Design and Comparison of Regular and Irregular Multi-Storey Building Located in High Seismic Zone with IS Code 1893-2002 and IS Code 1893-2016

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ABSTRACT : In the present study G+7 R.C.C framed building of four totally different shapes like Rectangular, L-shape, H-shape, and PLUS-shape are used as comparison models have been prepared and were analysed with the assistance of ETABS v19.1.0 version. In the present examination, Equivalent diagonal strut (EDS) method is used to find out the width of the strut. For Macro model, Equivalent diagonal strut (EDS) method is used to find out the width of the strut. The results of Story displacement, base shear, story drift, axial force, interstorey drift ratio (IDR) with and without considering the effect of infill walls are discussed and conclusions are made in this studies. The results indicate that building with severe irregularity produces more deformation than those with less irregularity particularly in high seismic zones and parameters computed by IS1893:2002 are found to be significantly higher compared to new IS1893:2016 which gives better and safe result.

Keywords: *ETABS, Equivalent diagonal strut, member, Base shear, NLTHA, Base Shear, IDR.*

1. INTRODUCTION:

A vast portion of India is prone to seismic hazards. Hence, for the design of structures seismic load considerations are important. In structures the lateral forces generated because of seismic tremor involve concern. These lateral forces induce critical and undesirable stresses, vibrations and lateral displacement of the structure at the top relative to its base. Generally, seismic criteria approaches are expressed in the form of capacity of a structure to guarantee the minor and regular shaking force without maintaining any harm, therefore leaving the structure serviceable after the occasion. The structure ought to withstand direct level of seismic earthquake ground movement without basic harm, however potentially with some auxiliary and additionally non-basic harm. This point of confinement state may compare to quake power equivalent to the most grounded either experienced or estimate at the site. In introduce contemplate the outcomes are examined for reaction range strategy. The primary parameters considered in this investigation to think about the seismic execution of various models are base shear and time period.

1.1 Objectives of Earthquake Resistant Design of Structures:

To ensure sufficient ductility, interconnection between members must be ensured so that structure selected for case study should have enough strength and ductility to withstand large earthquakes. As per IS 1893(part-1) design approach that should be kept in mind are (a) that structures have no less than a minimum strength to withstand minor earthquakes (DBE), which happen as often as possible, without harm; (b) that structures oppose direct earthquakes (DBE) without significant structural harm however some non-basic harm may happen; and (c) that structures withstand real earthquakes (MCE) without collapse.

2. METHODOLOGY AND MATERIALS

To insure the dependability and correctness of the demand parameters a large number of real accelerogram data from past earthquakes of the zone-V region have been selected for the study. Five earthquakes data from different stations across the northeast region of India which recorded these earthquakes were selected as shown in the TABLE 1.0.

According to ASCE 7-05, three to five number of ground motions should be taken for the fair estimation of the response of the structure. Here five selected earthquake motions are normalized and each is then scaled to six PGA levels of 0.06 to 0.36 g. The scale factor= $x * \frac{g}{2}$ (considering Design Basis Earthquake) is applied. Where x can be 0.06, 0.12 etc. Each station records the ground motion in three mutually perpendicular directions, in the study the one with highest PGA was adopted so that the response obtained is maximum.

For nonlinear seismic analysis, the ground motion has to be represented through time histories. Five Spectrum Compatible Ground Motion (SCGM) has been generated. For this five different earthquake records are taken from USGS (United States Geological Survey) site and are converted into SCGMs (Spectrum Compatible Ground Motion) by KUMAR software (2004). The table 1.0 below shows the earthquake location, date of occurrence, its magnitude and duration of occurrence Ground Motion Data. While ground motion data represented into graphical format shown from fig.2.1 to 2.5 respectively.

TABLE 1.0 SCGM (Spectrum Compatible Ground Motion)

Sr No	Near-Fault Earthquake Ground Motions	Recording Station	Time (sec)	Magnitude(Mw)	PGA (g)
1	May 18,1987 Halflong, Assam,	Halflong	0.54	7.6	0.544
2	Aug 6,1988 Hojai, Assam,	Hojai	27.64	6.5	0.46
3	Feb 6,1988 Halflong, Assam,	Halflong	0.18	7.3	0.34
4	Jan 10,1990 Hojai, Assam,	Hojai	0.74	6.7	-0.40
5	May 08, 1997 Silchar, Assam,	Silchar	7.04	6.3	-0.48

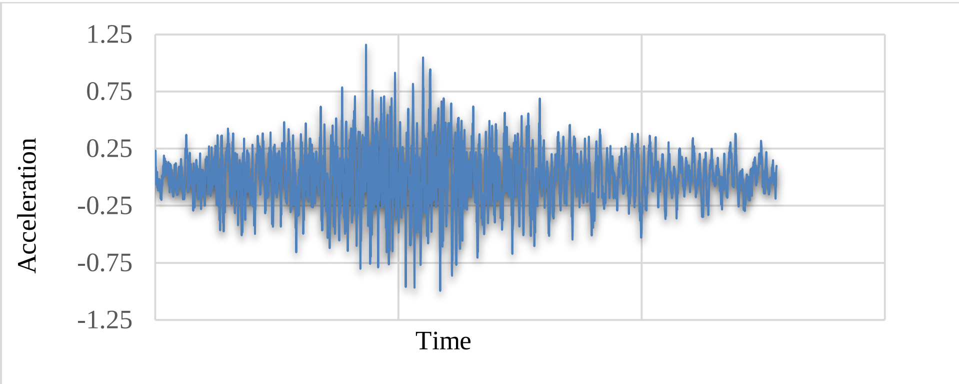


FIGURE2.1 Halflong 1987 Ground Motion

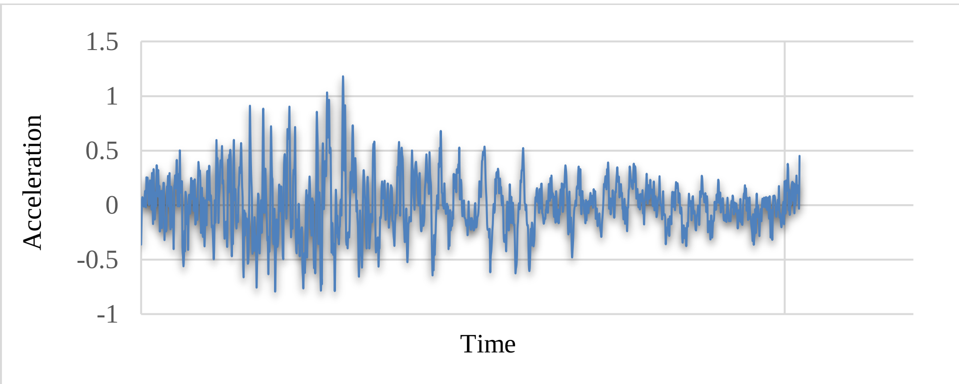


FIGURE2.2 Hojai 1988 Ground Motion

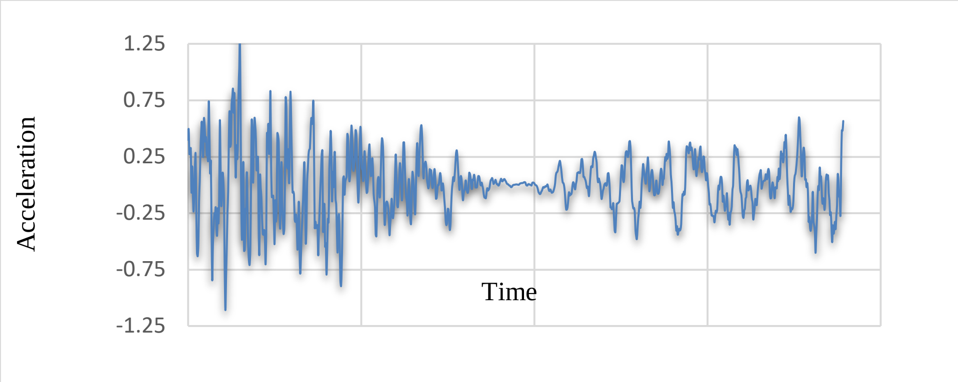


FIGURE2.3 Halflong 1988 Ground Motion

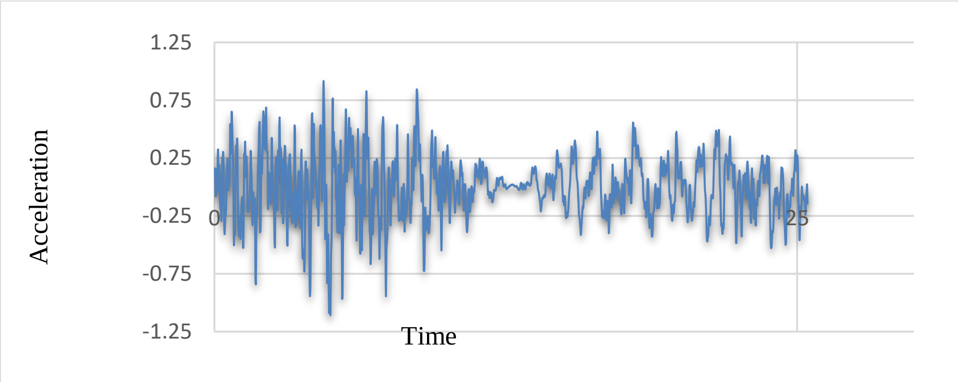


FIGURE2.4 Hojai 1990 Ground Motion

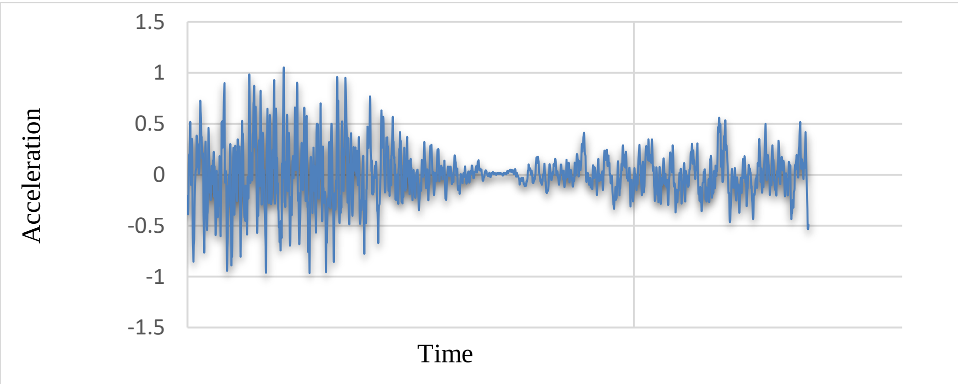


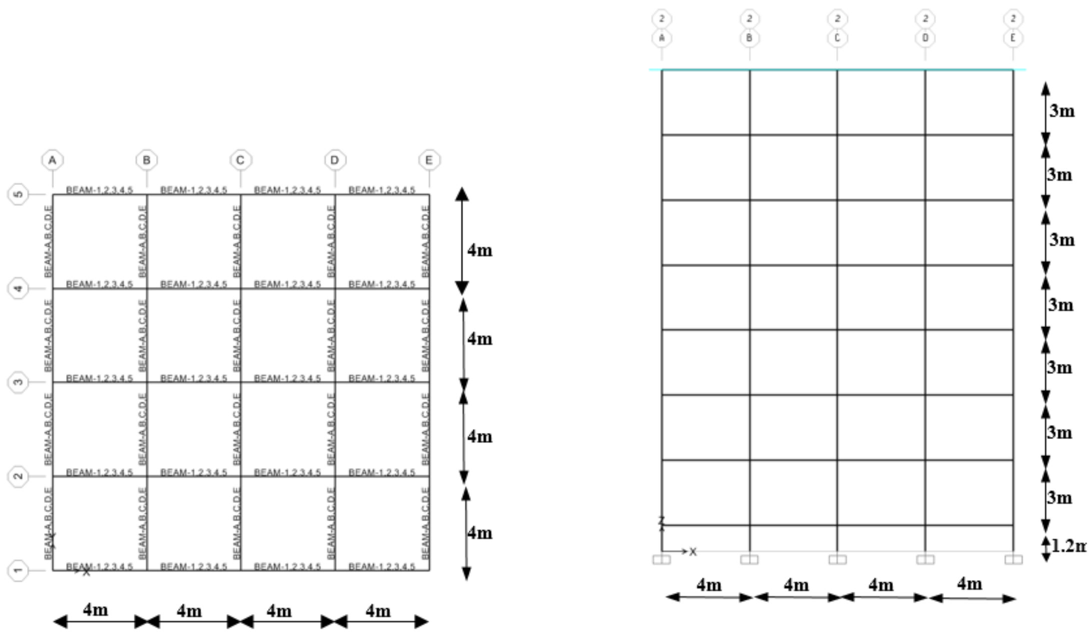
FIGURE2.5 Silchar 1997 Ground Motion

2.1 DETAILS OF BUILDING UNDER CONSIDERATION

The four different building Regular-shape, H-shape, T-shape, and Plus-shape whose plan and elevation are shown in below FIGURE used in this case study are RC moment resisting framed building with 4x4 bay configuration. Each bay is of size 4m. The building is detailed as per seismic detailing code (IS13920-1993) and is located in seismic zone V. Similar empirical expressions given in IS1893:2002 and IS1893:2016 is used to calculate Fundamental time period for each four types of building. The loads considered on each floor, are (a) all dead loads on each floor, (b) half weight of the columns and walls above and below the floor, and (c) the live load. Fundamental time periods of the buildings are estimated by using empirical relations given in the two versions of IS code. Holzer's i.e. period and mode shapes for first three modes of the buildings method is used for dynamic characteristics.

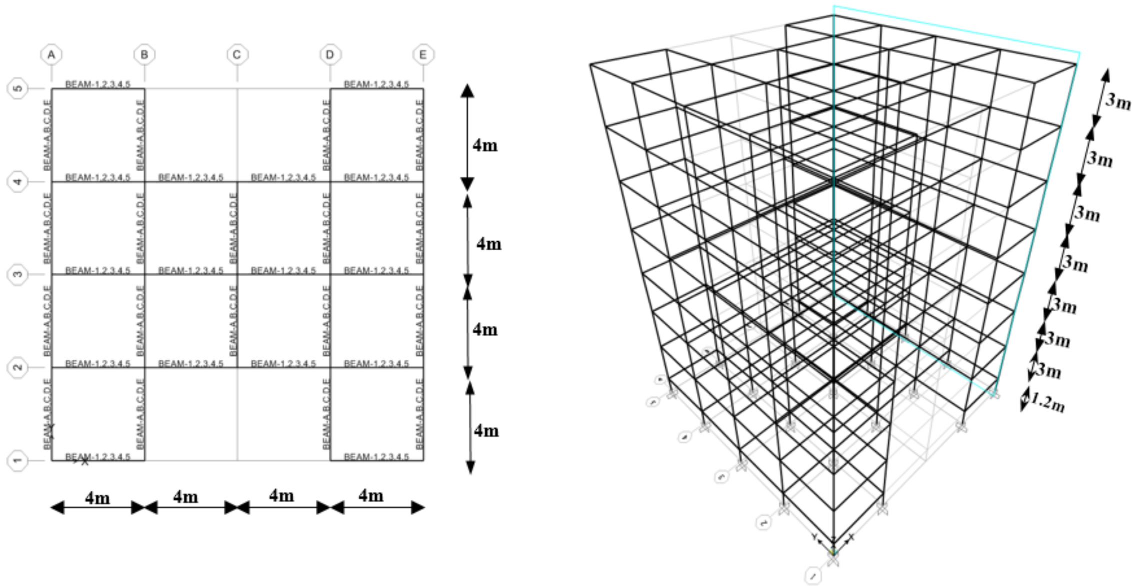
TABLE 2.0 Details of Beams and Columns used for frame

Specifications	Regular-Shape (mm)	Plus-Shape (mm)	H-Shape (mm)	T-Shape (mm)
PB (1,2,3,4,5)	400 x 400	500 x 400	480 x 480	500 x 400
PB (A,B,C,D,E)	400 x 400	500 x 400	480 x 480	500 x 400
BEAM (1,2,3,4,5)	450 x 350	350 x 350	400 x 400	450 x 400
BEAM (A,B,C,D,E)	450 x 350	370 x 350	400 x 400	450 x 400
COLUMN (1 to 4)	550 x 550	430 x 430	460 x 460	470 x 470
COLUMN (5,6)	500 x 500	380 x 380	430 x 430	430 x 430
COLUMN (7.8)	450 x 450	350 x 350	380 x 380	400 x 400



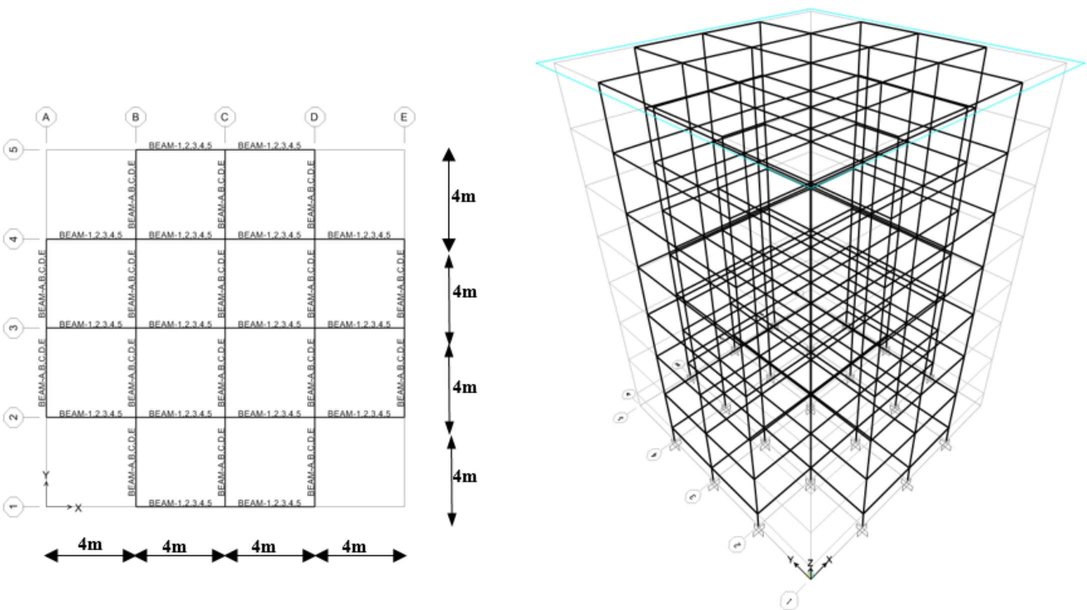
REGULAR PLAN **REGULAR ELEVATION**

FIGURE2.6 Pan and Elevation of Regular frame



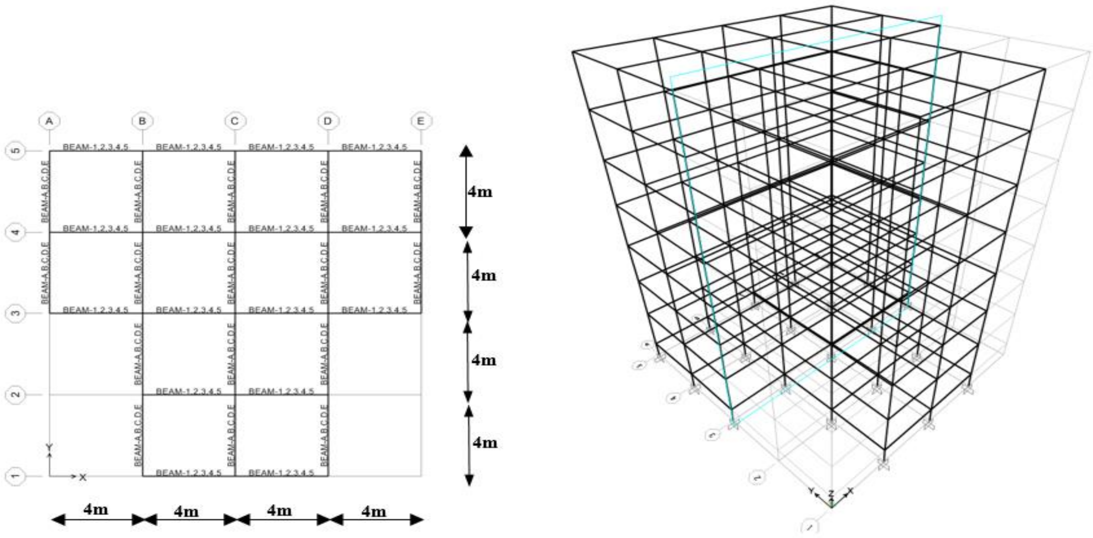
H-SHAPE PLAN H-SHAPE ELEVATION

FIGURE2.7 Pan and Elevation of H - frame



PLUS-SHAPE PLAN PLUS-SHAPE ELEVATION

FIGURE2.8 Pan and Elevation of PLUS – frame



T-SHAPE PLAN T-SHAPE ELEVATION

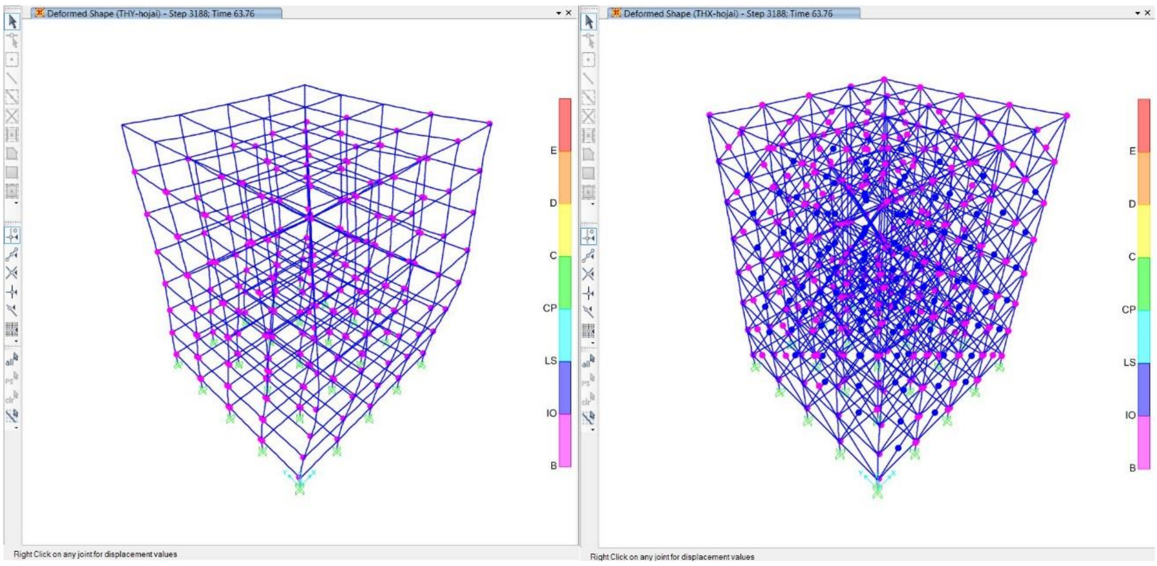
FIGURE2.9 Pan and Elevation of T - frame

3. RESULTS AND ANALYSIS

3.1 Hinge Formation

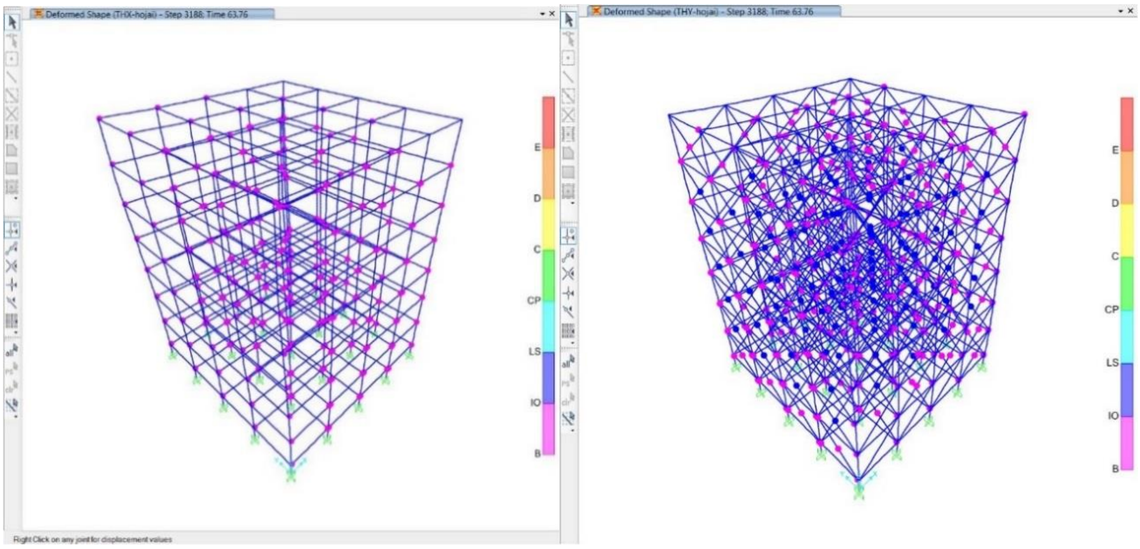
3.1.1 Regular Shape

The time history last second hinge formation of that particular best location is checked in order to ensure that no nonlinear hinges should form on columns. The SCGMs records in which worst kind of hinges are forming is taken into consideration and are shown here. Here it is found that only IO and LS level hinges are forming on beams and columns are free from hinges.



(a) Regular-Shape By Is1893:2002 (b) Regular-Shape By Is1893:2016

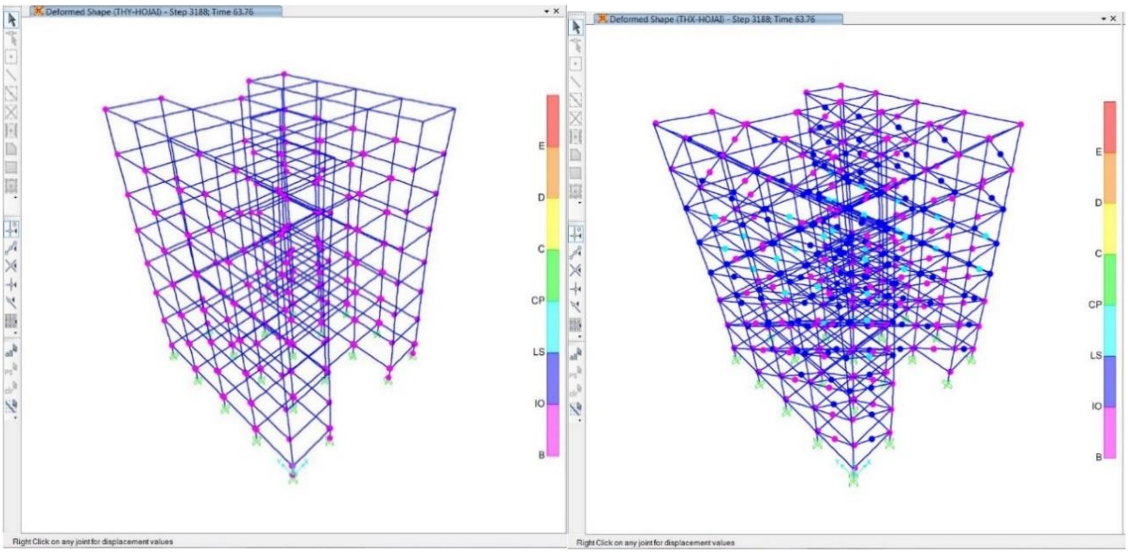
FIGURE3.1 Plastic Hinge Formation in X-Direction



(a) Regular-Shape By Is1893:2002 (b) Regular-Shape By Is1893:2016

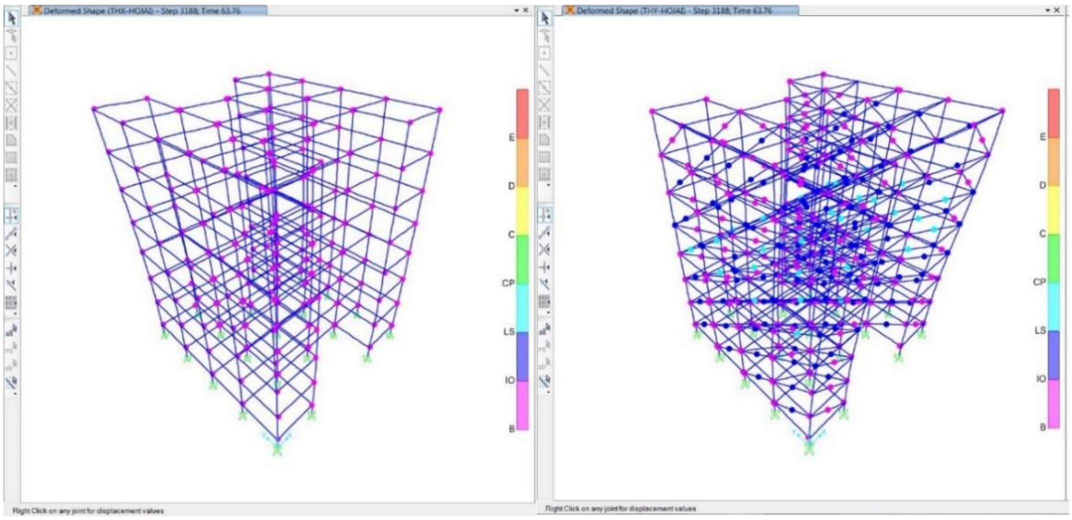
FIGURE3.2 Plastic Hinge Formation in Y-Direction

3.1.2. H-Shape



(a) H-Shape By IS1893:2002 (b) H-Shape By IS1893:2016

FIGURE 3.3 Plastic Hinge Formation in X-Direction

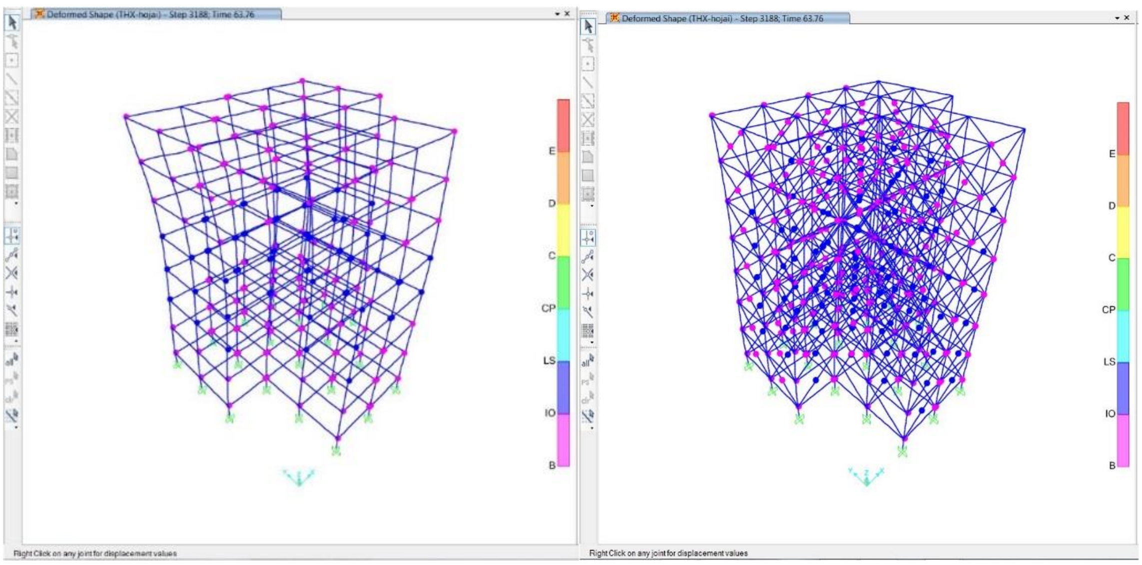


(a) H-Shape By IS1893:2002 (b) H-Shape By IS1893:2016

FIGURE3.4 Plastic Hinge Formation in Y-Direction

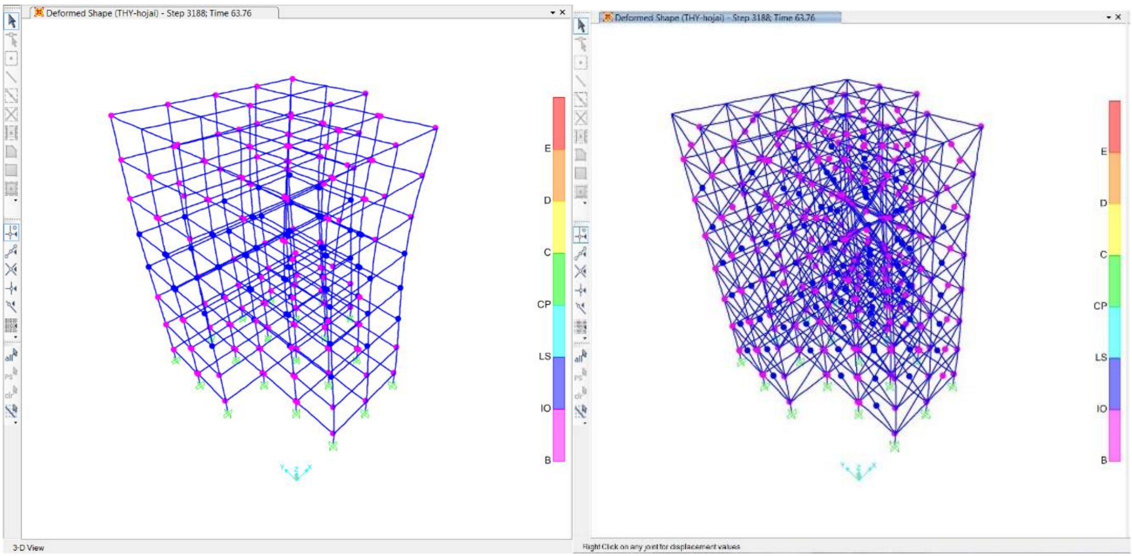
The time history last second hinge formation of both the building's design from old and new code are checked in order to ensure that no nonlinear hinges should form on columns. The SCGMs records in which worst kind of hinges are forming is taken into consideration and are shown from fig.6.3 and fig.6.4. Here it is found that as per IS 1893: 2002 only IO level hinges are forming on beams and as per IS 1893: 2016 hinges on beams can reach up to CP level. In both cases columns are free from hinges

3.1.3. T-Shape



(a) T-Shape By IS1893:2002 (b) T-Shape By IS1893:2016

FIGURE3.5 Plastic Hinge Formation in X-Direction

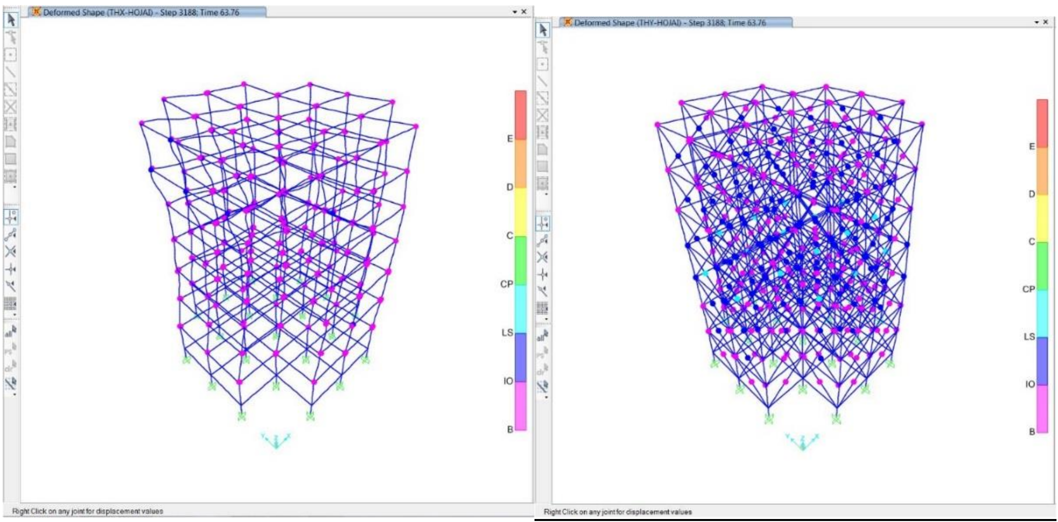


(a) T-Shape By IS1893:2002 (b) T-Shape By IS1893:2016

FIGURE3.6 Plastic Hinge Formation in Y-Direction

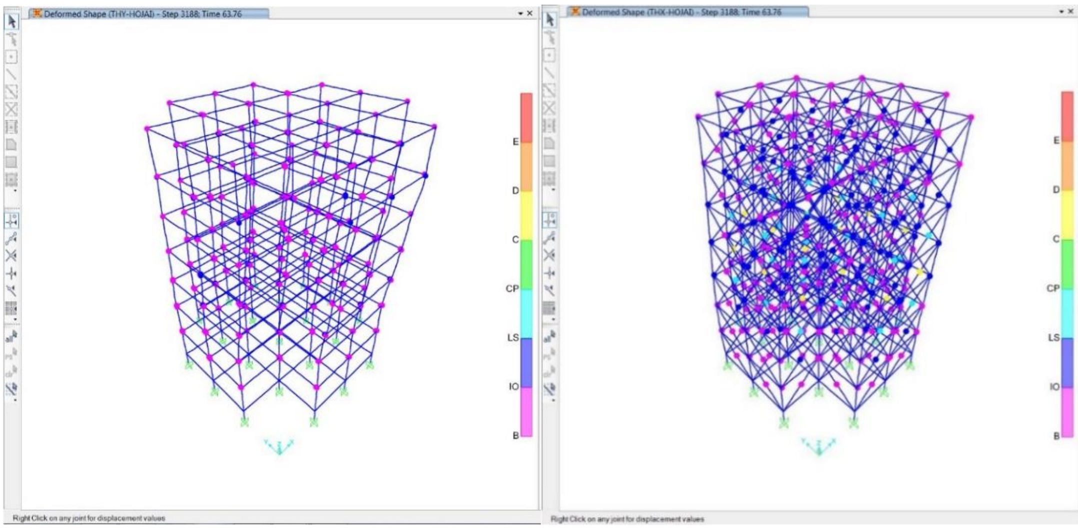
The time history last second hinge formation of both the building's design from old and new code are checked in order to ensure that no nonlinear hinges should form on columns. The SCGMs records in which worst kind of hinges are forming is taken into consideration and are shown from fig.6.6 and fig.6.7. Here it is found that as per IS 1893: 2002 only IO level hinges are forming on beams and as per IS 1893: 2016 hinges on beams can reach up to CP level. In both cases columns are free from hinges

3.1.4. Plus-Shape



(a) Plus-Shape By IS1893:2002 (b) Plus-Shape By IS1893:2016

FIGURE 3.7 Plastic Hinge Formation in X-Direction



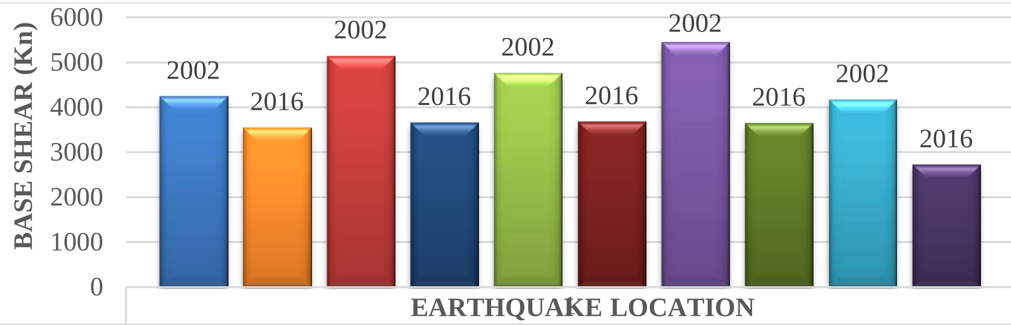
(a) Plus-Shape By IS1893:2002 (b) Plus-Shape By IS1893:2016

FIGURE 3.8 Plastic Hinge Formation in Y-Direction

The time history last second hinge formation of both the building's design from old and new code are checked in order to ensure that no nonlinear hinges should form on columns. The SCGMs records in which worst kind of hinges are forming is taken into consideration and are shown from fig.6.7 and fig.6.8. Here it is found that as per IS 1893: 2002 only IO level hinges are forming on beams and as per IS 1893: 2016 hinges on beams can reach up to CP level. In both cases columns are free from hinges

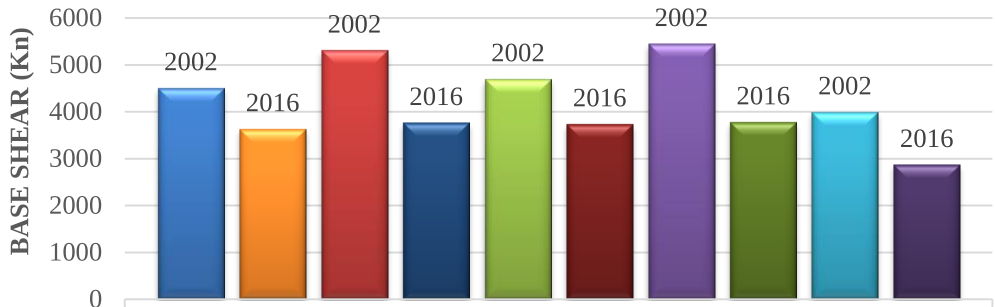
3.2 BASE SHEAR

3.2.1. Regular Shape



	EARTHQUAKE LOCATION
HALFLONG-2002	4241.78863
HALFLONG-2016	3546.03243
HOJAI-2002	5143.47077
HOJAI-2016	3659.72822
NE1988-2002	4759.93201
NE1988-2016	3677.93899
NE1990-2002	5449.20792
NE1990-2016	3646.16932
NE1997-2002	4167.46442
NE1997-2016	2719.7095

FIGURE3.9 Base Shear along X-Direction for Different SCGM

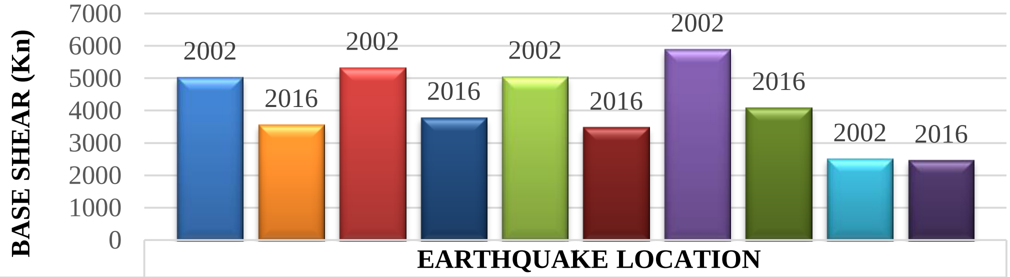


	EARTHQUAKE LOCATION
HALFLONG-2002	4506.71726
HALFLONG-2016	3631.77671
HOJAI-2002	5310.09292
HOJAI-2016	3764.92757
NE1988-2002	4698.53485
NE1988-2016	3737.06884
NE1990-2002	5449.20792
NE1990-2016	3779.84067
NE1997-2002	3992.14024
NE1997-2016	2868.91269

FIGURE3.10 Base Shear along Y-Direction for Different SCGM

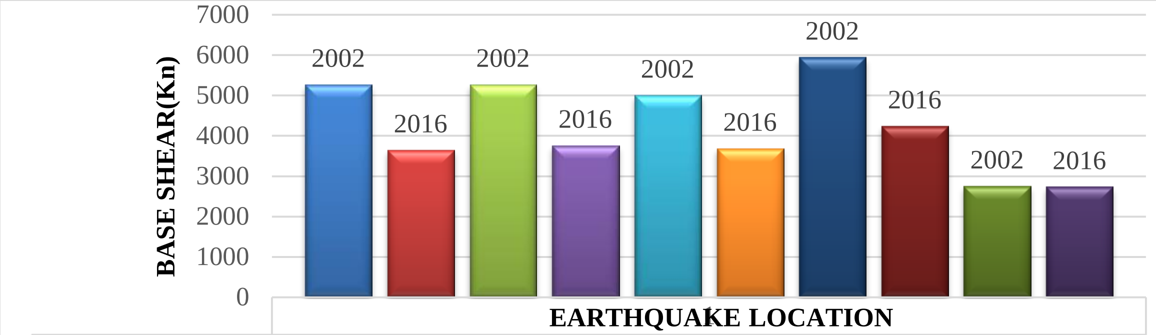
From fig.6.9 and fig 6.10, The Base shear calculated as per old version IS 1893:2002 for Regular-frame, found to be higher than new version of IS 1893:2016 by 28.84% approximately for selected Hojai SCGM this values valid for both X and Y direction.

3.2.2. H-Shape



	EARTHQUAKE LOCATION
HALFLONG-2002	5040.83217
HALFLONG-2016	3574.83487
HOJAI-2002	5340.89516
HOJAI-2016	3798.29968
NE1988-2002	5064.47026
NE1988-2016	3490.50039
NE1990-2002	5906.82612
NE1990-2016	4100.79692
NE1997-2002	2516.34859
NE1997-2016	2471.50026

FIGURE3.11 Base Shear along X-Direction for Different SCGM

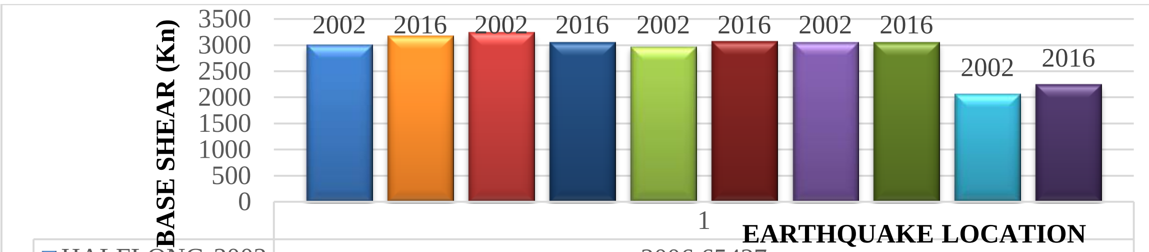


HALFLONG-2002	5269.96901
HALFLONG-2016	3646.15052
HOJAI-2002	5269.97062
HOJAI-2016	3760.71491
NE-1988	5002.45899
NE1988-2016	3685.96656
NE1990-2002	5944.00904
NE1990-2016	4241.08661
NE1997-2002	2751.67004
NE1997-2016	2734.65604

FIGURE3.12 Base Shear along Y-Direction for Different SCGM

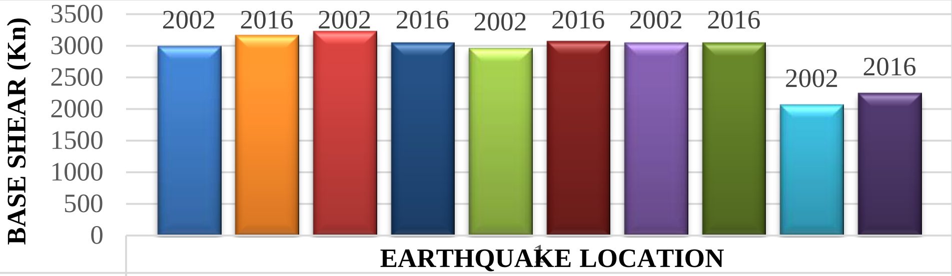
From fig.6.11 and fig 6.12, Base shear calculated as per old version IS 1893:2002 for H-frame, found to be higher than new version of IS 1893:2016 by 30.42% approximately for selected Hojai SCGM this values valid for both X and Y direction.

3.2.3. T-Shape



HALFLONG-2002	3006.65427
HALFLONG-2016	3175.27753
HOJAI-2002	3242.16617
HOJAI-2016	3056.0483
NE1988-2002	2975.47934
NE1988-2016	3073.4268
NE1990-2002	3055.84608
NE1990-2016	3055.63228
NE1997-2002	2070.39088
NE1997-2016	2252.09339

FIGURE3.13 Base Shear along X-Direction for Different SCGM

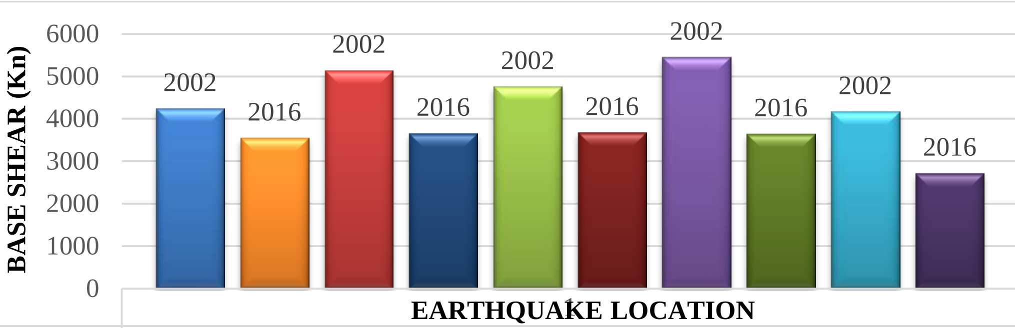


HALFLONG-2002	2998.9095
HALFLONG-2016	3170.60279
HOJAI-2002	3236.36748
HOJAI-2016	3053.65155
NE1988-2002	2966.2112
NE1988-2016	3071.10905
NE1990-2002	3053.50525
NE1990-2016	3052.70467
NE1997-2002	2070.3927
NE1997-2016	2254.64181

FIGURE3.14 Base Shear along Y-Direction for Different SCGM

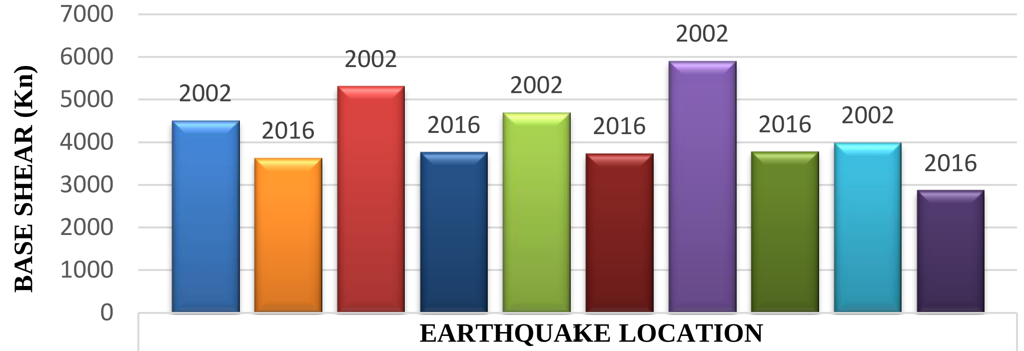
From fig.6.13 and fig 6.14, Base shear calculated as per old version IS 1893:2002 for T-frame, found to be higher than new version of IS 1893:2016 by 5.8% approximately for selected Hojai SCGM this values valid for both X and Y direction.

3.2.4. Plus-Shape



HALFLONG-2002	4241.78863
HALFLONG-2016	3546.03243
HOJAI-2002	5143.47077
HOJAI-2016	3659.72822
NE1988-2002	4759.93201
NE1988-2016	3677.93899
NE1990-2002	5449.20792
NE1990-2016	3646.16932
NE1997-2002	4167.46442
NE1997-2016	2719.7095

FIGURE3.15 Base Shear along X-Direction for Different SCGM



HALFLONG-2002	4506.71726
HALFLONG-2016	3.63E+03
HOJAI-2002	5310.09292
HOJAI-2016	3764.92757
NE1988-2002	4698.53485
NE1988-2016	3737.06884
NE1990-2002	5906.75217
NE1990-2016	3779.84067
NE1997-2002	3992.14024
NE1997-2016	2868.91269

FIGURE3.16 Base Shear along Y-Direction for Different SCGM

From fig.6.13 and fig 6.14, Base shear calculated as per old version IS 1893:2002 for PLUS-frame, found to be higher than new version of IS 1893:2016 by 29.09% approximately for selected Hojai SCGM this values valid for both X and Y direction

4. CONCLUSIONS

1) Base shear calculated as per old version IS 1893:2002 for Regular-frame, H-frame, T-frame and Plus-frame found to be higher than new version of IS 1893:2016 by 28.84%, 30.42%, 5.8%, and 29.09% respectively for selected Hojai EQ data this values valid for both X and Y direction.
2) Shear Force (S.F.) calculated from IS 1893:2002 for Regular-frame, H-frame, T-frame and Plus-frame found to be greater by 30%, 34%, 31.75%, and 33% respectively for frame no. 192 in comparison of IS 1893:2016 and load combination preferred for S.F. result is 1.5(DL ± EQ)
3) Bending moment (B.M.) calculated from IS 1893:2002 for Regular-frame, H-frame, T-frame and Plus-frame found to be greater by 43%, 52%, 44%, and 60% respectively for frame no. 192 in comparison of IS 1893:2016 and load combination preferred for S.F. result is 1.5(DL ± EQ)
4) Max Roof displacement in X-direction by IS 1893:2016 for Regular-frame, H-frame, and Plus-frame found to be reduced by 38.58%, 44%, and 10% respectively in comparison with old seismic code for selected North East (year-1988) SCGM data
5) Similarly max Roof displacement in Y-direction by IS 1893:2016 for Regular-frame, H-frame, and Plus-frame found to be reduced by 36.83%, 50%, and 18.8% respectively in comparison with old seismic code for selected North East (year-1988) SCGM data
6) Max Inter Storey Drift Ratio (IDR) in X-direction as per IS 1893:2016 for Regular-frame, H-frame, Plus-frame and T-frame found to be reduced by 0.094mm, 0.38mm, 0.33mm, and 0.24mm respectively when compared with old seismic code.
7) Similarly max Inter Storey Drift Ratio (IDR) in Y-direction as per IS 1893:2016 for Regular-frame, H-frame, Plus-frame and T-frame found to be reduced by 0.072mm, 0.63mm, 0.1mm, and 0.26mm respectively when compared with old seismic code

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