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Lateral behaviour of low and middle rise buildings with flat slabs

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Abstract

Lateral behaviour of RC Buildings is a great importance when it is in question the earthquake happening, so in this paper are presented the differences between buildings which have slabs without beams compared with those that in their slabs have included beams. Analysis is done for low and middle rise building, because these buildings are predominant in Kosovo and our region. The reason why we have analysed here the lateral behaviour of such cases is due to the fact that nowadays around us are used so many building using slabs without beams because they represent a flexible solution in functional organizing the internal area in the aspect of architectural requirements. Analysis is done for some typical cases just to present the differences in the aspect of lateral behaviour and important parameters such are: inter-story drifts, top displacements, periods and some other similar parameters when is in question the lateral displacements.

Key words: flat slab, capacity, inter-story drifts, ductility

1 Introduction

A reinforced concrete slab supported directly by concrete columns or shear walls without use of beams, such slab is called flat slab. It elevates more clear space inside of usage areas and construction of this type of slabs is easy and fast in terms of time. This type of slabs offers a variety of advantages for architectural aspects as well for ceiling installation compared to the slabs which have beams connecting to the columns and shear walls. The strength of flat slabs is often limited due to the punching shear action around columns. The performance of building with flat slabs is not so good compared with to frame structures due to the lack of frame action, which in the case of earthquake happening leads to extensive lateral deformation. Usually to decrease the lateral deformation in such structures are used shear walls in particular position and direction.
The objective of this paper is to present the differences of lateral behaviour of building with RC slabs which have beams compared to those which have a flat slab.

2 Analysed cases

Since the objective of this paper is presentation of differences of lateral behavior of low and middle rise buildings which have slabs with beams and flat slabs, in this paper are analyzed two typical structures:
- Case-1 (Four story building-4SB) and
- Case-2 (Ten story building-10SB)

For each case are analyzed two typical situation:
- Structure with columns without additional shear walls (Case-1' & Case-2')
- Structure with columns and with additional shear walls (Case-1" & Case-2")

Also for each above mention situation are performed analysis for three possible variants:
- Structure which have RC slabs with beams in two directions
- Structure which have RC flat slabs and only perimeter beams
- Structures which have only flat slabs without any beams

2.1 Input data

For two typical cases analysis is performed with ETABS software [7]. The geometry of typical floor for typical cases and above mentioned situation are presented below:

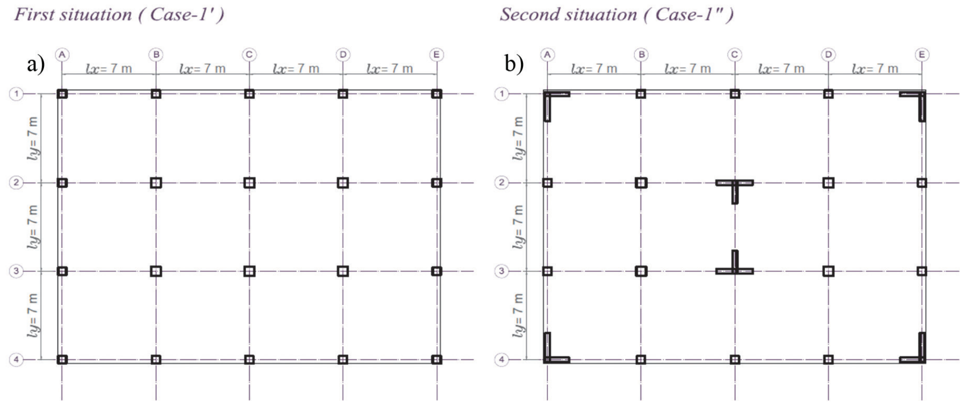

Figure 1. Four story building (4SB). a) Structure without additional shear walls; b) Structure with additional shear walls

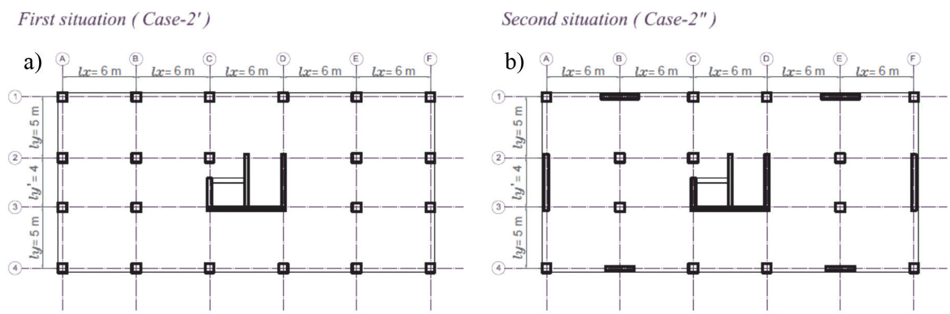

Figure 2. Ten story building (10SB). a) Structure without additional shear walls; b) Structure with additional shear walls

Main data for low rise building (4SB) which can be used as a shopping trade center:

- Concrete class (C30/37)
- Number of story (4) G+3
- Height of each story (3.5m')
- Peak ground acceleration (Ag=0.2g)
- Type-1 of Elastic spectra according of EN 1998-1
- Soil type (B)
- Middle Ductility Class (DCM)

Main data for middle rise building (10SB) which can be used as a residential building:

- Concrete class (C30/37)
- Number of story (10) G+9
- Height of each story (3.0m')
- Peak ground acceleration (Ag=0.2g)
- Type-1 of Elastic spectra according of EN 1998-1
- Soil type (B)
- Middle Ductility Class (DCM).

2.2 Structural analysis performed

Load intensity is based on EN 1991-1-1 [1] for each case taking in consideration their dedication. Dimensions of structural elements are taken based on the capacity demands in order to fulfill requirements form EN 1992-1-1 and EN 1998-1 [2-3]. When we have to deal with flat slabs the thickness is determinate taking in consideration punching effect at columns, limitation for vertical deformation and limitation of cracks.
An important parameter during the structural analysis determining the lateral deformation of each cases for listed situations when we have the earthquake action is behavior factor "q" which is taken based on the information and assumption on Eurocode 8 (EN 1998-1), Spanish seismic code (NCSE-02), Italian seismic code (NTC), Greece (EKOS 2000) and New Zealand (NZS 3101) [4-6]. When there is used a flat slab, Eurocode8 does not cover exactly determination of q factor, value 1.5 is the basic assumption for elastic design.

3 Results

Since the objective of this paper is presentation of differences of lateral behavior of low and middle rise buildings which have slabs with beams and flat slabs, in this paper are analyzed two typical structures:

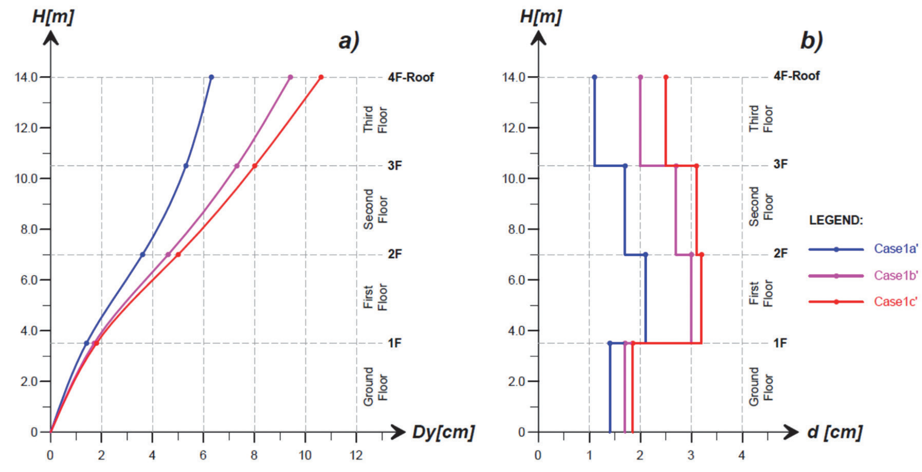

Figure 3. 4SB_Case-1' (without additional shear walls). a) Lateral Deformation; b) Story Drifts

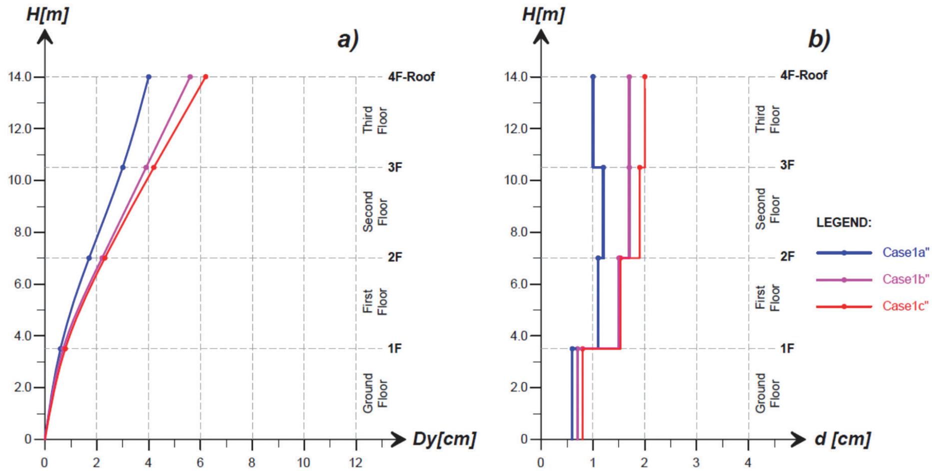

Figure 4. 4SB_Case-1" (with additional shear walls). a) Lateral Deformation; b) Story Drifts

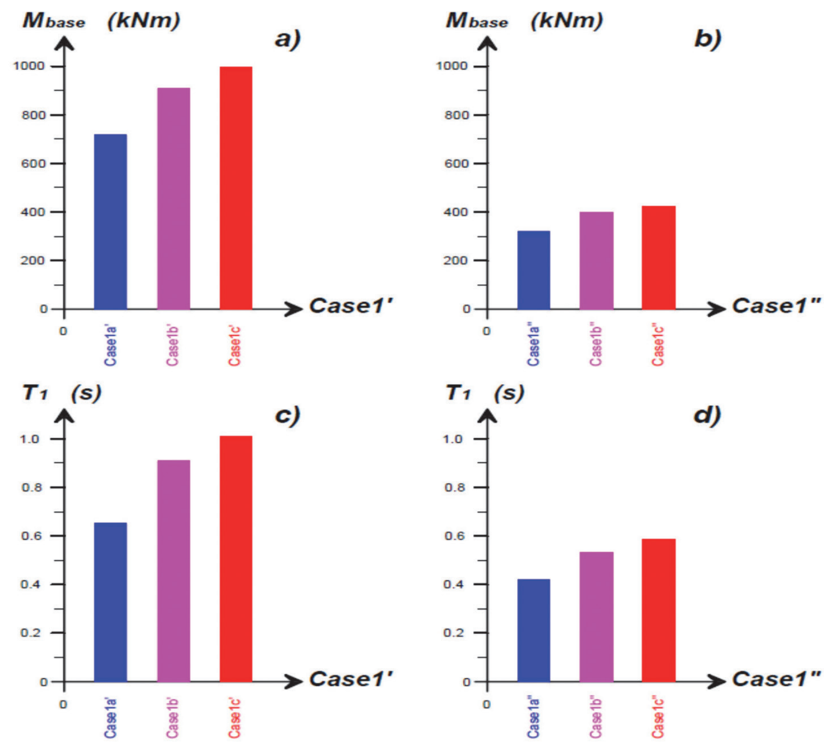

Figure 5. 4SB_Case 1' and Case-1". a) & b) Bending moment at critical column at base for two situations and three analysed cases; c) & d) Fundamental Period (T1) for two situations and three analysed cases

Table 1. Lateral deformations and some of the main characteristics regarding lateral behavior from the analysis performed at 4SB

Case-No.1 4 Story Building (4SB)	Case No-1' (Without Additional Shear Walls)			Case No-1" (With Additional Shear Walls)		
Case-No	Case-1a'	Case-1b'	Case-1c'	Case-1a"	Case-1b"	Case-1c"
T1(s)	0.65	0.92	1.07	0.42	0.54	0.59
Mbase(kNm)	720	895	982	325	391	429
F4-Dy(mm)	6.3	9.4	10.6	4.0	5.6	6.2
F3-Dy(mm)	5.3	7.3	8.1	3.0	3.9	4.2
F2-Dy(mm)	3.6	4.6	5.0	1.7	2.2	2.3
F1-Dy(mm)	1.4	1.7	1.8	0.6	0.7	0.8

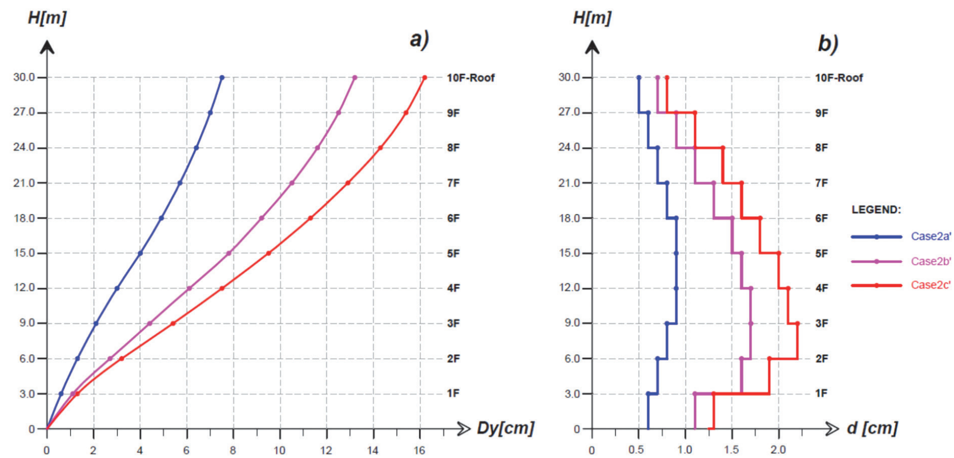

Figure 6. 10SB_Case-1' (without additional shear walls). a) Lateral Deformation; b) Story Drifts

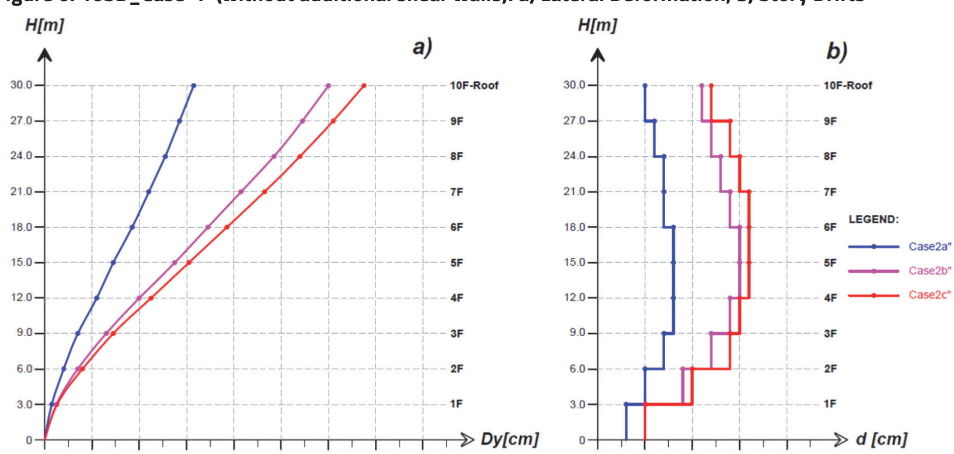

Figure 7. 10SB_Case-1" (with additional shear walls). a) Lateral Deformation; b) Story Drifts

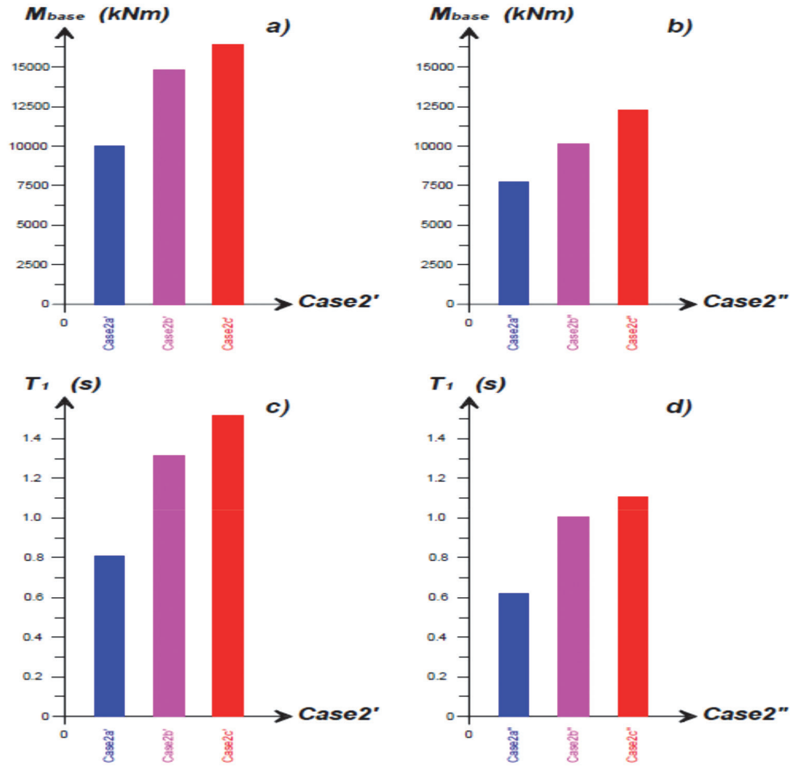

Figure 8. 10SB_Case 2' and Case-2". a) & b) Central shear wall bending moment at base for two situations and three analysed cases; c) & d) Fundamental Period (T1) for two situations and three analysed cases

Table 2. Lateral deformations and some of the main characteristics regarding lateral behaviour from the analysis performed at 10SB

Case-No.2 10 Story Building (10SB)	Case No-2' (Without Additional Shear Walls)			Case No-2" (With Additional Shear Walls)		
Case-No	Case-2a'	Case-2b'	Case-2c'	Case-2a"	Case-2b"	Case-2c"
T1(s)	0.82	1.35	1.55	0.62	1.0	1.1
Mbase(kNm)	9600	14500	16700	7700	10300	12100
F10-Dy(cm)	7.5	13.2	16.2	6.3	12.0	13.5
F9-Dy(cm)	7.0	12.5	15.4	5.7	10.9	12.2
F8-Dy(cm)	6.4	11.6	14.3	5.1	9.7	10.8
F7-Dy(cm)	5.7	10.5	12.9	4.4	8.3	9.3
F6-Dy(cm)	4.9	9.2	11.3	3.7	6.9	7.7
F5-Dy(cm)	4.0	7.8	9.5	2.9	5.5	6.1
F4-Dy(cm)	3.0	6.1	7.5	2.2	4.0	4.5
F3-Dy(cm)	2.1	4.4	5.4	1.4	2.6	2.9
F2-Dy(cm)	1.3	2.7	3.2	0.8	1.4	1.6
F1-Dy(cm)	0.6	1.1	1.3	0.3	0.5	0.5

4 Conclusions

In this paper is elaborated lateral deformation of the analyzed cases in terms of Top Displacements, Story Drifts, Bending Moment at Base and Fundamental Period.

Regarding the Lateral Deformation the Top Displacement is the most representable parameter and its value is increased considerably in the buildings which have flat slabs compared with those who have beams and this difference is decreased significantly when there are includes some additional shear walls. This difference is appeared in terms of Inter-story Drifts as well.

Fundamental Period and Bending Moment at Base for critical columns and shear walls is increased for the cases when the presence of beams is not present in the RC slabs.

Using the flat slabs at RC buildings should be done with a great care, because the Inter-story Drifts and Top Displacement can cause considerable damages in the infill masonry partitions and sensitive facade elements. Also when are used the flat slabs in the buildings should be intended to add some shear walls in particular position in order to decrease the values for above mentioned parameters.

Based on the presented results and taking in the consideration that the lateral deformation are the most representative parameters for seismic performance of buildings at actual design seismic codes, it should be avoided using flat slabs at buildings in high seismic regions, especially in middle and high rise buildings and should be keep in mind that in case when the flat slabs are used it is needed to add some shear walls in order to fulfill the requirements in term of lateral displacements.

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