Performance Based Study on R.C Framed Structure by Considering Stiffness of Slab Subjected To Seismic Load

Pediveeti Sai Kumar[1] G.Pavan Kumar[2]
[1,2]Department of Structural Engineering
[1,2]SVR Engineering College, Nandyal, India

Abstract— Till recent times to predict the exact capacity of the R.C structure with considering stiffness of slab, need to depend on non-linear static analysis .To Model the Complex behavior of reinforced concrete analytically in its non-linear zone is difficult. This has led Engineers in the past to rely heavily on empirical formulas which were derived from numerous experiments for the design of reinforced concrete structures for structural design and assessment of reinforced concrete structures including force redistribution This analysis of the nonlinear response of R.C Structures to be carried out in routine fashion, it helps in the investigation behavior and the cracks pattern. R.C Structure with considering stiffness of slab Skeleton framing system, composed of only reinforced concrete columns, beams and slabs, have been adopted in analysis for many framed buildings. Generally, flexural stiffness of slabs is ignored and the floor load is transferred as uniformly distributed load on to the supporting beams in the conventional analysis of bare frame structures.
Keywords: R.C Structure; Stiffness, Seismic Load

I. INTRODUCTION

The Buildings, which appeared to be strong enough, may crumble like hours of cards during earthquake and deficiencies may be exposed. Experience gain from the recent earthquake of Bhuj, 21 demonstrates that the most of buildings collapsed were found deficient to meet out the requirements of the present day codes. In last decade, four devastating earthquakes of world have been occurred in India, and low to mold intensities earthquake of world frequently. Due to wrong construction practices and ignorance for earthquake resistant design of buildings in our country, most of the existing buildings are vulnerable to future earthquakes.

A. Necessity of Non-Linear Static Pushover Analysis)

The existing building can become seismically deficient since seismic design code requirements are constantly upgraded and advancement in engineering knowledge. Further, Indian buildings built over past two decades are seismically deficient because of lack of awareness regarding seismic behavior of structures

B. Pushover Analysis:

The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. The equivalent static lateral loads approximately represent earthquake induced forces. A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity.

The seismic design can be viewed as a two step process. The first, and usually most important one, is the conception of an effective structural system that needs to be configured with due regard to all important seismic performance objectives, ranging from serviceability considerations. This step comprises the art of seismic engineering. The rules of thumb for the strength and stiffness targets, based on fundamental knowledge of ground motion and elastic and inelastic dynamic response characteristics, should suffice to configure and rough-size an effective structural system.

C. Limitations of Pushover Analysis:

Although pushover analysis has advantages over elastic analysis procedures, underlying assumptions, the accuracy of pushover predictions and limitations of current pushover procedures must be identified. The estimate of target displacement, selection of lateral load patterns and identification of failure mechanisms due to higher modes of vibration are important issues that affect the accuracy of pushover results.

D. Non-Linear analysis Method:

1) General:

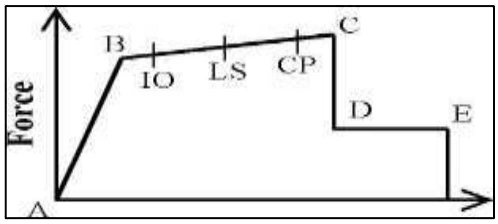
In order to investigate the nonlinear behavior of the building structures having soft stories, nonlinear static pushover and nonlinear time history analysis are performed on the analytical models. In this project, the nonlinear material properties used in this study and the underlying principles on the nonlinear static pushover time history analysis methods is explained.

2) Nonlinear Behavior of Structural Elements:

The nonlinear behavior of building structure of a building structure depends on the nonlinear response of the elements that are used in the lateral force resisting system. Therefore, before applying any nonlinear analysis method on a building structure, the nonlinear behavior of such elements must be clearly described and evaluated.

3) Element Description of ETABS 9.4:

In ETABS, a frame element is modeled as a line element having linearly elastic properties and nonlinear force-displacement characteristics of individual frame elements are modeled as hinges represented by a series of straight line segments. A generalized force-displacement characteristic of a non-degrading frame element or hinge properties in ETABS.



Deformation
Force-Deformation for Pushover Hinge

Point A corresponds to unloaded condition and point B represents yielding of the element. The ordinate at C corresponds to nominal strength and abscissa at C corresponds to the deformation at which significant strength degradation begins. The drop from C to D represents the initial failure of the element and resistance to lateral loads beyond point C is usually unreliable. The residual resistance from D to E allows the frame elements to sustain gravity loads. Beyond point E, the maximum deformation capacity, gravity load can no longer be sustained. Hinges can be assigned at any number of locations (potential yielding points) along the span of the frame element as well as element ends.

E. Objective of the Present Study:

1) The objective of the present work is study the nonlinear static behavior of the structure with and without considering stiffness of slab, subjected to seismic loading.
2) Comparing the two models of frame such has Skeleton framed structure (SFS) and Skeleton framed Structure with considering stiffness of slab (SFWS) at different seismic zones, the effect of increased stiffness on the above parameters studied & increased capacity of framed systems were also studied.

F. Scope of the Present Study:

1) For the purpose of Comparison, building type, floor system, floor area, bay size and column height are kept constant throughout the study.
2) Ordinary moment resisting frames (OMRF) with response reduction factor of 3 and importance factor 1 (general building) is considered throughout the study.
3) The study is made for 6 storied structures with plan dimensions of 15 m X 15 m, in all the seismic zones of India (Zones II to Zone V)

II. Literature Review

Structures are expected to deform in elastically when subjected to severe earthquakes, so Seismic performance evaluation of structures should be conducted considering post-elastic behavior. Therefore, a nonlinear analysis procedure must be used for evaluation purpose a post-elastic behavior cannot be deter mind directly by an elastic analysis. Moreover, maximum inelastic displacement demand of structures should be deter mind to adequately Estimate the seismically induced demands on structures that exhibit inelastic behavior.

A. Past studies on Pushover Analysis:

Santhosh.D(214)Pushover analysis is nonlinear static analysis in which Provide 'capacity curve' of the structure, it is a plot of total base force vs. roof displacement. The analysis is carried out up to failure; it helps determination of collapse load and ductility capacity of the structure.

A.K.Chopra(21) extracted an improved Direct Displacement-Based Design Procedure for Performance-Based seismic design of structures. Direct displacement-based design requires a simplified procedure to estimate the seismic deformation of an inelastic SDF system, representing the first (elastic) mode of vibration of the structure.

Chung-Yue Wang et al., (27) in this paper he presented a method for the determination of the parameters of plastic hinge properties (PHP) for structure containing RC wall in the pushover analysis is proposed. Nonlinear relationship between the lateral shear force and lateral deformation of RC wall is calculated.

III. Methodology

This software is able to predict the geometric nonlinear behavior of space frames under static or dynamic loadings, taking into account both geometric nonlinearity and material under static or dynamic loadings, taking into account both geometric nonlinearity and material inelasticity. software accepts static loads (either forces or displacements) as well as dynamic actions and has the ability to perform Eigen values, nonlinear static pushover and nonlinear dynamic analysis.

1) Terminology:

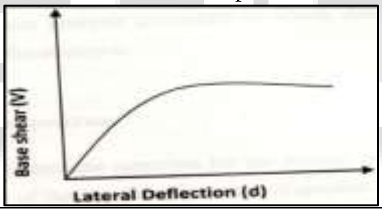
This software is able to predict the geometric nonlinear behavior of space frames

2) Capacity:

It is expected ultimate strength in (flexural, shear, or axial loading) of a structural component excluding the reduction factors commonly used in design of concrete members. The capacity usually refers to the strength at the yield point of the element or structure's capacity curve.

3) Capacity Curve:

It is the plot of the base shear v, on a structure, against the lateral deflection, d, of the roof of the structure as shown in Fig This is often referred to as the pushover curve.



Geometric details

Floor	Column Size mm x mm	Beam Size mm x mm	Load For Walls kN / m	Live Load kN / m^2	Floor Finish kN / m^2
G. Floor	3 x 45	23 x 42	12.	2.	1.5
1st.Floor	3 x 45	23 x 42	12.	2.	1.5
2nd.Floor	3 x 45	23 x 42	12.	2.	1.5
3rd.Floor	3 x 45	23 x 42	12.	2.	1.5
4th.Floor	3 x 45	23 x 42	12.	2.	1.5
5th.Floor	3 x 45	23 x 42	3.	1.5	1.5

Pushover curve

A. Pushover Analysis for Multi-Storeyed building using ETABS:

The following steps are included in the pushover analysis. Steps 1 through 4 discuss creating the computer model, step 5 runs the analysis, and step 6 through 1 reviews the pushover analysis results.

1) Create the basic computer model (without the pushover data) in the usual manner using the graphical interface of ETABS makes the quick and easy task.
2) Define properties and acceptance criteria for the pushover hinges as shown in Figure.
3) The program includes several built in default hinge properties that are based on average values from ATC-4 for concrete members and average values from FEMA-273 for steel members. These built in properties can be useful for preliminary analysis, but user-defined properties are recommended for final analysis. This example uses default properties.
4) Locate the pushover hinges on the model by selecting one or more frame members and assigning them one or more hinge properties and hinge locations.

Typically a gravity load pushover is force controlled and lateral pushovers are displacement controlled. ETABS allows the distribution of lateral force used in the pushover to be based on a uniform acceleration in a specified direction, a specified mode shape, or a user-defined static load case. Here how the displacement controlled lateral pushover case that is based on a user-defined static lateral load pattern named PUSH is defined for this example.

B. *Material Properties:*

The material used for construction is Reinforced concrete with M-25 grade concrete and fe-415 grade reinforcing steel. The Stress-Strain relationship used is as per I.S.456:2 .
The basic material properties used are as follows:
Modulus of Elasticity of steel, Es = 2.1x1 ^{5} MPa
Modulus of Elasticity of concrete, E_C = 2.5x1 ^{4} MPa
Characteristic strength of concrete, f_{ck} = 25 MPa
Yield stress for steel, f_y = 415 MPa
Ultimate strain in bending, ε_{cu} = .35

1) *Model Geometry:*

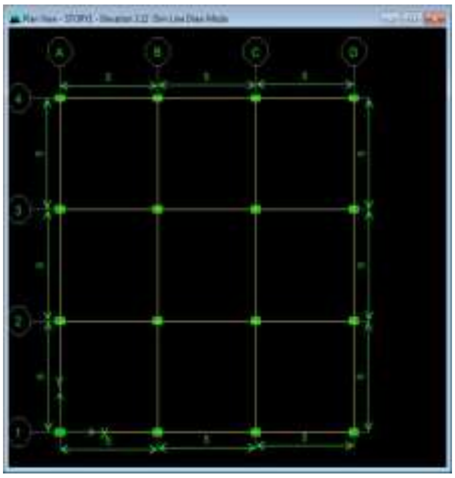
The structure analyzed is a four-storied, one bay along X-direction and two bays along Y-direction moment-resisting frame of reinforced concrete with properties as specified above. The concrete floors are modeled as rigid. The details of the model are given as:
Number of stories = 6
Number of bays along X-direction = 3
Number of bays along Y-direction = 3
Storey height = 3 m
Bay width along X-direction = 5. m
Bay width along Y-direction = 5. M

2) *Earth Quake load parameters:*

Parameters	Values
seismic zone factor, Z	.1, .16, .24& .36
Importance factor, I	1.
Response reduction factor ,R	3.
Percentage damping	5%
Fundamental time period, T	.433
Soil type	Type-III(soft soil)
Average response acc.coeff.,(Sa/g)	2.5

3) *Plan of Building:*

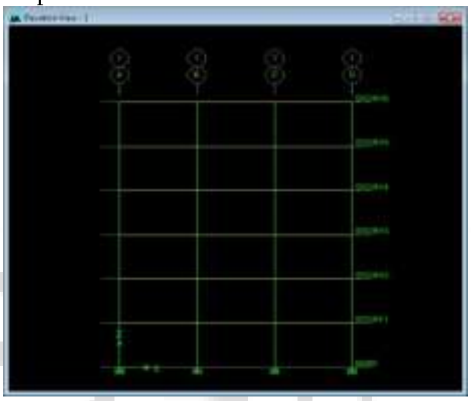
The plan of the building is shown in the Fig. The bay width, column positions and beams positions.



Plan of building

4) *Elevation of Building:*

The Figure shows the sectional elevation of the structure. The storey heights, Column lines, description of slabs etc. can be seen in this picture.



Elevation of building

Manual Calculations:

5) *Calculation of seismic loading at Seismic Zone –II:*

Weight of the Beams = 24 x .23 x .42 x 5. x 25 = 289.8 kN
Weight of the columns = 16 x 2.7 x .3 x .45 x 25= 145.8 kN
Weight of the slab = 15 x 15 x .12 x 25= 675 kN
Weight of walls = (4x13.8 x .23x2.7 x18) + (4 x 13.2 x .23x2.7 x18)= 12 7.22 kN
Weight of parapet wall = 59.54 x 1. x .15 x 18 = 16 .758 kN
Loads:
Floor Finish= 1.5 x 15 x 15= 337.5 kN

Geometric Details						
Floor	Column Size mm x mm	Beam Size mm x mm	Load For Walls kN / m	Live Load kN / m^2	Floor Finish kN / m^2	Floor Height m
G.Floor	3 x 45	23 x 42	12.	2.	1.5	3
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3rd.Floor	3 x 45	23 x 42	12.	2.	1.5	3
4th.Floor	3 x 45	23 x 42	12.	2.	1.5	3
5th.Floor	3 x 45	23 x 42	3.	1.5	1.5	3

Live load = 2. x 15 x 15 = 45 kN
Taken live load only 25% (IS 1893:2 2) =45 x 25/1 = 112.5 kN
Roof Weight = 289.8 + 145.8/2 + 675 + 16 .758 = 1198.45 kN
Floor Weight =289.8 + 145.8 + 675 + 12 7.22 + 112.5 + 337.5 =2767.82 kN
Seismic Weight of the Building = 5 x 2767.82 +1198.45 = 15 37.55 kN
The total base shear is given by

$$V_b = A_h.W$$

Where Ah = is the design horizontal seismic coefficient.

$$A_h = \frac{Z \quad I \quad S_a}{2 \quad R \quad g}$$

T= (. 9 X 18.72)/√ 15 = .435
A_h= .1 /2 X 1/3 X 2.5 = . 41
V_b = . 41 X 15 37.55=626.564 kN

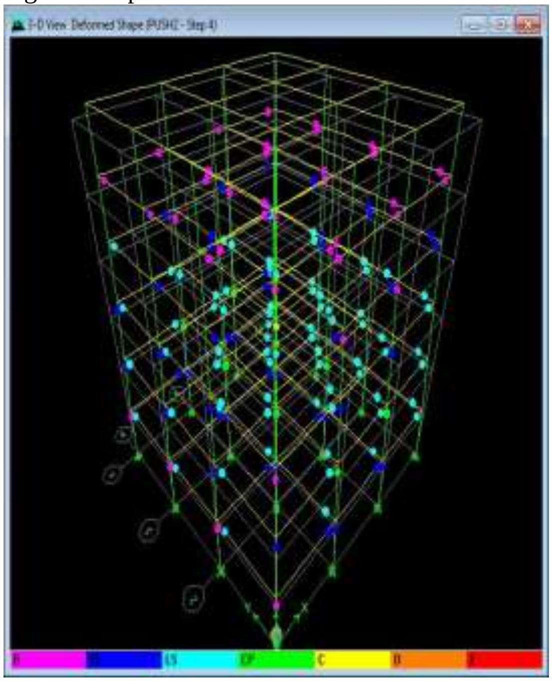
IV. RESULTS AND DISCUSSIONS

Studied the nonlinear static behavior of the structure with and without considering stiffness of slab, subjected to seismic loading. By comparing the two models of frame such has Skeleton framed structure (SFS) and Skeleton framed Structure with considering stiffness of slab (SFWS) at different seismic zones, the effect of increased stiffness on the above parameters & increased capacity of framed systems were studied.

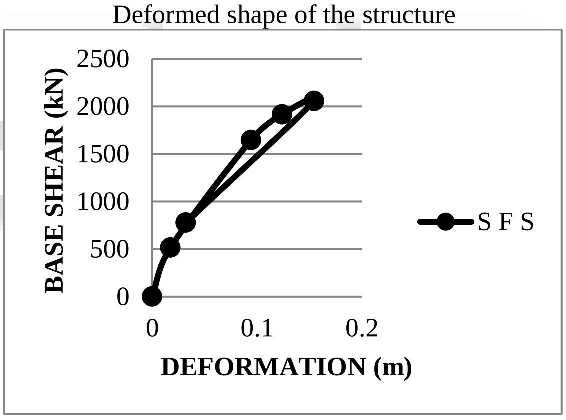
A. The R.C Framed Structure without considering Stiffness of slab

(SFS) for Seismic Zone –II:

- In this case, considered G+5 Symmetrical R.C framed structure without considering stiffness of slab at seismic zone-II.
- The columns are of 3 mm x 45 mm size and beams are of 23 mm x 42 mm size.
- 12 mm thick Slab is considered on the all floors & Roof.
- The loads acting on the structure are assigned. Here self weight, live load, wall loads, slabs Loads& Seismic loads are considered.
- Then the structure is analyzed for non-linear static analysis and the deformed shape is obtained for Pushover load case.
- In the figure all the nodes are yellow color within the' C' level.
- All the nodes pink color represented that they belong to A-B zone is the range of elastic range.
- All the nodes in the dark blue color represent that they belong IO-LS zone is the range of life safety.
- All nodes represented in light blue color represent they belong LS-CP zone is the range of moderate.
- All the nodes represented in green color represented they belong CP-C zone is the range of severe.
- All the nodes represented in yellow color represented at the point 'C 'on its force-Displacement that hinges must begin to drop load.



Deformed shape of the structure



curve for SFS at seismic zone-II

B. Comparison of Pushover Curves:

Pushover or nonlinear static analysis is carried out for all the cases considering in the thesis and finally pushover curves are obtained. Pushover curves are obtained with displacement on x-axis and base reaction on y-axis Depending on the pushover curves comparisons are carried out between.

1) The comparison of R.C Framed Structure without and with considering stiffness of slab(SFS &SFWS) to seismic zones-II, III, IV, V.
2) The comparison of R.C Framed Structure without considering stiffness of slab(SFS) to seismic zone-II and with considering stiffness of slab(SFWS) for seismic zones-III
3) The comparison of R.C.C Framed Structure without considering stiffness of slab(SFS) to seismic zone-III with considering stiffness of slab(SFWS) for seismic zones-IV

4) The comparison of R.C Framed Structure without considering stiffness of slab(SFS) to seismic zone-IV and with considering stiffness of slab(SFWS) for seismic zones-V.

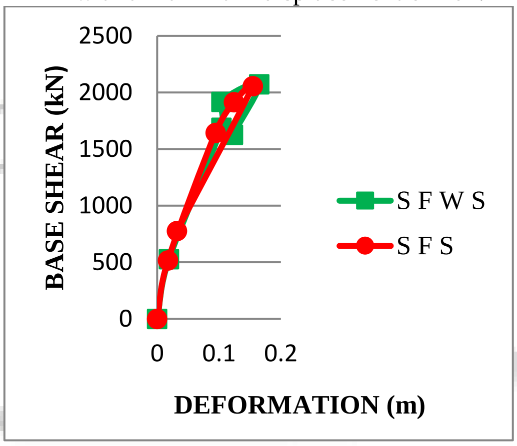
1) Comparison -1:

The R.C Framed Structure with and without considering Stiffness of slab (SFWS & SFS) for seismic zone-II:

R.C Framed structure with considering Stiffness of slab (SFWS) can take the
Base force of $2.72x1^{3}$ kN and Displacement of $164.7x1^{-3}$ m.
R.C Framed structure without considering Stiffness of slab (SFS) can take the
Base force of $2.57x1^{3}$ kN and Displacement of $154.6x1^{-3}$ m.

Structure	Displacement (m)	Base force (kN)
With considering stiffness of slab	$164.7x1^{-3}$	$2.72x1^{3}$
Without considering stiffness of slab	$154.6x1^{-3}$	$2.57x1^{3}$

In the above comparison, that R.C frame with considering stiffness of slab can resist a maximum Base force $2.72x1^{3}$ kN with a maximum displacement of $164.7x1^{-3}$m.



Comparison of capacity curve for SFS & SFWS at seismic zone -II

V. Conclusions

The performance R.C frame with & without considering stiffness of slab (SFS & SFWS) was investigated using the pushover analysis. Following were the major conclusions drawn from the Study.

Zone – II:

1) Comparing with SFS and SFWS, The SFS Base Shear is 7.2% less than SFWS.
2) Comparing with SFS and SFWS, The SFS Displacement is 6.53% less than SFWS.

Zone – III:

1) Comparing with SFS and SFWS, The SFS Base Shear is .1% less than SFWS.
2) Comparing with SFS and SFWS, The SFS Displacement is 7.2% less than SFWS.

Zone – IV:

1) Comparing with SFS and SFWS, The SFS Base Shear is 3.9% less than SFWS.
2) Comparing with SFS and SFWS, The SFS Displacement is 6.7% less than SFWS.

Zone – V:

1) Comparing with SFS and SFWS, The SFS Base Shear is 3.6% less than SFWS.
2) Comparing with SFS and SFWS, The SFS Displacement is 11% less than SFWS.
   1) In the comparison of performance based study on R.C. framed structure with and without considering Stiffness of slab (SFWS & SFS) to seismic load at different zones-II, III, IV, V, the capacity curve based on with considering stiffness of slab (SFWS) can with stand for more deformation and base shear than without considering stiffness of slab (SFS).
   2) From the pilot study, non-linear analysis of R.C structures with considering stiffness of slab (SFWS) to seismic load can resist for more deformation than Skelton framing system (SFS).

A. Scope for Further Study:

1) The similar study can be carried out for structures with irregularities
2) In this present work, studied the effect of stiffness of slab elements along with frames. Can also study the effects of infill walls.

