SEISMIC RESPONSE OF RC FRAME STRUCTURE WITH SOFT STOREY

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Abstract

Multistoried buildings with open ground floor are inherently vulnerable to collapse due to earthquake load, their construction is still widespread in the developing nations due to social and functional need for provide car parking space at ground level. Engineering community warned against such buildings from time to time. Along with gravity load structure has to withstand to lateral load which can develop high stresses which leads to destruction of buildings. In this case study R.C.C. building is modeled and analyzed in three cases. I) Model with no infill wall (Bare Model). II) Model with bottom storey open. III) Model with steel bracing system at bottom storey.

Dynamic analysis of the building models is performed in ETABS. The performance of the building is evaluated in terms of Storey Drifts, Lateral Displacements, Lateral Forces, Storey Stiffness, Base shear, Time period, Torsion. It is found that steel braced system significantly contributes to the structural stiffness and reduces the maximum inter story drift, lateral displacement of R.C.C building. The results of bare frame, steel braced system and open bottom storey frame are discussed and conclusions are made.

Keywords: *Storey Drifts, Storey Stiffness, bare frame.*

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1. INTRODUCTION

The primary purpose of all kinds of structural systems used in the building type of structures is to transfer gravity loads effectively. The most common loads resulting from the effect of gravity are dead load, live load and snow load. Besides these vertical loads, buildings are also subjected to lateral loads caused by wind, blasting or earthquake. Lateral loads can develop high stresses, produce sway movement or cause vibration. Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces.

Retrofitting of RC buildings is much more systematic and rational process than that of non-engineered load bearing wall buildings. “Making changes to the systems inside the building or even the structure itself at some point after its initial construction and occupation

2. AIMS AND OBJECTIVES

In this study R.C.C. building is modeled and analyzed in five Parts

1. Model with no infill
2. Model with bottom storey open
3. Model with steel bracing system

The performance of the building is evaluated in terms of Storey Drifts, Lateral Displacements, Lateral Forces, Storey Stiffness, Base shear, Time period, Torsion.

3. METHOD OF ANALYSIS

The most commonly used methods of analysis are based on the approximation that the effects of yielding can be accounted for by linear analysis of the building, using the design spectrum for inelastic system. Forces and displacements due to each horizontal component of ground motion are separately determined by analysis of an idealized building having one lateral degree of freedom per floor in the direction of the ground motion component being considered. Such analysis may be carried out by the seismic coefficient method (static method) or response spectrum analysis procedure (dynamic method).

3.1 Response Spectrum Analysis

In the response spectrum method, the response of a structure during an earthquake is obtained directly from the earthquake response (or design) spectrum. This procedure gives an approximate peak response, but this is quite accurate for structural design applications. In this approach, the multiple modes of response of a building to an earthquake are taken into account. For each mode, a response is read from the design spectrum, based on the modal frequency and the modal mass. The responses of different modes are combined to provide an estimate of total response of the structure using modal combination methods such as complete quadratic combination (CQC), square root of sum of squares (SRSS), or absolute sum (ABS) method. Response spectrum method of analysis should be performed using the design spectrum specified or by a site – specific design spectrum, which is specifically prepared for a structure at a particular project site. The same may be used for the design at the discretion of the project authorities

4. ANALYSIS OF BUILDING FOR DIFFERENT CONFIGURATIONS

A hypothetical building is assumed for seismic analysis that consists of a G+5 R.C.C. residential building. The plan of the building is irregular in nature as it has all columns not at equal spacing. The building is located in Seismic Zone V and is founded on medium type soil. The building is 24.00 m in height 28.50m in length and 8.17m in width. The important

Table -1: Building Features

Structure	OMRF
Floors	G.F + 5
Ground storey height	4.0m
Typical storey height	4.0m
Depth of Foundation	3.0 m
Live load	2.0 kN/m^2 [typical floor] 3.0kN/m^2[corridors, staircase] 1.5 kN/m^2 [terrace]
Floor finish	1.0 kN/m^2
Water proofing	1.0 kN/m^2
Storey height	4 m
Walls Thickness	230 mm
Materials	Fe415 & M20
Zone	V
Size of columns	230mm x 525mm
Sizes of beams in transverse and longitudinal direction	230mm x 450mm
Thickness of slab	125mm

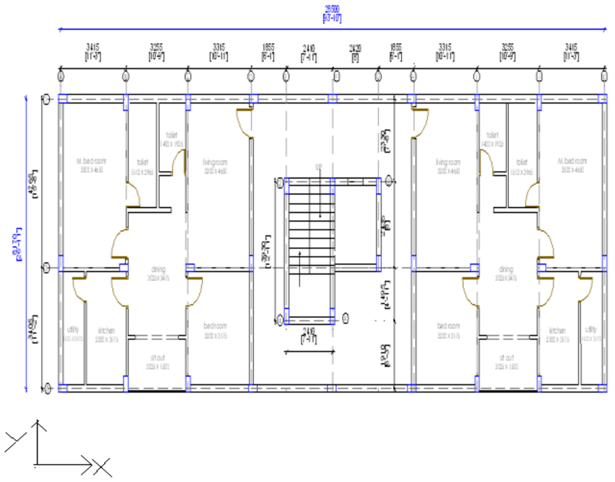

Fig - 1: Building Plan

The E-TABS software is used to develop 3D model and to carry out the analysis. Dynamic analysis of the building models is performed on ETABS. The lateral loads generated by ETABS correspond to the seismic zone V and the 5% damped response spectrum given in IS: 1893-2002.

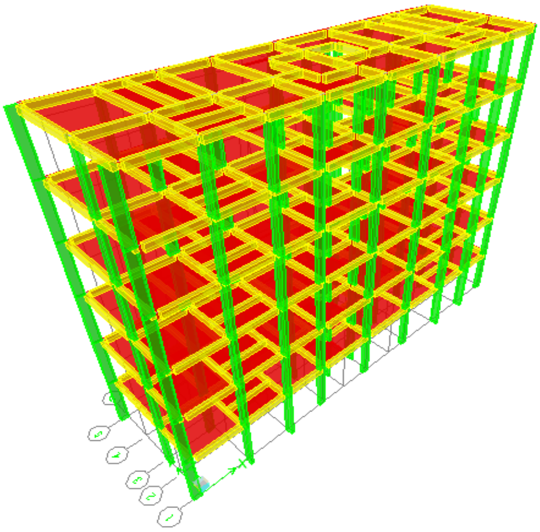

Fig -2: Bare Model

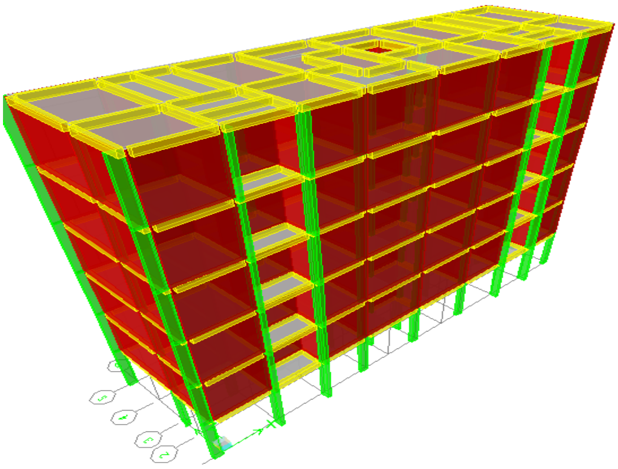

Fig -3: Open Bottom Storey

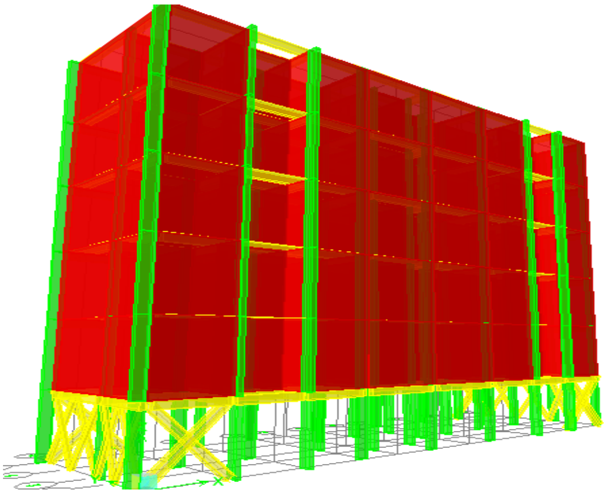

Fig - 4: Steel Bracings in Open Bottom Storey

4.1 Storey Drift

It is the displacement of one level relative of the other level above or below. The storey drift in any storey shall not exceed 0.004 times the height of storey height

Height of Storey = 4000mm

0.004(h) = 0.004(4000) = 16mm

Hence after analyzing the Building the results obtained for five models in both longitudinal and transverse direction and there comparisons are presented in tabular form.

Table - 2: Storey Drift of Building in Longitudinal direction

Bare Model	Open Bottom Storey	Steel Bracings in Bottom Storey	Storey no.
0.0009	0.000045	0.00008	**6**
0.0017	0.000053	0.000094	**5**
0.0022	0.000063	0.000113	**4**
0.0025	0.000073	0.00015	**3**
0.0028	0.000113	0.000272	**2**
0.0022	0.004857	0.002009	**1**

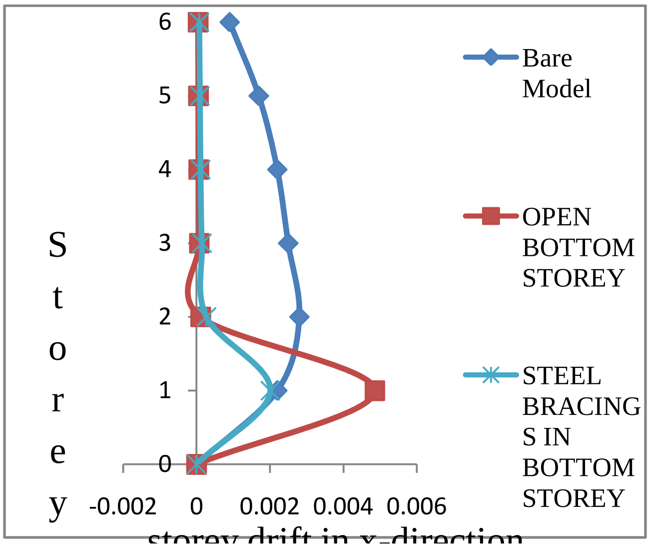

Fig - 5: Storey Drift of Building in Longitudinal direction

Table - 3: Storey Drift of Building in Transverse direction

Bare Model	Open Bottom Storey	Steel Bracings in Bottom Storey	Storey no.
0.0011	0.000279	0.000475	**6**
0.0019	0.000287	0.000492	**5**
0.0024	0.000293	0.000504	**4**
0.0027	0.000296	0.00051	**3**
0.0029	0.000305	0.000514	**2**
0.0021	0.004272	0.001891	**1**

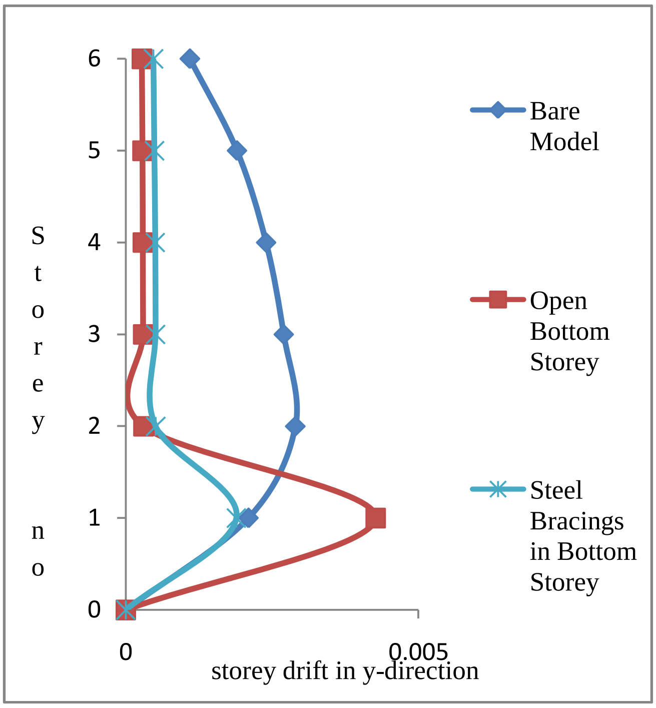

Fig – 6: Storey Drift of Building in Transverse direction

4.2 Lateral Displacements

It is displacement caused by the Lateral Force on the each storey level of structure. Lateral displacement will be more on top storey. Hence after analyzing the Building the results obtained for five models in both longitudinal and transverse direction and there comparison is presented in tabular form.

Table - 4: Lateral Displacements of Building in Longitudinal direction

Bare Model (mm)	Open Bottom Storey (mm)	Steel Bracings in Bottom Storey(mm)	Storey no.
46.29	20.58	9.98	**6**
43.29	20.4	9.67	**5**
37.7	20.21	9.32	**4**
33.9	19.97	8.91	**3**
20.15	19.75	8.43	**2**
8.81	19.35	7.56	**1**

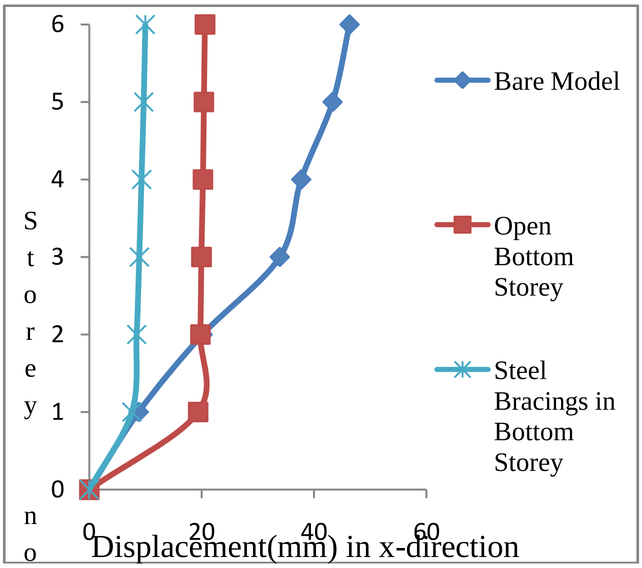

Fig – 7: Lateral Displacements of Building in Longitudinal direction

Table - 5: Lateral Displacements of Building in Transverse direction

Bare Model(mm)	Open Bottom Storey(mm)	Steel Bracings in Bottom Storey(mm)	Storey no.
50.19	22.54	16	**6**
46.25	21.44	14.11	**5**
39.7	20.31	12.15	**4**
31	19.18	10.14	**3**
20.38	18.09	8.11	**2**
8.47	17.08	6.09	**1**

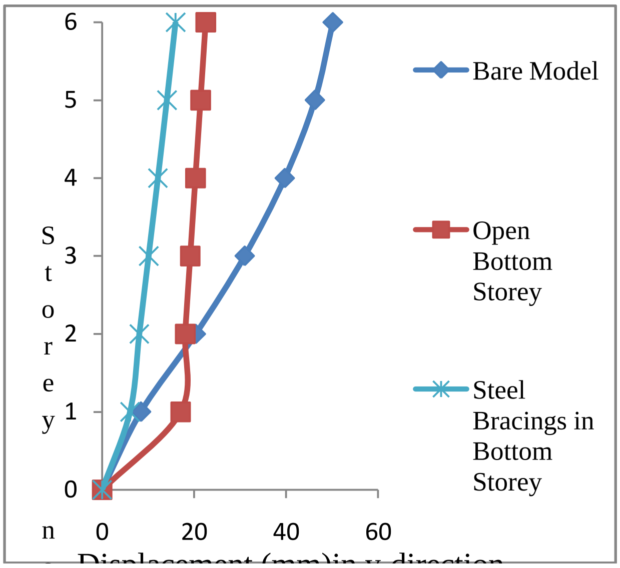

Fig – 8: Lateral Displacements of Building in Transverse direction

4.3 Lateral Force

It is the horizontal seismic force acting on perpendicular to the axis of structure. Hence after analyzing the Building the results obtained for five models in both longitudinal and transverse direction and there comparisons are presented in tabular form.

Table – 6: Comparisons of Lateral Forces (kN) in Longitudinal direction for five models

Bare Model(kN)	Open Bottom Storey(kN)	Steel Bracings in Bottom Storey(kN)	Storey No
283	457	459	**6**
296	689	694	**5**
170	681	687	**4**
107	672	679	**3**
141	663	672	**2**
94	459	468	**1**

Table -7: Comparisons of Lateral Forces (kN) in Transverse direction for five models

Bare Model(kN)	Open Bottom Storey(kN)	Steel Bracings in Bottom Storey(kN)	Storey No
286	526	526	**6**
281	749	750	**5**
141	700	703	**4**
105	656	661	**3**
141	618	625	**2**
90	411	419	**1**

4.4 Design Seismic Base Shear (Vb):

It is the total design lateral force at the base of a structure. Hence after analyzing the Building the results obtained for five models in both longitudinal and transverse direction and there comparisons are presented in tabular form

Table – 8: Comparisons of Base Shear (kN)

Direction	With No Infill (kN)	Open Ground Storey (kN)	Steel Bracings In Bottom Storey (kN)
Longitudinal	1091	3621	3659
Transverse	1044	3660	3684

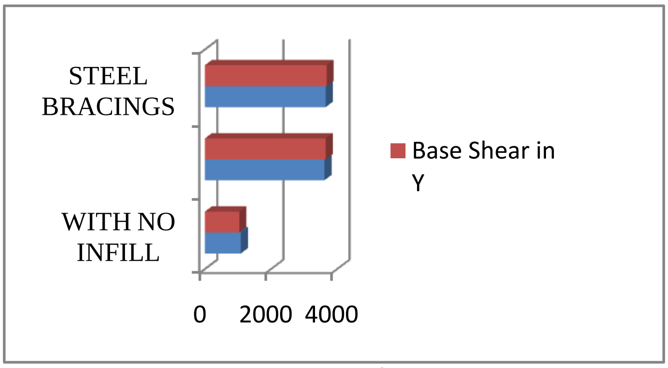

Figure - 9: Comparisons of Base Shear (kN)

4.5 Torsion:

Table - 9: Comparisons of Torsion (kN-m)

Storey No.	With No Infill (kNm)	Open Ground Storey (kNm)	Steel Bracings In Bottom Storey (kNm)
6	1143	2010	1868
5	1206	3103	2839
4	673	3056	2818
3	486	3023	2793
2	572	2986	2764
1	375	2051	1913
	4455	16229	14995

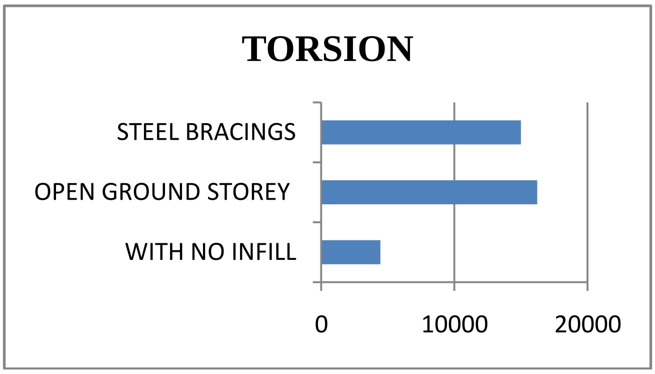

Fig - 10: Comparisons of Torsion (kN-m)

4.6 Fundamental Natural Period (T_i)

It is the first (longest) modal time period of vibration Hence after analyzing the Building the results obtained for five models in both longitudinal and transverse direction and there comparisons' are presented in tabular form

Table – 10: Comparisons of Time Period (sec)

Direction	With No Infill (Sec)	Open Ground Storey (Sec)	Steel Bracings In Bottom Storey (Sec)
Longitudinal	1.767	0.9727	0.492
Transverse	1.848	0.9606	0.586

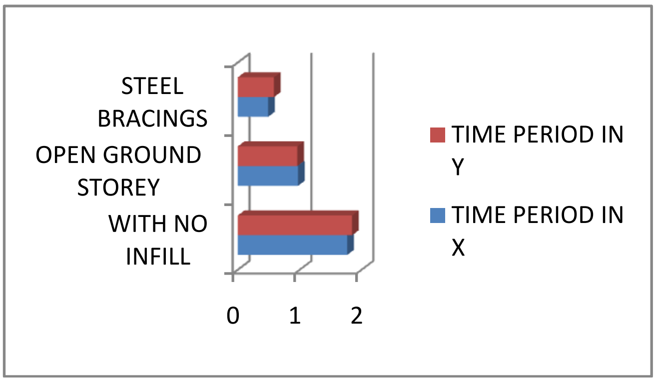

Fig - 11: Comparisons of Time Period (sec)

4.7 Stiffness

It is the rigidity of an object – the extent to which it resists deformation in response to the applied force.

$$K = \frac{P}{\Delta}$$

Hence after analyzing the Building the results obtained in both longitudinal and transverse direction and there comparisons are presented in tabular form.

4.8 Soft Storey:

It is one in which the lateral stiffness is less than 70 percent of that in the storey above.

Table - 11: Calculation of Stiffness (kN/m) for open Bottom Storey model in Longitudinal Direction

Open Bottom Storey				
Storey No.	**Load(kN)**	**Displacements(mm)**	**Stiffness (kN/m)**	**Ratio**
(top storey)6	457	20.58	22206	
5	689	20.4	33775	
4	681	20.21	33696	
3	672	19.97	33650	
2	670	19.75	33924	
1	452	19.45	23239	68

Table - 12: Calculation of Stiffness (kN/m) for Steel Bracings model in Longitudinal Direction

Steel Bracings In Bottom Storey				
Storey No.	**Load(kN)**	**Displacements(mm)**	**Stiffness (kN/m)**	**Ratio**
(top storey)6	459	9.98	45992	
5	694	9.67	71768	
4	687	9.32	73712	
3	679	8.91	76206	
2	672	8.43	79715	
1	468	7.56	61904	**77**

Here lateral stiffness is **more than** 70 percent of that in the storey above. Hence it is safe when steel braced system is provided in open bottom storey.

Table - 13: Calculation of Stiffness for open Bottom Storey model in Transverse Direction

Open Bottom Storey				
Storey No.	**Load(kN)**	**Displacements(mm)**	**Stiffness (kN/m)**	**Ratio**
(top storey)6	526	22.54	23336	
5	749	21.44	34935	
4	700	20.31	34466	
3	656	19.18	34202	
2	638	18.09	35268	
1	411	17.08	24063	68

Table - 14: Calculation of Stiffness for steel bracing model in Transverse Direction

Steel Bracings In Bottom Storey				
Storey No.	**Load(kN)**	**Displacements(mm)**	**Stiffness (kN/m)**	**Ratio**
(top storey)6	526	16	32875	
5	750	14.11	53153	
4	703	12.15	57860	
3	661	10.14	65187	
2	625	8.11	77065	
1	419	6.09	68801	**89**

Here lateral stiffness is **more than** 70 percent of that in the storey above. Hence it is safe when steel braced system is provided in open bottom storey.

5. OBSERVATIONS AND CONCLUSIONS

1. Storey drift of steel braced system at bottom storey is within the limit as clause no 7.11.1 of IS-1893 (Part-1):2002.
2. Storey Stiffness of steel braced model at bottom storey is within the limit as clause no 4.20 of IS-1893 (Part-1):2002.
3. Deflection in case of bare frame is very large, when compared to other cases. The presence of steel bracing system can affect the seismic behavior of frame structure to large extent, and the steel bracing system increases stiffness of the structure.
4. It is found that the steel bracing system at open bottom storey significantly contributes to the structural stiffness and reduces the maximum inter story drift, lateral displacement of R.C.C building.
5. It is found that the X type of steel bracing system at bottom storey has less torsion effect.

RC frame buildings with open bottom storey are known to perform poorly during in strong earthquake shaking. Thus, it is clear that such buildings will exhibit poor performance during a strong shaking. This hazardous feature of Indian RC frame buildings needs to be recognized immediately and necessary measures taken to improve the performance of the buildings.

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