Effects of Soft storey Irregularity on RC building Response

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ABSTRACT

Albanian building stock is composed of reinforced concrete and masonry buildings. Most of these buildings are designed with Old Albanian Codes (KTP Codes) and some of them are constructed without any project. Considering these facts and the observations done in Albanian construction industry, presence of structural irregularities is very common in these buildings. Irregularities are weak points in the building which may cause fail of one element or total collapse of the building during an earthquake. Irregularities encountered in Albanian construction practice consist of short column, large and heavy overhangs, reinforcement details and soft story irregularity. Since Albania is a high seismic country which has been hit many times from earthquakes of different magnitudes establishes the need to study the effect of irregularities. Among all these irregularities in this study is taken in consideration the soft story effect under seismic loads in low and mid-rise buildings of Albanian construction practice. In order to get the effect of soft story irregularity in RC buildings several number of Nonlinear Static (Pushover) Analyses are done for regular frames, frames with soft story because of higher height and lack of masonry infill walls in ground story or because of the presence of both cases for the two types of structures, 3 and 6-story frames representing low and mid-rise buildings respectively. The analysis has been performed by ETABS software. The results of the analyses indicate that low and mid-rise structures with soft story irregularity due to absence of infill walls and higher height of ground story are more vulnerable during earthquakes.

Keywords: *Low and Mid-Rise RC buildings, Soft Story, Nonlinear Static Pushover Analysis.*

INTRODUCTION

The inadequate performance and the huge number of collapsed buildings during past earthquakes because of diverse structural irregularities determines the idea to analyse the buildings with dissimilar irregularities in order to understand the effect of them in RC buildings under the seismic effect. Different researchers [1, 2] have studied altered vertical and horizontal irregularities with different methods of analysis such: nonlinear static (pushover) analysis, dynamic analysis and time history analysis, etc. and realized which type of them are more risky during an earthquake and what should be taken in consideration from the designers during the design process. This study aims to get the seismic performance of low and mid-rise frames, which are more vulnerable during earthquake, with soft stories by using nonlinear static analysis. Soft story irregularity is one of the main irregularities affecting the damages of the buildings during an earthquake, it has also been studied from different researchers. [1, 3] Soft story irregularity in most of the cases occurs because of the lower stiffness of first story of the buildings which may be originated as a result of non-uniform distribution of masonry infill walls or because of the higher height of one story compared to the other ones which in most of the cases is done for commercial reasons. In this study both cases are taken into consideration, lack of infill walls and higher story height, for low and mid-rise buildings. The considered cases will be studied separately and composed, firstly the masonry infill walls will be removed from the first story, and then story height will be 4.5m instead of 3m normal height. Capacity curves of the considered cases are obtained by using nonlinear static analysis, which are performed by using ETABS software. Frame elements, beams and columns are modelled as nonlinear elements with lumped plasticity by defining plastic hinges at both ends of them. Masonry infill walls are modelled as diagonal strut, with specifications from FEMA-356. [4] Effect of soft story in low and mid-rise RC buildings is evaluated in observation of capacity curves which are very beneficial to understand its effect during earthquakes.

AIM AND SCOPE

This study aims to assess the seismic performance of the major portion of low and mid-rise building stock in Albanian construction practice. Seismic performance of the selected buildings is done by considering reinforced concrete elements and as well as masonry infill walls. Selected buildings are modified to have the structural deficiency like soft story, created because of non-uniform distribution of masonry infill walls and because of higher story height compared to the other ones or because of both of them, even though soft story may also arise as a result of changes in load carrying and slab system, observed in damaged buildings during the last earthquakes in Albania and worldwide. The most frequent reason of soft story creation is the abrupt change of masonry infill walls between different stories since infill walls are not considered as part of load carrying system, so they are considered in the structural behaviour of the frame. For this reason, most of the civil engineers don not give attention to the creation of soft story because of infill walls. In order to increase the level of knowledge and achieve the aim of this study a 3 and 6-story reinforced concrete buildings are selected to represent the reference low and mid-rise buildings. The certain buildings are typical RC frame buildings with no shear walls in which the irregularities will be implemented.

BUILDING MODELS

The selected 3 and 6-story frame buildings are regular 20m by 16 m in plan as shown in Figure 1 below. They have 5 bays by 4m along X direction and 4 bays by 4m along Y direction (Figure 1). Typical floor height is 3m. The location of masonry infill walls in plan is shown by the hatch of beams (Figure 1). The selected buildings have the plan view as shown in Figure 1:

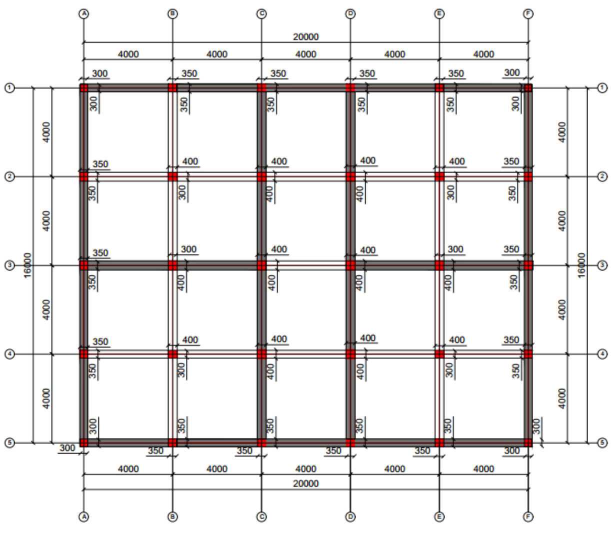

Figure 1 Structural Plan view of 3, 6-Story frame (units in mm)

Beam and column dimensions of the reference buildings represent the most common frame elements for low and mid-rise frames in Albanian construction practice. The 3-story frame consists of 300mm x 300mm corner columns and 350mm x 350mm outside columns, identified as C1 and C2 respectively, 300mm x 400mm, 400mm x 300mm and 400mm x 400 mm inside columns, identified as C5,C4 and C3 respectively, as shown in Figure 2. Beams have all the same section for the 3- story frame which consists of 300mm x 400 mm, Figure 4. The 6-story consists of 400mm x 400 mm corner columns and 500mm x 500 mm outside columns, identified as C3 and C6 respectively, and 600mm x 600mm, 500mm x 400mm and 400mm x 500 mm inside columns, identified as C7, C8 and C9 respectively, as shown in Figure 3 and the beams have all the same section 300mm x 400 mm, Figure 4.

Material properties are based on most common materials used in Albanian construction practice; it is assumed 20 MPa for the concrete compressive strength and 355 MPa for the yield strength of reinforcement. Then in order to get the effect of soft story structural irregularity in reinforced concrete structures the selected buildings are modified to have above-mentioned structural deficiency, soft story. The cases which will be analysed are:

1- Reference regular building, infilled frame, (Ref), Figure 5a
2- Reference regular building without masonry infill walls, bare frame, (RefWW), Figure 5c
3- Soft story due to increased ground story height (3 m to 4.5 m) (SSH), Figure 5e
4- Soft story due to absence of walls at ground story (SSW), Figure 5b
5- Soft story due to increased height and absence of walls at ground story (SS-H-W), Figure 5d

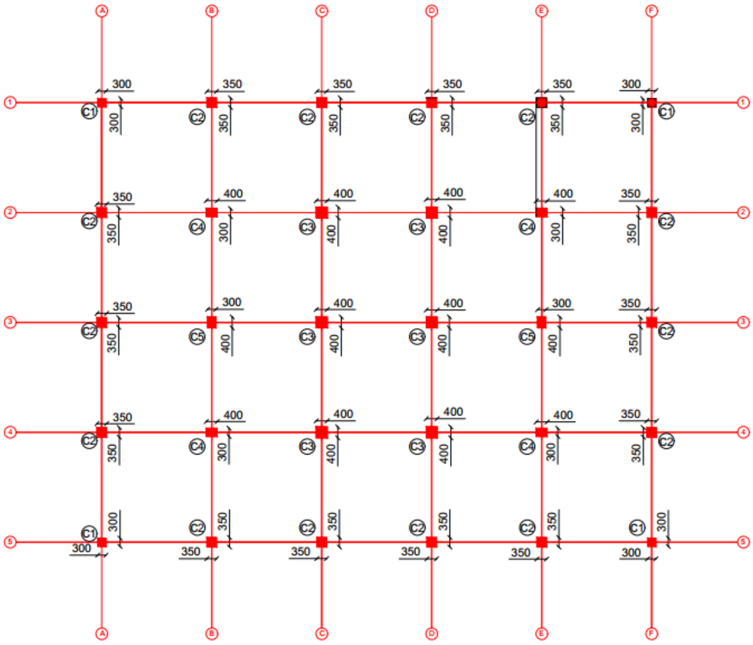

Figure 2 Column plan view of 3 Story frame (units in mm).

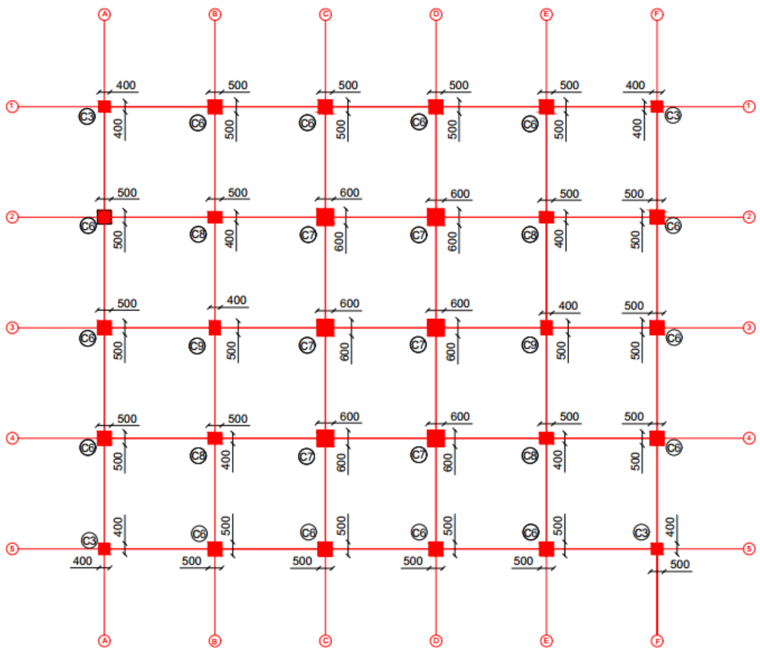

Figure 3 Column plan view of 6 Story frame (units in mm)

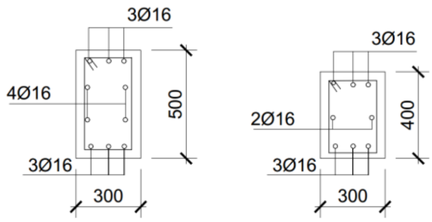

Figure 4 Beam Sections (units in mm)

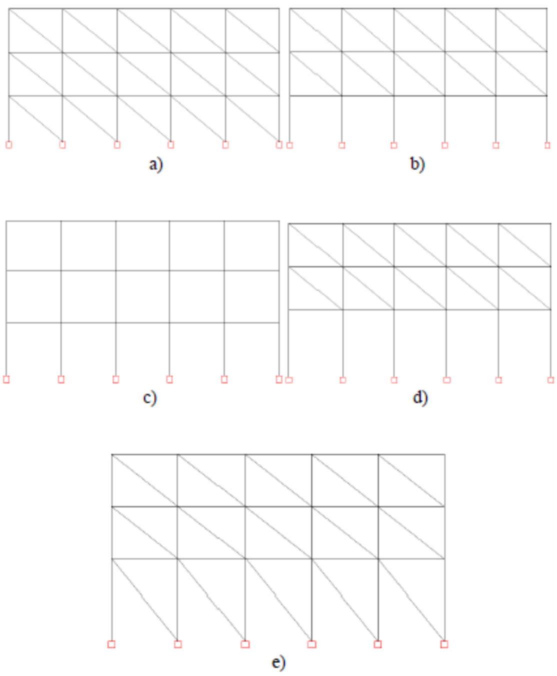

Figure 5 : Elevation view of building models a) Ref, b) SSW, c) RefWW, d) SS-H-W, e) SS-H

PUSHOVER ANALYSIS

Nonlinear static pushover analysis is a type of analysis which is performed by subjecting a monotonically increasing pattern of lateral loads in the structure which represents the forces that the structure may experience during an earthquake. Under incrementally increasing loads various structural elements may yield sequentially. Consequently, at each
event, the structure experiences a loss in stiffness. Using a pushover analysis, a characteristic non-linear force displacement relationship can be determined. Guidelines like FEMA 356 have mentioned the modelling procedures, acceptance criteria and analysis procedures for the pushover analysis. (FEMA, 2000) This code defines the force-deformation criteria for possible locations of lumped inelastic behaviour defined as plastic hinges in the pushover analysis. In figure 6 is shown the plastic hinge force-deformation behaviour by using five points labelled as A, B, C, D, and E and three point's labelled IO (Immediate Occupancy), LS (Life Safety) and CP (Collapse Prevention) are used to define the acceptance criteria for the hinge.

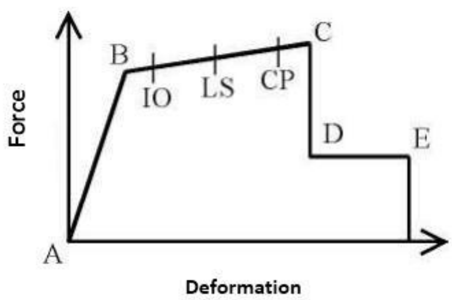

Figure 6 Pushover Curve (FEMA, 2000)

The values assigned to each of these points vary depending on the type of member as well as many other parameters, such as the expected type of failure, the level of stresses with respect to the strength, or code compliance.

ANALYSIS RESULTS

Pushover analysis has been conducted for the 10 building models. The material nonlinearities are assigned as hinges; M3 flexural hinges for beams and PM2M3 flexural hinges for columns. Infill panels are modelled by one nonlinear strut elements, which only has compressive strength. Then each lateral load pattern is applied and static pushover analyses results of the case study buildings are generated. Behaviour of the structure is represented by capacity curves that represents the base shear force and displacement of the roof. Figures 7-10 illustrates capacity curves obtained from the pushover analysis of the 3 and 6-story frames. In x-axis is shown the roof drift ratio that is roof displacement normalized by the building height and in y-axis is shown the shear strength coefficient that is the base shear force normalized by the seismic weight.

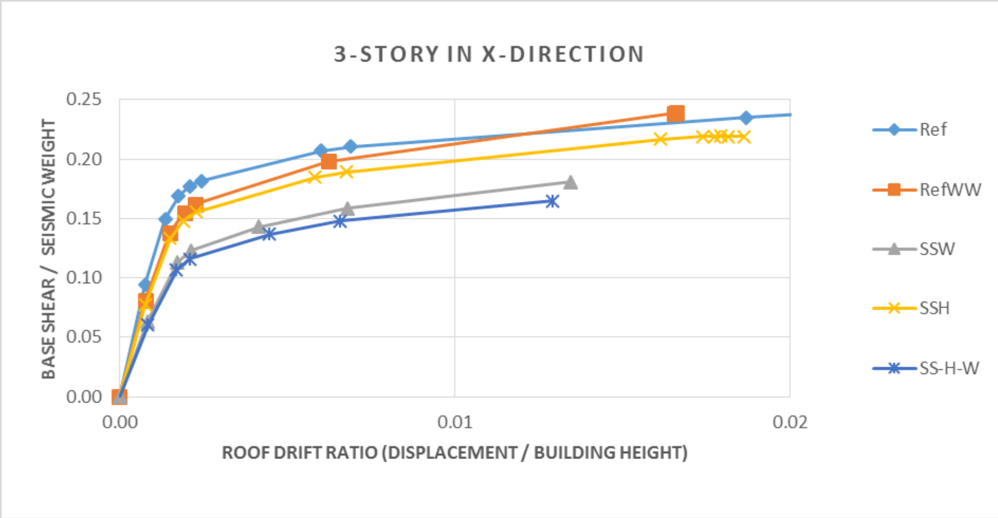

Figure 7 Capacity Curve of 3- story Frame, X-direction

Figure 8 Capacity Curve of 3- story Frame, Y-direction

From the normalized graphs (see Figures 7-10) is showed that presence of masonry infill walls for both frames increases both stiffness and strength of the frames. Infilled (Ref) frame has shown approximately a stiffness of 1.4 and strength of 1.2 that of bare frame for the 3 story case and a 1.2 strength and 1.3 stiffness of the bare frame for the 6 story case.
From the normalized graphs, presence of soft story irregularity effects the seismic performance of the frame, it both weakens and softens the system as shown in Figures (7- 10) below. Soft story due to absence of masonry infill walls at the ground story is found to be more damaging than the soft story due to greater height of the ground story in both cases low and mid-rise buildings, 3-and 6-story respectively. Soft story due to absence of infill has shown approximately 1.2 lower strength than soft story due to higher story height and 1.4 lower strength than the Ref building.

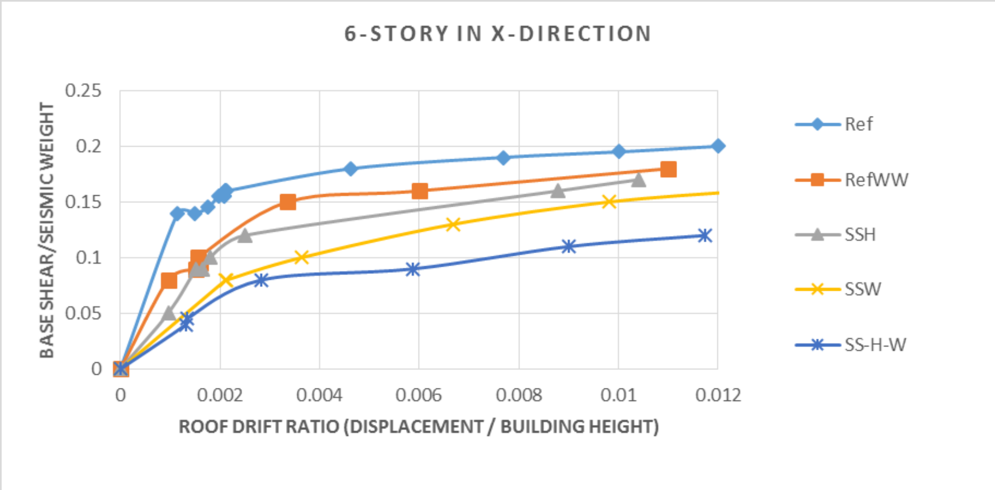

Figure 9 Capacity Curve of 6- story Frame, X-direction

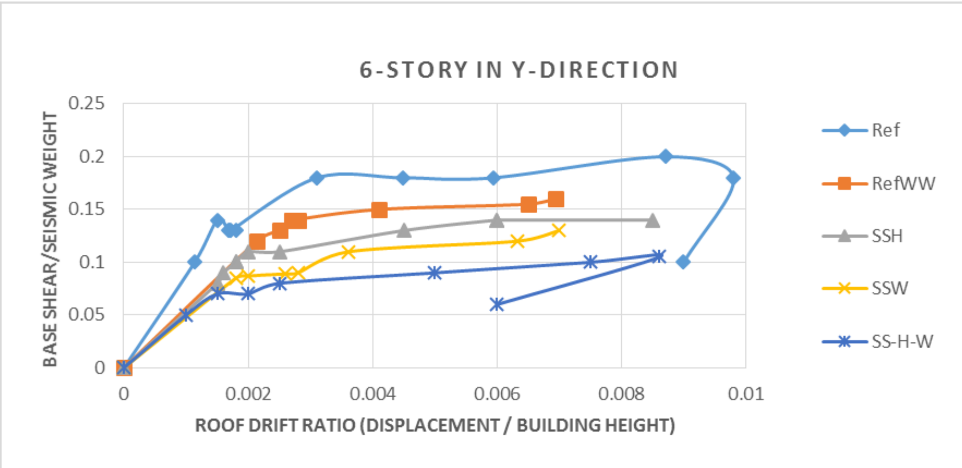

Figure 10. Capacity Curve of 6- story Frame, Y-direction

But the most unfavourable case is soft story due to both absence of infill walls and higher height of the ground story. The capacity curve of 6-story SS-H-W building has shown approximately 1.7 lower strength and 1.2 lower stiffness than Ref building, and capacity curve of 3 story SS-H-W building has shown 1.6 lower strength and 1.9 lower stiffness than capacity curve of Ref building.
The drift ratios obtained in this study (see Figure 7-10) obviously show that the demands of 3-story buildings are higher than those of 6-story ones.

CONCLUSION

This study assesses the seismic performance of bare and masonry-in filled RC frames, frames with soft story due to absence of masonry infill walls and higher height of the ground story considering the cases separately and composed for the two types of structures low and mid-rise buildings.
Results of pushover analysis show an increase in initial stiffness, strength, and energy dissipation of the infilled frame (Ref), compared to the bare frame (RefWW), despite the wall's brittle failure modes.
Presence of soft story irregularity effects the seismic performance of the frame, it both weakens

and softens the system.
Soft story due to absence of masonry infill walls (SSW) at the ground story is found to be more destructive than the soft story due to greater height (SSH) of the story in both cases low and mid-rise buildings, 3-and 6-story respectively.
The most unfavourable case is soft story due to both absence of infill walls and higher height of the ground story (SS-W-H).
Drift ratios shown in capacity curves Figures 7-10, visibly show that the demands of 3-story buildings are higher than those of 6-story.

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