
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1. Introduction

Structures with flexible floor systems behave differently under dynamic lateral loading than structures with rigid diaphragms. The rigid floor assumption distributes forces between lateral resistant elements according to the proportion of elements rigidity. In addition, this assumption decreases the degrees of freedom and makes the analysis simpler. Several codes, for instance Iranian code of practice for seismic resistance of buildings (Standard 2800) present some criterions for the diaphragm. According to the mentioned standard, diaphragm is to be considered flexible when the diaphragm deflection exceeds twice the story drift. However, flexible diaphragm systems are still analyzed with criteria and recommendation developed for structure with rigid diaphragms. Variables such as structural system can affect diaphragm behavior and causes rigid diaphragm treatment was not accurate. In this study analysis was performed in a linear mode and for each structures, modeling was performed considering both real rigidity and rigid diaphragm assumption.

2. Model description

A basic plan according to the below figure is provide in order to set up the modeling procedure, having 3m height, 5m width, 6 and 10 m spans. The diaphragm is assumed to be concrete slab.

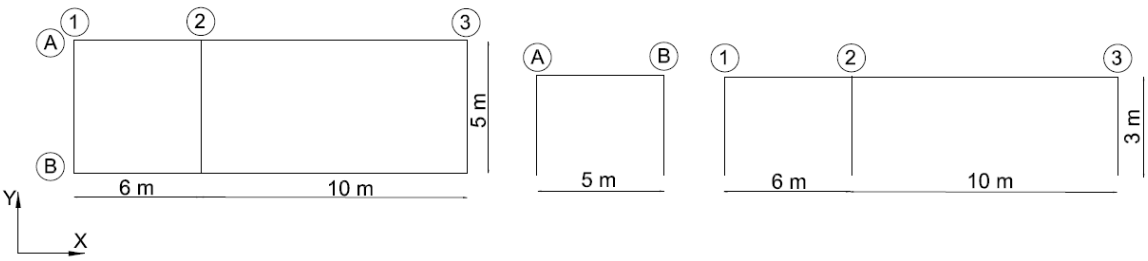


Figure.1. Model description

Loading is performed based on Iranian earthquake code and the analysis type is static. The selected structural systems are concrete structure with shear wall, concrete moment frame, steel braced frame and steel moment frame. The braces and shear walls are in 1, 2, 3 directions and earthquake load is applied in x direction. The numerical modeling is made in SAP2000 for both rigid and flexible cases of diaphragms.

Table.1. Shear wall (SH) modeling characteristics

Mass load (flex))kg(	Mass load (rigid))kg(	Column cm× cm	Beam cm× cm	Shear Wall Thickness)cm(	Diaphragm Thickness (cm)	Variation	Model No
93.3	9514	35×35 8Ø32	25×40	25	5	Slab thickness	SH_1
107.4	10954				10		SH_2
121.5	12394				15		SH_3
149.7	15274				25		SH_4
178	18154				35		SH_5
133.9	13654	35×35 8Ø32	25×40	5	25	Shear wall thickness	SH_6
139.3	14209			10			SH_7
145.8	14869			20			SH_8
153.7	15679			30			SH_9
161.7	16489			40			SH_{10}
144.8	14766	35×35 8Ø32	25×35	25	25	Beam dimensions	SH_{11}
165.1	16839		35×55				SH_{12}
195.4	19927		50×75				SH_{13}

Table.2. Concrete moment (MC) modeling characteristics

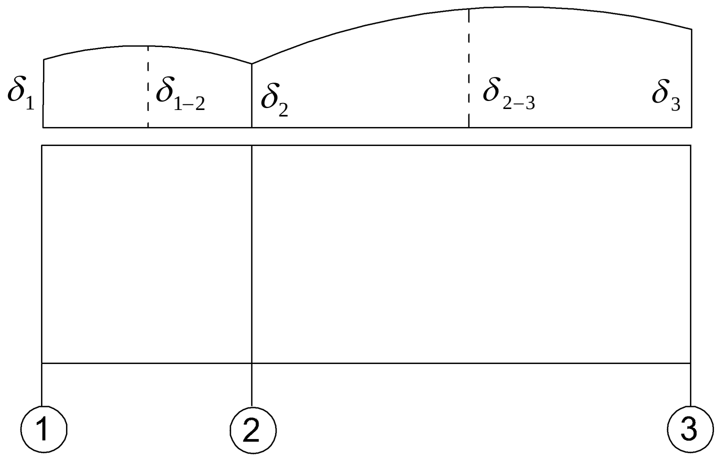
Mass load (flex))kg(	Mass load (rigid))kg(	Column cm× cm	Beam cm× cm	Diaphragm Thickness (cm)	Variation	Model No
69.7	7109	40×40 8Ø30	30×45	5	Slab thickness	MC_1
81.9	8357			10		MC_2
94.2	9605			15		MC_3
118.6	12101			25		MC_4
143.1	14597			35		MC_5
113.6	11588	40×40 8Ø30	25×40	25	Beam dimensions	MC_6
133.7	13641		40×60			MC_7
166.4	16977		55×85			MC_8
116.7	11904	30×30 8Ø24	30×45	25	Column dimensions	MC_9
121.1	12354	50×50 8Ø32				MC_{10}
127.7	13028	70×70 12Ø32				MC_{11}

3. Comparison criterions

Here, some criterions are defined in order to make it possible to compare the results between rigid and flexible modeling results. The parameter δ is chosen as displacement symbol. In fact $\delta_3, \delta_2, \delta_1$ are the displacement for the three direction in the below figure.

$$\delta_\Delta = \left(\delta_2^{'} - \delta_2\right)/\,\delta_2,$$

$$\delta_2^{'} = \left(2\delta_1 + \delta_3\right)/\,3$$



There are also parameters such as Δ_1 , Δ_2 and finally Δ that must be defined here:

$$\Delta_1 = \left(\delta_{1-2} - (\delta_1 + \delta_2\right)/\,2)\,/((\delta_1 + \delta_2)\,/\,2),$$

$$\Delta_2 = \left(\delta_{2-3} - (\delta_2 + \delta_3\right)/\,2)\,/((\delta_2 + \delta_3)\,/\,2),$$

$$\Delta = Max\{\Delta_1, \Delta_2\}$$

4. Illustrative graphs

To completely understand the results for the structures modeling, in this part different graphs according to variation of some variables are plotted.

Table.3. Graphs for SH models

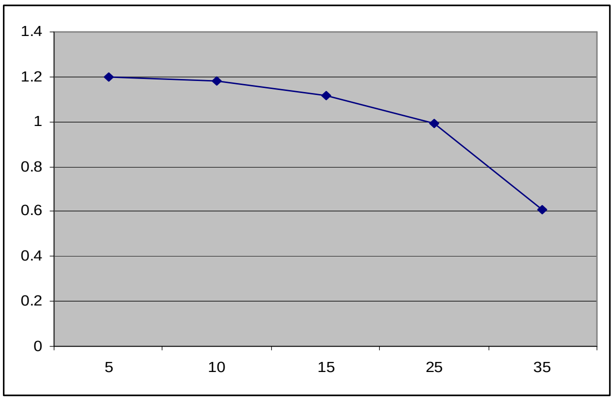
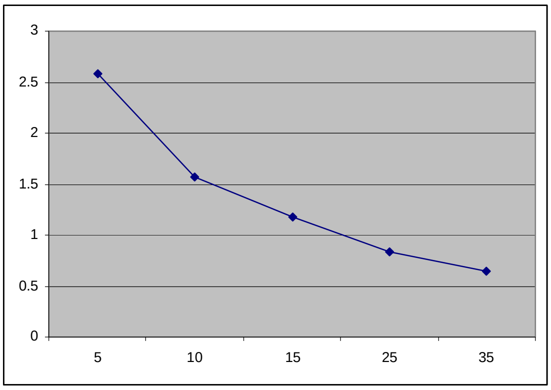
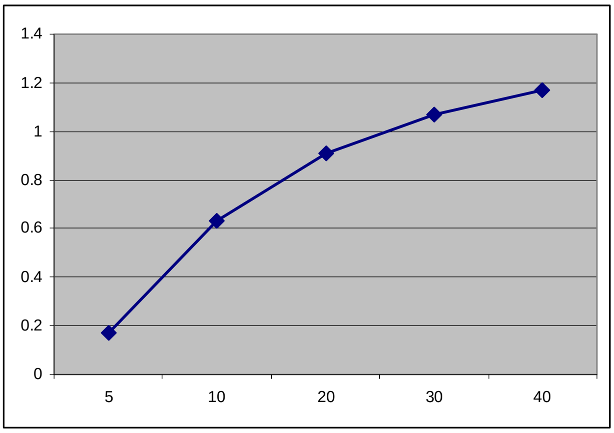
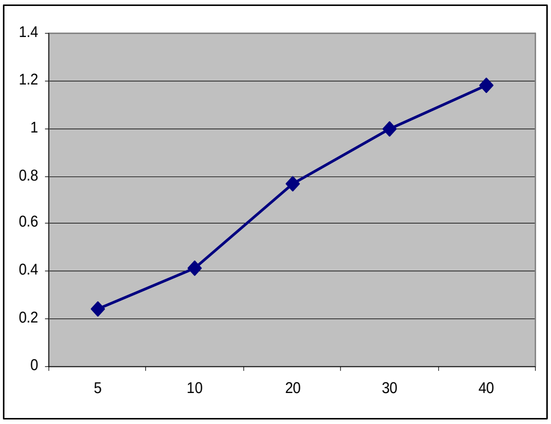
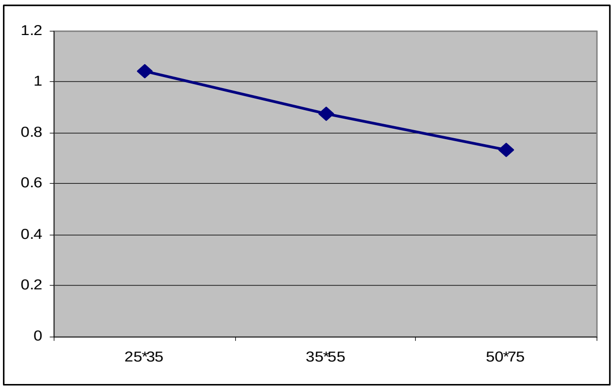
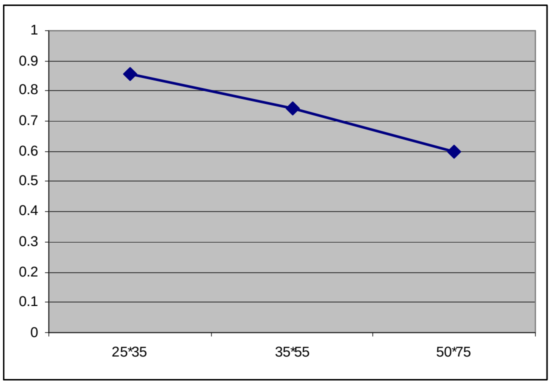
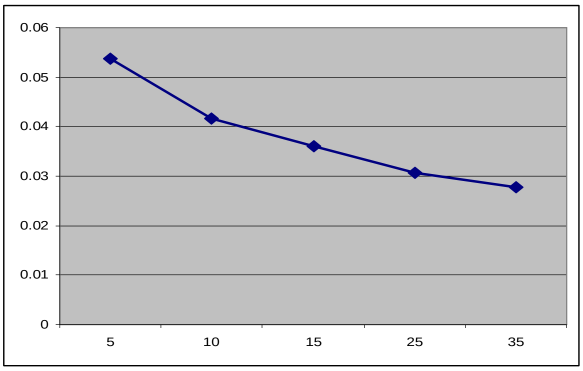
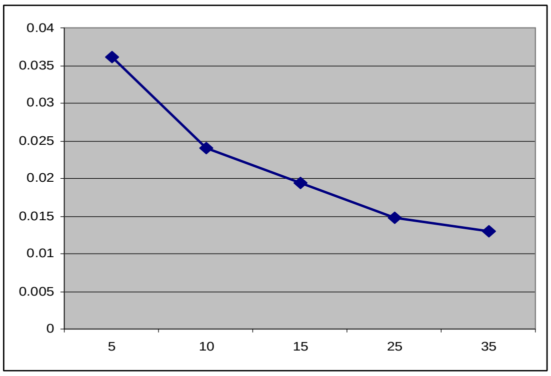
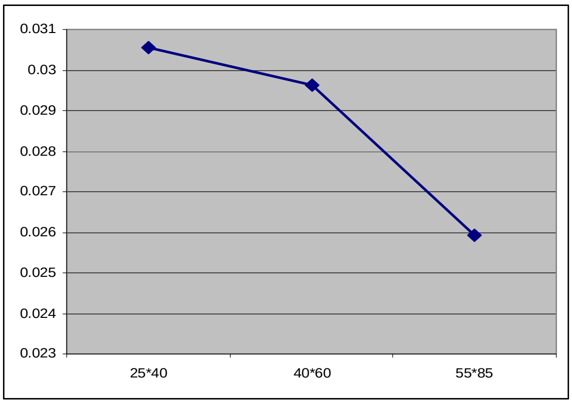
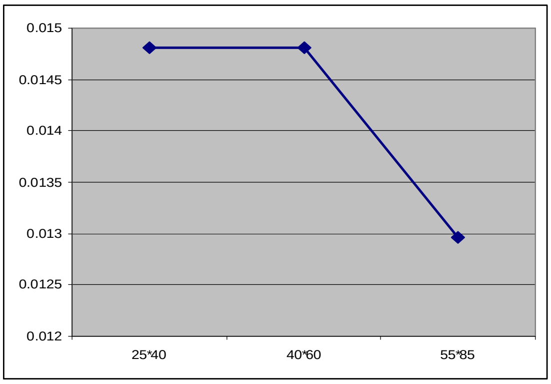
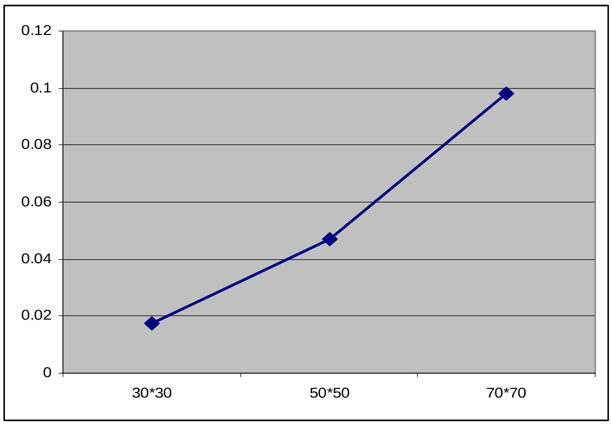
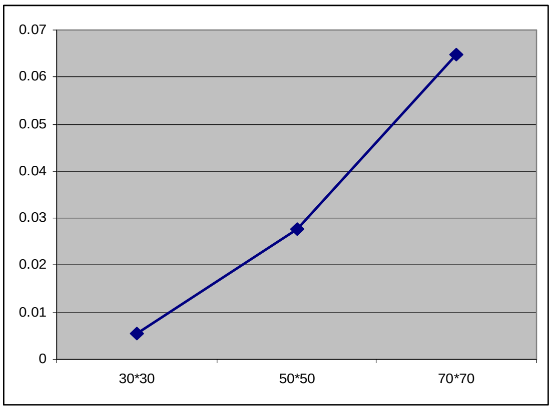
$Displacement - \delta_{\Delta}$	$Displacement - \Delta$
Variation of slab thickness	
	
Variation of shear wall thickness	
	
Variation of beam dimensions	
	

Table.4. Graphs for MC models

$Displacement - \delta_{\Delta}$	$Displacement - \Delta$
Variation of slab thickness	
	
Variation of beam dimensions	
	
Variation of column dimensions	
	

5. Results

Based on the previous graphs for the 4 mentioned structural systems, the results are concluded here.

SH_n (n=1-13) models

According to the results for this part, table.1, $0.24 < \Delta < 2.58$ and $0.16 < \delta_\Delta < 1.19$. The extreme amount for this parameter shows that in this part, the diaphragms are mostly flexible. This could be because of rigid behavior of shear walls in this system.

MC_n (n=1-11) models

Based to the results for this part, table.2, $0.005 < \Delta < 0.064$ and $0.017 < \delta_\Delta < 0.098$. The models for concrete frames demonstrate more rigid diaphragms rather than shear wall models. The reason lies on the fact that slab rigidity is more than columns stiffness.

6. Conclusion

In this paper the effect of structural lateral load bearing systems on rigidity of concrete slabs is investigated. The results show that for a shear wall resisted structure the assumption of a rigid diaphragm is not valid. So designers should consider it as a flexible diaphragm in their designations.

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