PERFORMANCE ASSESMENT OF RC BUILDING FRAMES BY NON LINEAR ANALYSIS

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Abstract: Recent earthquakes in which many concrete structures have been severely damaged or collapsed, have indicated the need for evaluating the seismic adequacy of existing buildings. About 60% of the land area of our country is susceptible to damaging levels of seismic hazard. One of the procedures is the nonlinear static pushover analysis which is becoming a popular tool for seismic performance evaluation of existing and new structures. By conducting this pushover analysis, we can know the weak zones in the structure and then we will decide whether the particular part is to be retrofitted or rehabilitated according to the requirement. In the present study the push over analysis is performed on RC building frames by changing the footing, infill wall, aspect ratio and introduction of bracings on the SAP2000 (version 14). These four features have the capacity to increase the seismic performance of the building and the bracings can be used for retrofitting for buildings which are structurally weak

Index Terms— ASPECT RATIO, PUSHOVER ANLAYSISS, BRACINGS, RC BUILDING FRAME

1 INTRODUCTION

Nonlinear static analysis, or pushover analysis, has been developed over the past twenty years and has become the preferred analysis procedure for design and seismic performance evaluation purposes as the procedure is relatively simple and considers post elastic behavior. However, the procedure involves certain approximations and simplifications that some amount of variation is always expected to exist in Although, in literature, pushover analysis has been shown to capture essential structural response characteristics under seismic action, the accuracy and the reliability of pushover analysis in predicting global and local seismic demands for all structures have been a subject of discussion and improved pushover procedures have been proposed to overcome the certain limitations of traditional pushover procedures. However, the improved procedures are mostly computationally demanding and conceptually complex that use of such procedures are impractical in engineering profession and codes.

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As traditional pushover analysis is widely used for design and seismic performance evaluation purposes, its limitations, weaknesses and the accuracy of its predictions in routine application should be identified b studying the factors affecting the pushover predictions. In other words, the applicability of pushover analysis in predicting seismic demands should be investigated for low, mid and high-rise structures by identifying certain issues such as modeling nonlinear member behavior, computational scheme of the procedure, variations in the predictions of various lateral

load patterns utilized in traditional pushover analysis, efficiency of invariant lateral load patterns in representing higher mode effects and accurate estimation of target displacement at which seismic demand prediction of pushover procedure is performed.

Horizontal strength has constantly been a main issue of structures generally in the areas with high earthquake vulnerability, later this problem has been examined and eccentric, concentric and knee bracing systems have been proposed and as a result these systems were implemented by the civil engineers. Inelastic performance is one of the main issues impelling the choice of bracing systems. The bracing system that has a more plastic distortion before collapse can consume more energy during the earthquake. The scope of this study is that Special moment RC building frames are commonly constructed in earthquake prone countries like India since they provide much higher ductility. Failures observed in past earthquakes show that the collapse of such buildings is predominantly due to the formation of soft-story mechanism in the ground story columns. The study only deals with the RC framed buildings. The studies here contains the two different types of support condition that is fixed and hinged supports. The base of the column is fixed and the soil structure interaction is ignored. The bare frame, weak infill and strong infill wall are only used here. The steel bracings of ISMB100 is used as the bracings.

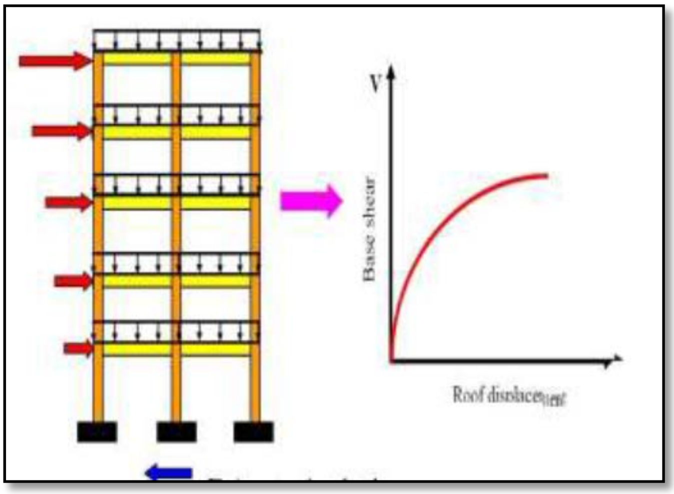


Figure.1 - Construction of pushover curve

2 Literature Review

The current study by Howard H.M Hwang [1] to achieve more stringent acceptable risk level required for high risk and essential buildings the important factor is to increase structural strength and stiffness. Therefore the seismic LFRD criteria developed in this study are applicable to three categories of building in different zones of America. The proposed seismic LRFD criteria will produce risk-consistent structures under various design conditions, because seismic-load factors and importance factors are determined from optimization. Two types of limit states, first yielding and collapse of a structure are considered. The study concludes that the collapse limit state controls the design and evaluation of buildings. It implies that if the design satisfies the requirement for life safety in the event of a large earthquake, it will also satisfy the requirement for no structural damage in the event of a moderate earthquake. This is especially true for buildings in eastern United States, where large earthquakes are infrequent.

The study was conducted by Pranamya [2] shaped a comparative study on an existing RC frame structure with and without considering infill stiffness for the 2D and 3D models in which the slabs were modelled as membrane with rigid diaphragms, membrane with semi rigid diaphragms, shell element and without any diaphragms using static nonlinear pushover analysis. Infill frames modelled based on equivalent strut approach. Non-linear pushover analysis was performed considering moderate seismic zone (ZONE-III) of India. From the analysis result, it was found that the bare frame and the infill frame with slab modelled as a shell element showed better performance in resisting base shear but relatively weak in showing the ductile behavior compared to other model considered. When evaluating the post elastic behavior of the bare frame with infill frames, it was found that the infill frame is showing better performance in terms of resisting base shear but weak in exhibiting the ductile behavior since the open ground floor exhibiting the soft story effect.

Helmut Krawinkleret al., [3] studied the pros and cons of Pushover analysis and suggested that element behavior cannot be evaluated in the context of presently employed global system quality factors such as the R and Rw factors used in present US seismic codes. They also suggested that a carefully performed pushover analysis will provide insight into structural aspects that control performance during severe earthquakes. For structures that vibrate primarily in the fundamental mode, the pushover analysis will very likely provide good estimates of global, as well as local inelastic, deformation demands. This analysis will also expose design weaknesses that may remain hidden in an elastic analysis. Such weaknesses include story mechanisms, excessive deformation demands, strength irregularities and overloads on potentially brittle elements such as columns and connections.

Oğuz, Sermin [4], ascertained the effects and the accuracy of invariant lateral load patterns utilized in pushover analysis to predict the behavior imposed on the structure due to randomly Selected individual ground motions causing elastic deformation by studying various levels of Nonlinear response. For this purpose, pushover analyses using various invariant lateral load patterns and Modal Pushover Analysis were performed on reinforced concrete and steel moment resisting frames covering a broad range of fundamental periods. The accuracy of approximate Procedures utilized to estimate target displacement was also studied on frame structures. Pushover analyses were performed by both DRAIN-2DX and SAP2000. The primary observations from the study showed that the accuracy of the pushover results depended strongly. On the load path, the characteristics of the ground motion and the properties of the structure.

Mehmet et al., [5], explained that due to its simplicity of Pushover analysis, the structural engineering profession has been using the nonlinear static procedure or pushover analysis. Pushover analysis is carried out for different nonlinear hinge properties available in some programs based on the FEMA-356 and ATC-40 guidelines and he pointed out that Plastic hinge length (LP) has considerable effects on the displacement capacity of the frames. The orientation and the axial load level of the columns cannot be taken into account properly by the default-hinge properties.

Vijayakumar and Babu, [6] estimated the behavior of G+2 reinforced concrete bare frame subjected to earthquake forces in zone III. The reinforced concrete structures were analyzed by nonlinear static analysis (Pushover Analysis) using SAP2000 software. It was found that the pushover analysis is a simple way to explore the nonlinear behavior of the buildings. The results obtained in terms of pushover demand, capacity spectrum and plastic hinges gave an insight into the real behavior of structures. The existing building designed and constructed using IS-456-1978 and analyzed as per IS-1893-1984 and is found inadequate in code IS-1893-2000 provisions. Most of the hinges have developed in the beams in the form of immediate occupancy, Life safety, Collapse prevention and few in the columns. The column hinges have limited the damage. Some of the beams have reached ultimate moments which have to be strengthened and improved by the performance of the structures.

3 PUSH OVER ANALYSIS

Linear elastic analysis gives a good indication of elastic capacity of structures and indicates where the first yielding will occur but it cannot predict failure mechanisms and accounts for redistribution of forces due to progressive yielding. Among different approaches described in ATC-40, Nonlinear Static Pushover analysis is very popular because of its simplicity and ability to estimate component and system level deformation demands with acceptable accuracy without intensive computational and modeling effort as dynamic analysis. Pushover analysis is a static, nonlinear procedure in which the magnitude of the structural loading is incrementally increased in accordance with a certain predefined pattern. Pushover analysis may be categorized as displacement controlled pushover analysis when lateral movement is executed on the building and its equilibrium designates the forces. In the same way, when lateral forces are enforced, the analysis is termed as force-controlled pushover analysis. The target displacement or target force is projected to signify the maximum displacement or maximum force expected to be qualified by the structure during the design earthquake. Response of structure beyond full strength can be bent on only by displacement controlled pushover analysis. Hence, in the present study, displacement-controlled pushover method is used for analysis of structural steel frames. A plot of the total base shear versus top roof displacement in a building is attained by this analysis that would specify any early failure or weakness. The analysis is performed up to failure, thus it permits purpose of collapse load and ductility capacity.

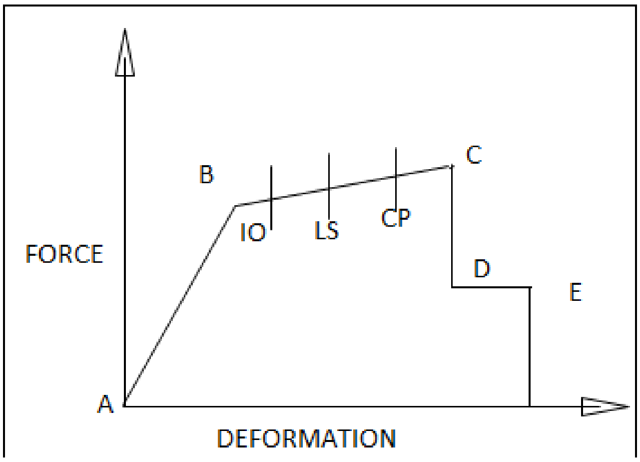


Figure.2 - Performance Levels Described By Pushover Analysis

A typical pushover curve is shown in Figure 2. Force versus displacement is plotted for gradually increasing lateral loads till failure. Beyond elastic limit, different states such as Immediate Occupancy (IO), Life Safety (LS), Collapse prevention (CP), >E collapse are defined as per ATC 40 and FEMA 356.

Immediate occupancy IO: damage is relatively limited; the structure retains a significant portion of its original stiffness.
Life safety level LS: substantial damage has occurred to the structure, and it may have lost a significant amount of its original stiffness. However, a substantial margin remains for additional lateral deformation before collapse would occur.
Collapse prevention CP: at this level the building has experienced extreme damage, if laterally deformed beyond this point, the structure can experience instability and collapse.

4 DESCRIPTION OF THE STRUCTURE

In the present study a three dimensional reinforced concrete building frames for the analysis of the footings and the infill wall and a two dimensional reinforced concrete building frames are used for the aspect ratio and the steel bracings. The building consists of G+9 stories. For simplicity all columns are assumed to be fixed at the base. The height of each floor is 3.0m. The sizes used for beam is 250 x 300, column is 300 x 300 and that of bracing is ISMB100. 2- Bay two dimensional steel frame structures with and without bracing systems with different aspect ratios ranging from 2.0 to 4.5 has been modelled and analyzed using SAP2000. Bracings considered for the study are X braced, V bracings Inverted V bracings, ZX bracings, and Zipper bracings. Live load on floor is taken as 3kN/m2 and on roof is 1.5kN/m2. Floor finish on the floor is 1kN/m2. Weathering course on roof is 2kN/m2. In the seismic weight calculation only 25% of floor live load is considered. The building is steel moment resisting frame considered to be situated in seismic zone V. The medium type of soil is considered in the analysis. . The code used for assigning earth quake is IS 1893 2002. The structure is assumed to be at zone V to get the maximum response of the structure due to earth quake. Considering all the aspect ratios.

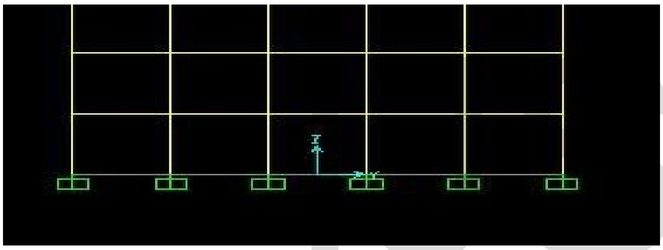
i. Bare Frame
ii. One Bay X Braced Frame
Iii.Two Bay X Braced Frame
Iv. One Bay V Braced Frame
v. Two bay V braced frame
vi. One bay ZX braced frame
vii. Two bay ZX braced frame
viii. One bay inverted v bracing
ix. Two bay inverted v bracing
x. One bay zipper bracing
xi. Two bay zipper bracing

5 Results And Discussions

The results of this study can be mainly included three sections.

Support Condition

In this study we considered only two support conditions that's fixed and hinged support condition.



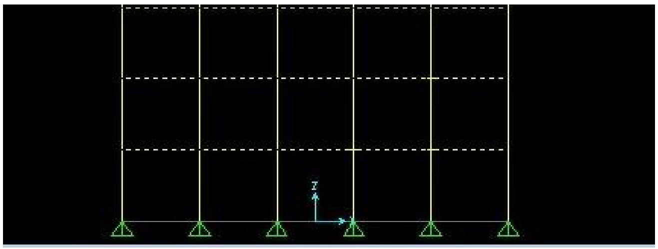


Figure.3 - Both support condition

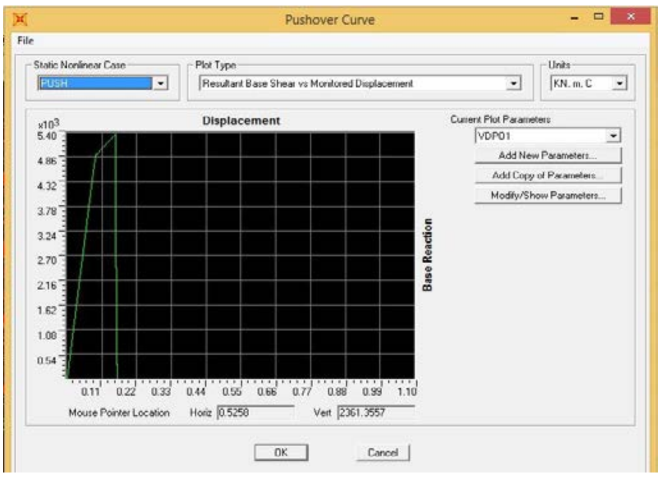


Figure.4–Push over curve

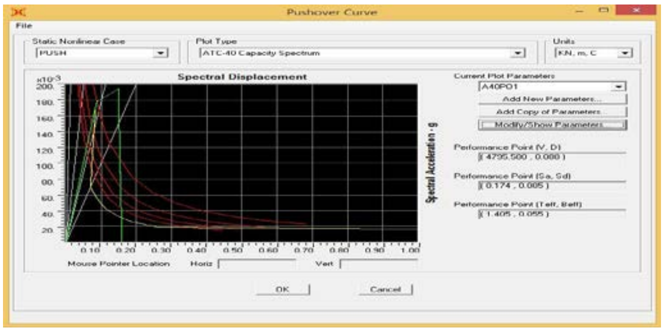
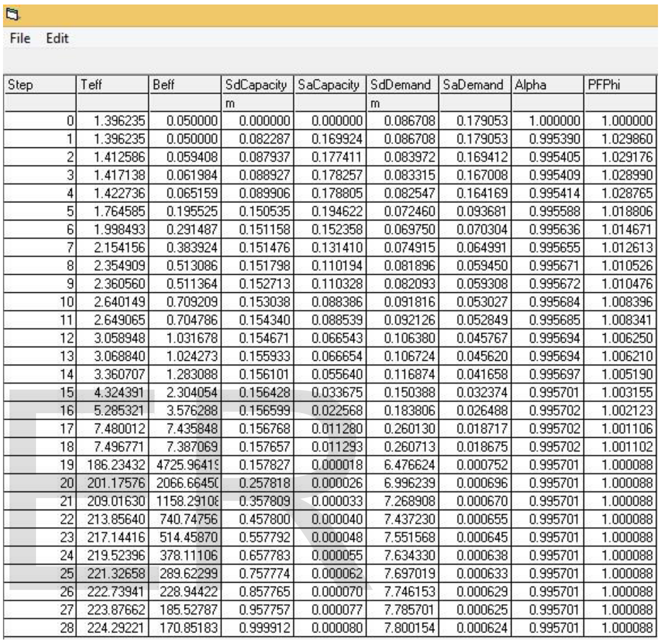


Figure.5–Capacity curve



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Step	Teff	Beff	SdCapacity	SaCapacity	SdDemand	SaDemand	Alpha	PFPhi
			m		m			
0	1.396235	0.050000	0.000000	0.000000	0.086708	0.179053	1.000000	1.000000
1	1.396235	0.050000	0.082287	0.169924	0.086708	0.179053	0.995390	1.029860
2	1.412586	0.059408	0.087937	0.177411	0.083972	0.169412	0.995405	1.029176
3	1.417138	0.061984	0.088927	0.178257	0.083315	0.167008	0.995409	1.028990
4	1.422736	0.065159	0.089906	0.178805	0.082547	0.164169	0.995414	1.028765
5	1.764585	0.195525	0.150535	0.194622	0.072460	0.093681	0.995588	1.018806
6	1.998493	0.291487	0.151158	0.152358	0.069750	0.070304	0.995636	1.014671
7	2.154156	0.383924	0.151476	0.131410	0.074915	0.064991	0.995655	1.012613
8	2.354909	0.513086	0.151798	0.110194	0.081896	0.059450	0.995671	1.010526
9	2.360560	0.511364	0.152713	0.110328	0.082093	0.059308	0.995672	1.010476
10	2.640149	0.709209	0.153038	0.088386	0.091816	0.053027	0.995684	1.008396
11	2.649065	0.704786	0.154340	0.088539	0.092126	0.052849	0.995685	1.008341
12	3.058948	1.031678	0.154671	0.066543	0.106380	0.045767	0.995694	1.006250
13	3.068840	1.024273	0.155933	0.066654	0.106724	0.045620	0.995694	1.006210
14	3.360707	1.283088	0.156101	0.055640	0.116874	0.041658	0.995697	1.005190
15	4.324391	2.304054	0.156428	0.033675	0.150388	0.032374	0.995701	1.003155
16	5.285321	3.576288	0.156599	0.022568	0.183806	0.026488	0.995702	1.002123
17	7.480012	7.435848	0.156768	0.011280	0.260130	0.018717	0.995702	1.001106
18	7.496771	7.387069	0.157657	0.011293	0.260713	0.018675	0.995702	1.001102
19	186.23432	4725.9641	0.157827	0.000018	6.476624	0.000752	0.995701	1.000088
20	201.17576	2066.6645	0.257818	0.000026	6.996239	0.000696	0.995701	1.000088
21	209.01630	1158.2910	0.357809	0.000033	7.268908	0.000670	0.995701	1.000088
22	213.85640	740.74756	0.457800	0.000040	7.437230	0.000655	0.995701	1.000088
23	217.14416	514.45870	0.557792	0.000048	7.551568	0.000645	0.995701	1.000088
24	219.52396	378.11106	0.657783	0.000055	7.634330	0.000638	0.995701	1.000088
25	221.32658	289.62299	0.757774	0.000062	7.697019	0.000633	0.995701	1.000088
26	222.73941	228.94422	0.857765	0.000070	7.746153	0.000629	0.995701	1.000088
27	223.87662	185.52787	0.957757	0.000077	7.785701	0.000625	0.995701	1.000088
28	224.29221	170.85183	0.999912	0.000080	7.800154	0.000624	0.995701	1.000088

Figure.6–Capacity table

Here in this analysis the fixed support and the hinge support almost same values. On the pushover analysis curve the performance point are all most same as 1.41 and 1.38. Hence the two support effect must be negligible while considering the effect on the RC building frames.

Infill Wall

For considering the effect of infill wall on the building the structure must be undergone design. For that the procedure as same as the pushover analysis. Then the frame subject to the design. We consider three types of frames of bare frame, weak infill wall and strong infill wall. Here in this analysis the strong infill wall can able to reduce 50% of the failure and the weak infill wall can reduce 10% of the failure than the bare frame.

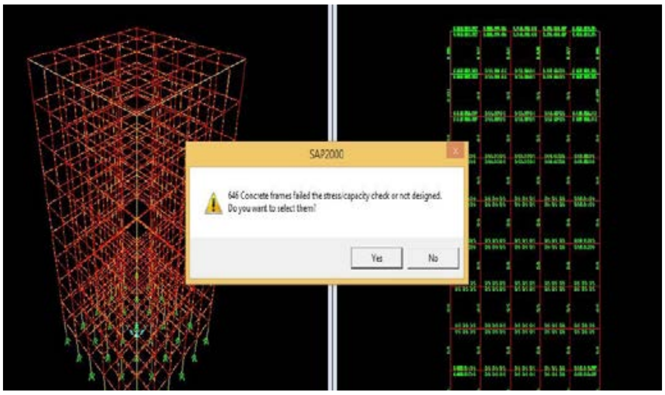


Figure.7–Bare frame result

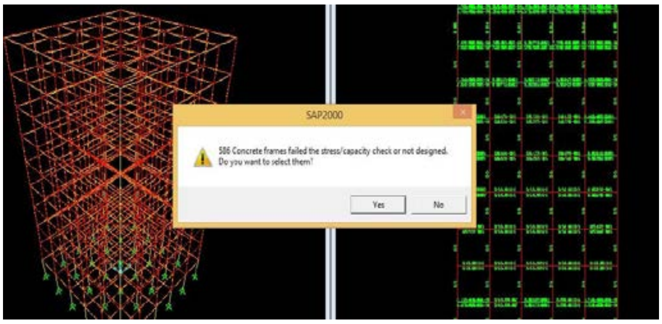


Figure.8–Weak infill wall result

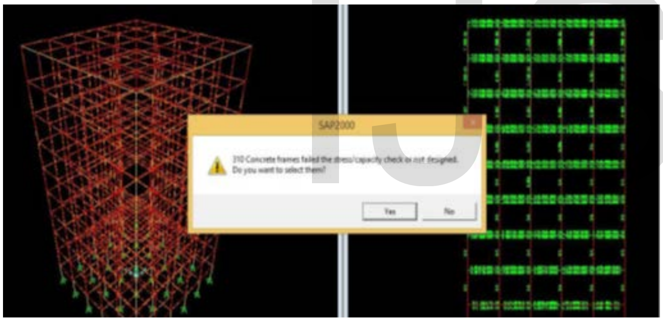
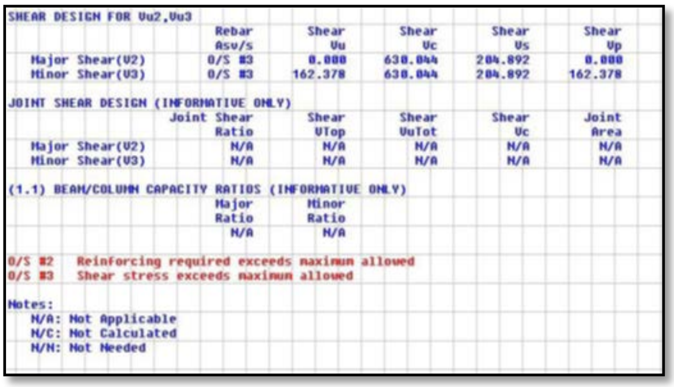


Figure.9 – Strong Infill Wall



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SHEAR DESIGN FOR Vu2,Vu3
                         Rebar      Shear      Shear      Shear      Shear
                         Asv/s      Vu         Vc         Vs         Vp
  Major Shear(V2)        O/S #3     0.000      630.044    204.892    0.000
  Minor Shear(V3)        O/S #3     162.378    630.044    204.892    162.378

JOINT SHEAR DESIGN (INFORMATIVE ONLY)
                    Joint Shear     Shear      Shear      Shear      Joint
                         Ratio      VTop       VuTot      Vc         Area
  Major Shear(V2)        N/A        N/A        N/A        N/A        N/A
  Minor Shear(V3)        N/A        N/A        N/A        N/A        N/A

(1.1) BEAM/COLUMN CAPACITY RATIOS (INFORMATIVE ONLY)
                         Major      Minor
                         Ratio      Ratio
                         N/A        N/A

O/S #2   Reinforcing required exceeds maximum allowed
O/S #3   Shear stress exceeds maximum allowed

Notes:
  N/A: Not Applicable
  N/C: Not Calculated
  N/N: Not Needed
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Figure.10 – Failure

BRACED FRAME WITH ASPECT RATIO

The aspect ratio from the 2 to 4 is considered for the analysis purpose. The ISMB100 is used as the steel bracings. About 9 type of the bracing styles are used in this analysis.

ASPECT RATIO	BARE FRAME	One Bay Inverted VBraced Frame	One Bay VBraced Frame	One Bay X Braced Frame	One Bay ZX Braced Frame	One bay zipper	Two Bay V Braced Frame	Two Bay Inverted V Braced Frame	Two bay zipper	Two Bay ZX Braced Frame	Two Bay X Braced Frame
2	29.3	7	7.9	8.3	8.2	7.2	3.5	2.6	3.5	3.6	2.3
2.5	27.6	7.2	8.5	8.4	8.9	7.5	3.8	2.9	3.5	3.76	2.8
3	22.5	7.6	8.9	8.65	9.3	7.69	4.2	3.5	3.8	3.8	2.9
3.5	21.4	8	10.6	8.89	9.61	8.32	4.5	4.2	4	4.5	3.5
4	21	8.2	11.8	9.2	10.5	8.5	4.9	4.51	4.5	4.6	3.67

Figure.11 – Roof displacement

ASPECT RATIO	BARE FRAME	One Bay Inverted VBraced Frame	One Bay VBraced Frame	One Bay X Braced Frame	One Bay ZX Braced Frame	One bay zipper	Two Bay V Braced Frame	Two Bay Inverted V Braced Frame	Two bay zipper	Two Bay ZX Braced Frame	Two Bay X Braced Frame
2	21.66	64.75	64.75	63.56	63.56	62.13	64.23	64.55	64.23	63.23	63.89
2.5	21.78	58.96	58.96	58.96	58.23	60.12	62.25	62.12	62.45	61.25	60.25
3	22.92	55.62	55.62	53.65	55.62	56.23	60.12	58.12	55.46	60.12	59.75
3.5	22.98	53.87	53.87	51.23	51.23	54.12	58.89	57.36	51.23	55.65	57.56
4	23.56	48.23	48.23	47.28	48.23	49.87	50.28	48.26	50.23	47.56	50.28

Figure.12 – Base shear

6 SUMMARY AND CONCLUSIONS

From my analysis I found that the support condition does not have any influence in the structure and the infill wall has certain importance in the structure. On the bare frame the failure will be very high. But on using the infill wall the percentage of the failure is reduced gradually. On the weak infill wall the 10% of reduction is done to the failure of the concrete frames. By the analysis of the strong infill wall there is a 50% reduction in the failure of the concrete frames. This shows the importance of the infill wall on the concrete frame performance. Use of the bracings increases the structural adequacy of the building. It increases the performance of building, significant change or reduction in roof displacement is shown when bracings are used. Usage of bracings increase the base shear capacity of buildings. The buildings which failed during seismic analysis (bare frame) shown structural adequacy when bracings are introduced. X and Zipper Bracings shown around 80- 90% increase in stability of buildings. Normally zipper bracing are not used for retrofitting purposes as it hard to find window or door openings for buildings. X and V bracings are commonly used for retrofitting purposes.

7 FUTURE SCOPE OF THE STUDY

The scope of this study is that Special moment RC building frames are commonly constructed in earthquake prone countries like India since they provide much higher ductility. Failures observed in past earthquakes show that the collapse of such buildings is predominantly due to the formation of soft-story mechanism in the ground story columns. The study only deals with the RC framed buildings. The studies here contains the two different types of support condition that is fixed and hinged supports. The base of the column is fixed and the soil structure interaction is ignored. The bare frame, weak infill and strong infill wall are only used here. The steel bracings of ISMB100 is used as the bracings.

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