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Effect of Floor Slabs on The Seismic Performance of Reinforced Concrete Frames Using Push Over Analsyis

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Abstract

The main objective of this research was to identify the effect floor slab on buildings seismic performance. The behavior of the slab and on how it contributes to the lateral strength is very significant for the analysis and design of reinforced concrete structures; this paper deals with the study focused on the effect of slabs at the joints in moment-frame structures subjected to large seismic deformations. Two interior beam-column subassemblies, one without a slab and one having floor slabs with varied slab parameters, were modelled. The methodology adopted in this paper was to have a strong column and weak beam concept. This methodology was used to assure that yielding point will occur only in the beams and the joint and the column will behave in an elastic manner. This same model was created in ABAQUS and ETABS 2016. For the frames model push over analysis was carried out using IS standard codes of practice.

Keywords *— IS codes, seismic, frames, joints, slabs*

INTRODUCTION

In a reinforced concrete construction beam column joints play a very important part when the building or structural component is subjected to a series of lateral forces known as seismic forces. The analysis and the design of such members are very difficult because the behavior of beam-column connections present in the frame are not predictable as before and it is very multifaceted. Huge amount of experimental investigations have been carried out for the past years and new innovations are also immerging the present area of research.

In practical applications, the construction of slab is done slab as a monolithically casted one having floor beams and the load from the slab is transmitted to the beam and then itacts togetherwith the other structural components. During seismic loading conditions the RC frames should be able to withstand and perform satisfactorily under severe load condition. Therefore, it is necessary to do detail analysis of cast in situ slabs subjected to seismic analysis.

LITERATURE SURVEY

(Agarwal P et al 2017) in their paper explained the recent method of analysis of structures using ground motion techniques, its analysis, design and damages occurring in the seismic resistant deign of structures.

(GaochuangCai&Qiwang Su 2017) studied the seismic performances of a bare 3 RC frame infilled using different lightweight materials subjected to cyclic loads. Some of the lightweight materials used were hollow bricks, gypsum blocks, and autoclaved lightweight concrete panels. The frames were subjected to lateral forces and its resisting capacity, stiffness, wall damage, ductility, and energy dissipation capacity of the frames were tested. Based on the experimental the paper discusses the ideal infill materials for RC frame structures and skeleton curve of the frames.

Wang- Xi Zhang et al (2017), to analyze a RC frame subjected to seismic loadings with and without slabs with different multiple parameter of analysis were carried out. The results of the two models were taken and were compared for various compression ratio and moment magnifying factors of column. It was finally concluded that when the slab is considered the performance of the structures gets degraded as the axial compression ratio gets increased when compared to with the structure without considering the slab.
Filipe L. A et al (2017), investigated the analysis of finite plastic hinges models by constructing those models and concluded the advantages over the concentrated plasticity hinge (CPH) models. In this paper a calibration procedure for finite plastic hinges models were formed and an algorithm was created and was compared and the results were discussed in a

detailed manner and were found to be better than the CPH model.

Yohei Endoet al (2017), presented the analysis for different nonlinear analysis of structures subjected to masonry structures, the results were mainly based on the lateral force distribution in the masonry structures using push over. The types of analysis carried out were pushover analyses with invariant lateral force distributions, adaptive pushover analysis and nonlinear dynamic analysis. Two base papers were used for carrying out the research work, i.e., a four-wall masonry building prototype without floor rigid diaphragms and a two-wall system with a cross-vault were used for carrying out the analysis. The results obtained from the analysis was very useful and showed more benefits in the analysis and design of masonry structures.

ChangaiZhai et al (2016) investigated the behavior of masonry infilled RC frames with/without openings which were subjected to seismic forces. For this investigation four masonry single frame single bay infill frames were constructed and were tested under constant vertical loads and quasi-static cyclic lateral loads. The output of the experimental work was concluded by saying that the infill wall was perfect enough to withstand lateral load. At the end, finite element models were created to verify the tested specimens, which effectively predicted that the load-displacement response of the structures, crack damage of masonry infill wall with acceptable accuracy.

Ning Ning et al (2017), in order to study the behavior and failure pattern of RC frame walls subjected to seismic loading a finite element model of RC frames with infill walls, half infill walls and no infill walls were created and the effective width of cast in situ slab, column moment, ratio of column beam strength were all analyzed and tabulated using Abaqus software.When frames were analyzed using infill walls the result obtained shows a decreasein the column beam ratio and effective width of slab. The actual effective width of the slab should be considered in the required ratio of column to beam strength.

Umarani Gunasekaran & Saddam M. Ahmed (2014),an experimental investigation for analysis of a bema column assembly was carried out by testing four half-scale joint models: considering with and without slab present in the structure. The joint present in between the beam, column and slab were tested by using static and cyclic loading conditions and the storey drift was calculated with the help strain gauges. It was finally concluded that if the effective slab with was larger than that which was usually used in the construction site, then it will result in large shear in both the joints of the beam and the column, which in turn results in premature shear failures.

BEHAVIOR OF STRUCTURE UNDER SEISMIC FORCES

The ICC PC defines performance-based design as “An engineering approach to design elements of a building based on agreed upon performance goals and objectives, engineering analysis and quantitative assessment of alternatives against the design goals and objectives using accepted engineering tools, methodologies and performance criteria.”

NON LINEAR PUSH OVER ANALYSIS

A framed structure is nothing but a combination of different structural elements each of which has its own properties, such as damping, inertia forces and restoring forces which can be analyzed separately by using linear or static method of by linear methods. During an earthquake all the three forces are getting triggered which makes the analysis difficult. Whenever, these forces active together we have dynamic response in the structure and name it as non linear analysis of structures with the response parameters, namely displacement, velocity, and acceleration. This can be solved with the help of different set of non-linear differential equations with the help of stiffness method of analysis.The stiffness non-linearity method comprisesof two types of analysis explicitly the geometric non-linearity and the material non-linearity.

The pushover analysis is a type of static non-linear analysis which can be performed for stablegravity loads and steadily rising lateral loads. The analysis is accepteduntil failure takes place in the structure, thus it enables determination of collapse load and ductility capacity. Therefore in the building frame plastic hinges are formed and its rotation capacity is monitored. An analytical model is created and lateral inelastic forces along with the displacement response for the entire structure. This type of analysisdetermine the fault in the structure which can be identified and retrofitting technique can be done for strengthening it. The sequence of yielding, plastic hinge formation and failure of various structural components are noted and the total force is plotted against displacement to define a capacity curve which is given as below in Figure 1. The nonlinear procedures of FEMA require definition of the nonlinear load-deformation relation. Such a curve is given in Figure 2.

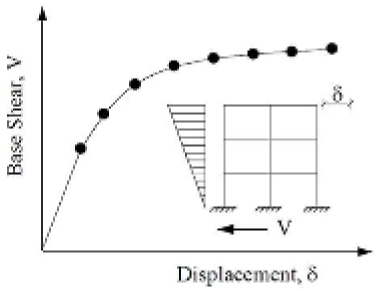

Figure 1. Capacity curve

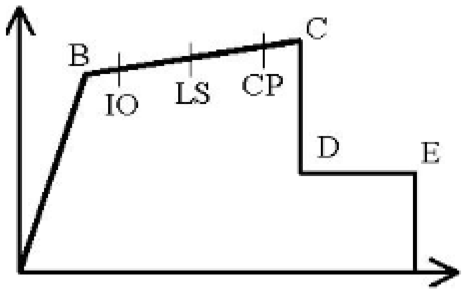

Figure 2. Typical load – deformation relation

Figure 2 explains about the typical load deformation relation which is used during seismic analysis of structures. In this Figure 2Point A corresponds to a point which the unloaded in nature. The next point refers to the yielding point of steel. The value of BC varies from 0 to 10%. IO in the graph represents the immediate occupancy level, LS is the life safety level and CP is the collapse prevention level. The next point C refers to the nominal strength equal to the resistance load. The next line CD refers to the initial failure point of the structural element. The failure point deals with the mechanism such fracture mechanism due to bending reinforcement, shear failure which is followed by initial yield. The line DE represents the residual strength of the member. The next point E corresponds to the deformation limit of the structure. E is a point having a value equal to the deformation as shown in Pont C and zero resistance.

The five points as shown in Figure from A to E are used to describe the rotation capacity of the hinge and its behaviour of RC members according to FEMA recommendations. From A to B there won't be any hinge formation, from B to C we have the hinge formation and it will be rotating fill till failure and after that the structure stats collapsing at point E.

Description of the framed model

The frame which is to be modeled in ETABS and Abaqus software are of the following dimensions.

f_{ck} = 25N/mm^2.

f_y = 500N/mm^2.

Spacing of frame = 3.5m

Height of portal frame = 6m

Bearing capacity of soil = 200kN/m^2.

Type of Seismic analysis = Push over analysis

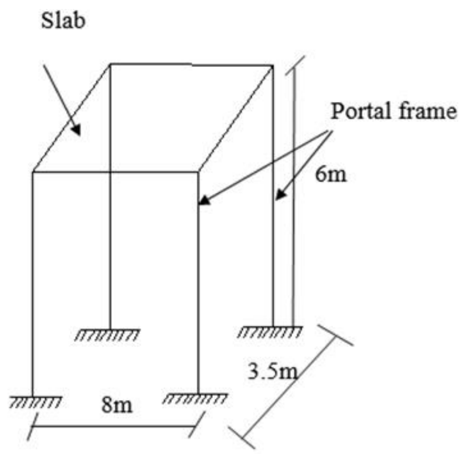

Figure 3. Frame model

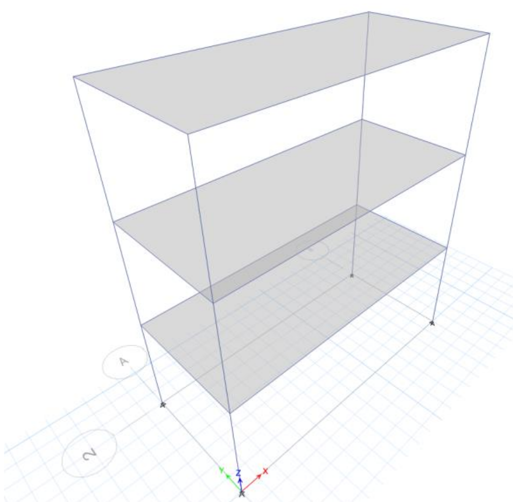

Figure 4. Framed model in ETABS with Slab

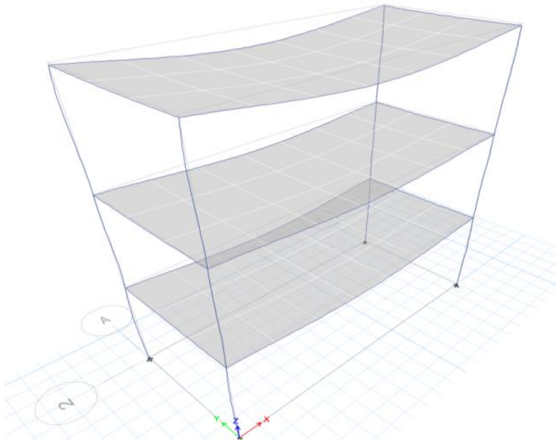

Figure 5. Deformed shape of the frame

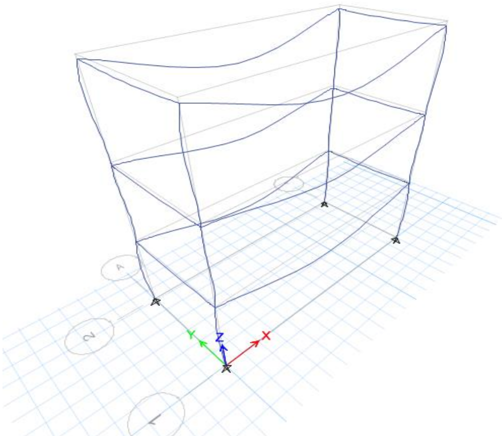

Figure 6. Moment values of the frame with slab without slab

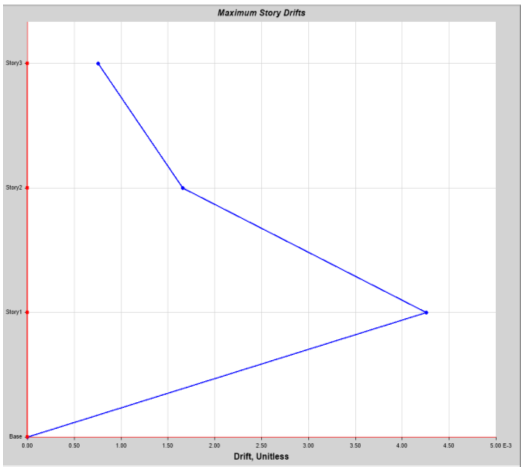

Figure 7. Maximum Storey drift of the frame

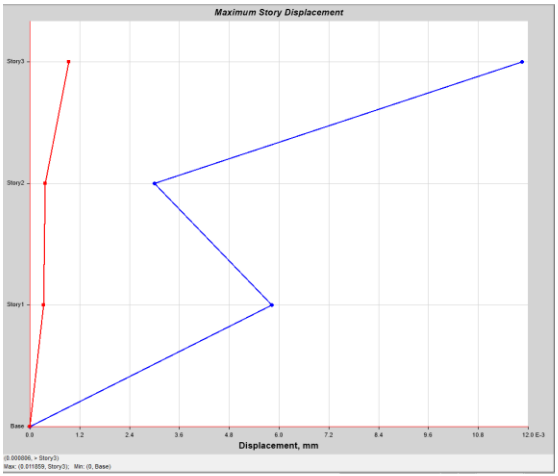

Figure 8. Maximum Storey drift of the frame

with slab

without slab

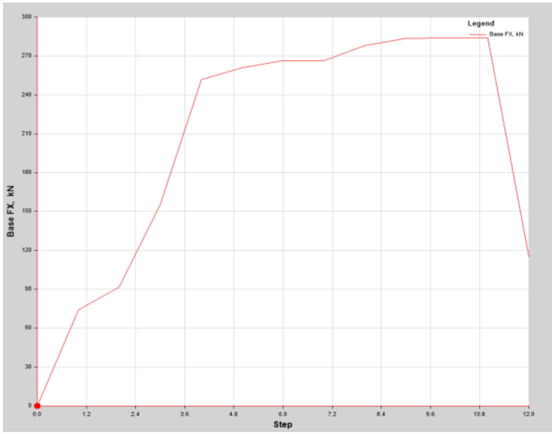

Figure 9. Maximum Storey drift of the frame

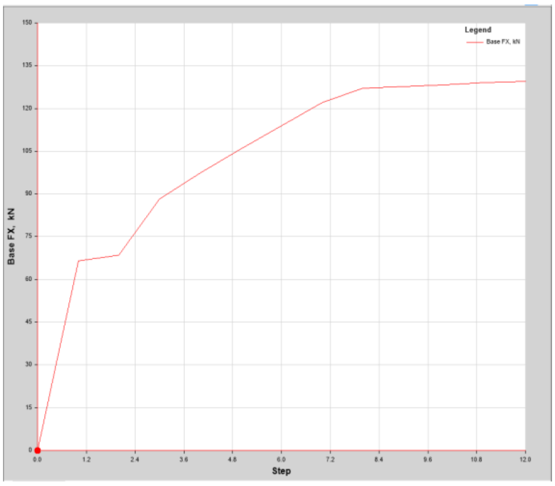

Figure 10. Maximum Storey drift of the frame

with slab without slab

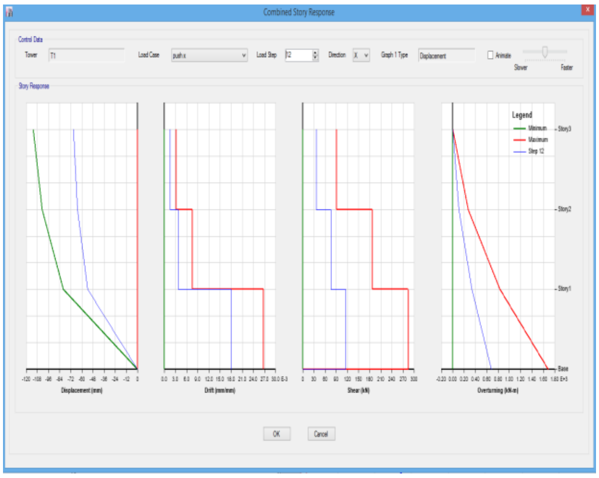

Figure 11: Combined Storey response plot for frame with slab

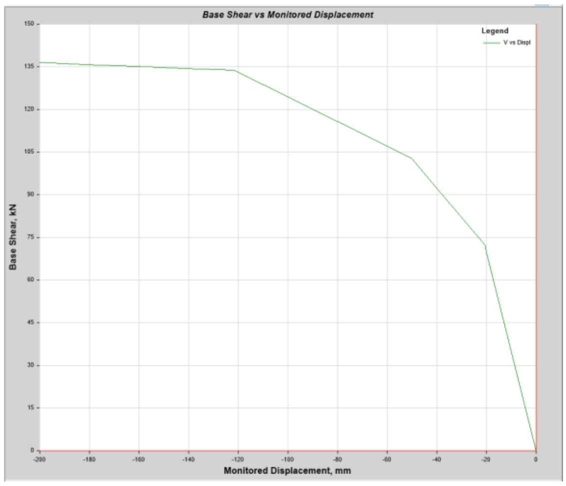

Figure14. Base shear vs Monitored

displacement of the frame with slab

displacement of the frame without slab

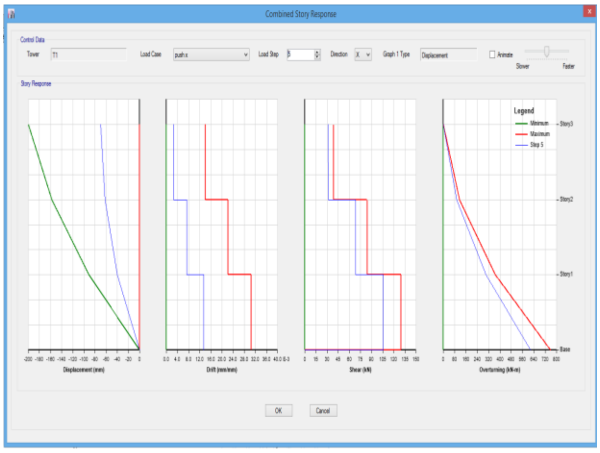

Figure 12: Combined Storey response plot for frame without slab

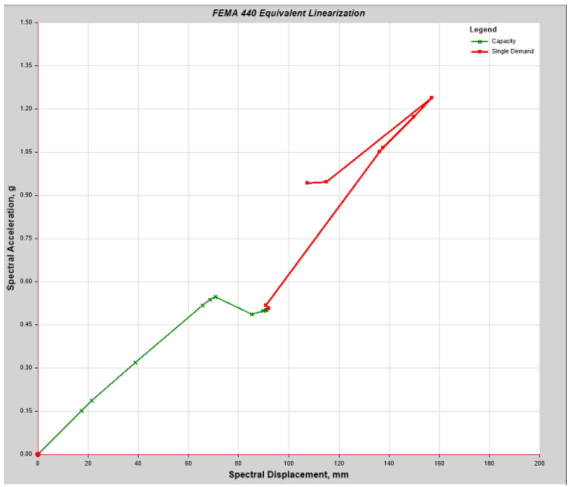

Figure 15. FEMA 440 with slab

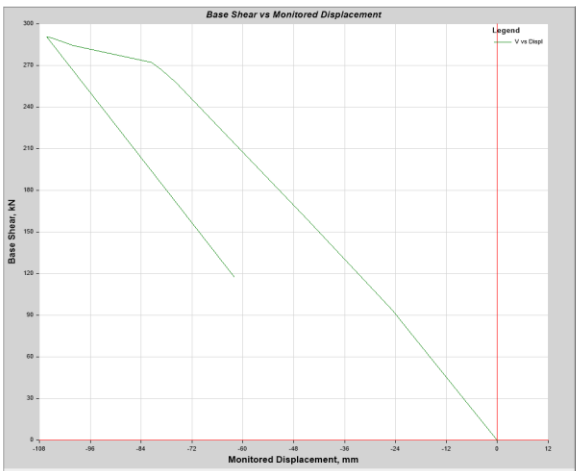

Figure 13. Base shear vs Monitored

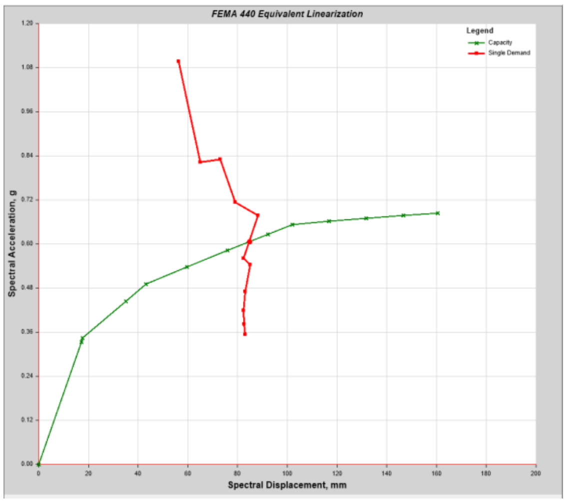

Figure16. FEMA 440 without slab

Table 1. Drift values of the frame with slab

Story	Load Comb	Direction	Drift	Label	X	Y	Z
Story3	Dead	X	5E-06	1	0	3.5	9
Story3	Dead	Y	4.379E-07	3	8	0	9
Story3	Live	X	1.8E-05	1	0	3.5	9
Story3	Live	Y	2E-06	3	8	0	9
Story3	push x Max	Y	1E-06	1	0	3.5	9
Story3	push x Min	X	0.003217	2	8	3.5	9
Story3	push y Max	X	4.451E-07	3	8	0	9
Story3	push y Min	Y	0.001526	1	0	3.5	9
Story2	Dead	X	1E-06	1	0	3.5	6
Story2	Dead	Y	1.625E-08	2	8	3.5	6
Story2	Live	X	3E-06	1	0	3.5	6
Story2	Live	Y	6.299E-09	2	8	3.5	6
Story2	push x Max	Y	2.6E-05	3	8	0	6
Story2	push x Min	X	0.007519	4	0	0	6
Story2	push y Max	X	1E-06	2	8	3.5	6
Story2	push y Min	Y	0.003708	3	8	0	6
Story1	Dead	X	2E-06	2	8	3.5	3
Story1	Dead	Y	1.08E-07	2	8	3.5	3
Story1	Live	X	7E-06	2	8	3.5	3
Story1	Live	Y	4.44E-07	2	8	3.5	3
Story1	push x Max	Y	0.000378	1	0	3.5	3
Story1	push x Min	X	0.026745	3	8	0	3
Story1	push x Min	Y	0.005262	2	8	3.5	3
Story1	push y Max	X	2E-06	1	0	3.5	3
Story1	push y Min	Y	0.014738	2	8	3.5	3

Table 2. Drift values of the frame without slab

Story	Load Comb	Direction	Drift	Label	X	Y	Z
Story3	Dead	Y	1.999E-07	3	8	0	9
Story3	Live	Y	2E-06	3	8	0	9
Story3	push x Max	Y	0	3	8	0	9
Story3	push x Min	X	0.014018	3	8	0	9
Story3	push y Max	Y	279.282393	4	0	0	9
Story3	push y Min	Y	452.297076	2	8	3.5	9
Story2	Dead	X	1E-06	4	0	0	6
Story2	Dead	Y	9.149E-08	3	8	0	6
Story2	Live	X	6E-06	4	0	0	6
Story2	Live	Y	1E-06	3	8	0	6
Story2	push x Max	Y	0	2	8	3.5	6
Story2	push x Min	X	0.022198	1	0	3.5	6
Story2	push y Max	Y	615.208891	2	8	3.5	6
Story2	push y Min	Y	1001.485752	4	0	0	6
Story1	Dead	X	2E-06	3	8	0	3
Story1	Dead	Y	1.126E-07	4	0	0	3
Story1	Live	X	1.5E-05	3	8	0	3
Story1	Live	Y	1E-06	4	0	0	3
Story1	push x Max	Y	0	3	8	0	3
Story1	push x Min	X	0.03045	1	0	3.5	3
Story1	push y Max	Y	1220.324214	2	8	3.5	3
Story1	push y Min	Y	4398.289195	3	8	0	3

Conclusions

From the above study it can be concluded that:

1. Push over analysis is one of the best method for analysis of inelastic demand prediction of structural elements subjected to seismic forces as it provides much appropriate results that elastic analysis.

2. This method enhances the design engineer to design the structures significantly for seismic resistant design and the result obtained

hasresonancefinding concerning the force generated in the structures and its respective deformation demands and prevents the seismic failure of the structure.

3. It can also be emphasized that the this method of analysis is an approximate method and it mainly depends on the static loading applied in the structure. This method has demerits such as it cannot perform well with dynamic phenomena with a large data and higher degree ofaccuracy. It may also not identify some important deformation modes that may occur in astructure subjected to severe seismic loadings.

4. Push over when analyzed for two types of frames with and without slab conditions and finally it was concluded that the frame with slab is more stiffening and is able to resist the siemsic loading better that the later one.

5. The study also confirms that this analysis is mainly based on the on the characteristics of the material used for design of the structure.