Seismic Performance of Steel Moment Resisting Frames (SMRF) With Torsional Irregularities

Mr. Abhinav Gupta[1], Dr. U. R. Awari[2]
[1] Dept of Civil Engineering
[2]Professor, Dept of Civil Engineering
[1, 2] AISSMS College of Engineering.

Abstract- *This paper presents the development and the SEISMIC performance evaluation of steel SMRFs with nonlinear replaceable links. Although existing SMRFs can provide life safety during a design level earthquake, they are expected to sustain significant damage at the locations of flexural yielding fuses in the beams. The design of the fuse is also interlinked with the design of the beam, often resulting in over-design. These drawbacks can be mitigated by introducing replaceable links at the locations of expected inelastic action. Four full-scale beam-to-column sub assemblages with two link types were tested under cyclic loading: i) double channels with bolted web connections, ii) W-sections with bolted end plate connections. The experiments demonstrated that MRFs with replaceable links can provide strength and ductility equivalent to existing MRFs. Finite element models were then developed to capture the observed experimental responses, including local buckling, bolt slipping, and bolt bearing. Finally, preliminary design guidelines were proposed.*

Keywords- SMRF, SAP, irregularities torsional.

I. INTRODUCTION

Earthquake is a natural phenomenon associated with violent shaking of the ground. Large strain energy released during an earthquake travels as Seismic waves in all directions through the Earth's layers, reflecting and refracting at each interface. The damage to structures due to earthquake depends on the material that the structure is made from, the type of earthquake wave (motion) that is affecting the structure, and the ground on which the structure is built. Thus, the Seismic loading on the structure during an earthquake is not external loading, but inertial effect due to motion of support. The various factors of the structure contributing to damage during earthquake are vertical irregularities,

Irregularity in strength and stiffness, mass irregularity, torsional irregularity. (Keerthan et al. 2016) Irregular configuration either in plan or in elevation was often recognized as one of the main cause of failure of buildings during past earthquakes. Hence to overcome these issues we need to identify the Seismic performance of the built environment through the development of various analytical procedures, which ensure the structures to withstand during frequent minor earthquakes and produce enough caution whenever subjected to major earthquake events. So that can save as many lives as possible. But nowadays need and demand of the latest generation and growing population has made the architects or engineers inevitable towards planning of irregular configurations. Hence earthquake engineering has developed the key issues in understanding the role of building configurations. In Asymmetric building, center of mass and center of rigidity not coincides with each which causes torsion in that building.

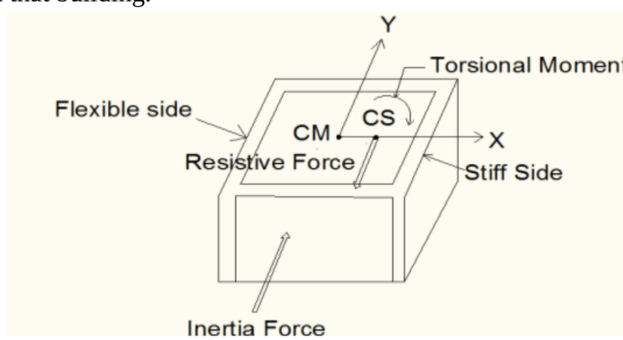


Fig 1 : Torsion irregularities with stiff diaphragm.

1.1 Problem Statement

Present research involves the study of Seismic performance of steel moment resisting frames with torsion irregularities. This research involves analysis of 3 and 9 storeys smrf building and designed according to asce 7-10. Seismic moment frames are placed at different positions in building to investigate effect of different degrees of torsional irregularity on the Seismic performance of building.

1.2 Objectives Of The Study

The main objective of the present work is

1. To study effect of torsional irregularity on performance of steel structure by using literature available.

2. To design 9 storey SMRF for various degrees of torsional irregularity in plan accordingly to ASCE 7-10 by using linear response spectrum analysis.
3. To perform non-linear analysis carried out of 9 stories SMRF by using relevant software for various degrees of torsional irregularity by using nonlinear time history analysis for selected ground motion

II. RESEARCH METHODOLOGY

The primary focus of this study is on the development of an in depth understanding of the SEISMIC behavior of typical SMRF structure for torsional irregularity. In first phase, detailed review factor affected due to torsional irregularity studied in detail with available literature.

In second phase 9-storey SMRF was designed for various degrees of torsional irregularity in plan accordingly to ASCE 7-10. Base shear and storey drift calculated using a linear response spectrum analysis. In third phase, Nonlinear analysis carried out of SMRF building for 9 storey SMRF using relevant software for selected ground motion data for different degree of torsion irregularities. SEISMIC performance evaluation of steel moment resisting frames including torsion irregularities for 9 storey building frame.

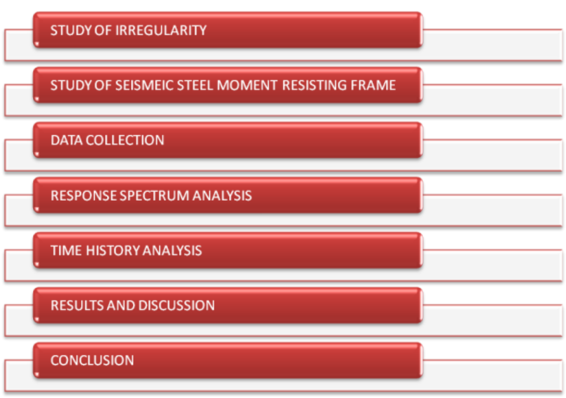


Fig 2 methodology flow chart

2.1 INTRODUCTION TO SAP2000

Objectives:

• Give an over view of the basic commands of SAP2000
• Use of SAP2000 to solve various structural problems
• Develop the ability to continue a self-learning process
• Check and solve assignment questions

Analysis Features

The SAPfire analysis engine offers the following features:

- Static and Seismic analysis
- Linear and nonlinear analysis
- Seismic Seismic analysis and static pushover analysis
- Vehicle live-load analysis for bridges
- Geometric nonlinearity, including P-delta and large-displacement effects
- Staged (incremental) construction
- Creep, shrinkage, and aging effects
- Buckling analysis
- Steady-state and power-spectral-density analysis
- Frame and shell structural elements, including beam-column, truss, membrane, and plate behavior
- Cable and Tendon elements
- Two-dimensional plane and axisymmetric solid elements
- Three-dimensional solid elements
- Nonlinear link and support elements
- Frequency-dependent link and support properties
- Multiple coordinate systems
- Many types of constraints
- A wide variety of loading options
- Alpha-numeric labels
- Large capacity
- Highly efficient and stable solution algorithms

Basic Steps to Solve a Structural Problem using SAP2000:

- Start-up by choosing units, setting up grids or by choosing a model from the library
- Define materials, element properties, loading patterns, analysis cases and combinations
- Draw the model using the powerful graphical interface and selection and editing tools
- Assign displacement boundary conditions (supports)
- Assign loads (forces, moments, displacements, pressure, temperature…)
- SOLVE system, use simplification if possible
- Display Output in graphical and/or tabular form
- Analyze results.

2.6 Torsion Amplification Factor

As pr1893:2002 Part 1 clause7.1 pg no. 17
Torsional irregularity coefficient η_t

$$\eta_t = \delta_{max} / \delta_{avg}$$

Then

(a) If $\eta_t < 1.2$ then torsional irregularity does not exist.
(b) If $1.2 < \eta_t < 2.083$ then torsional irregularity exists.

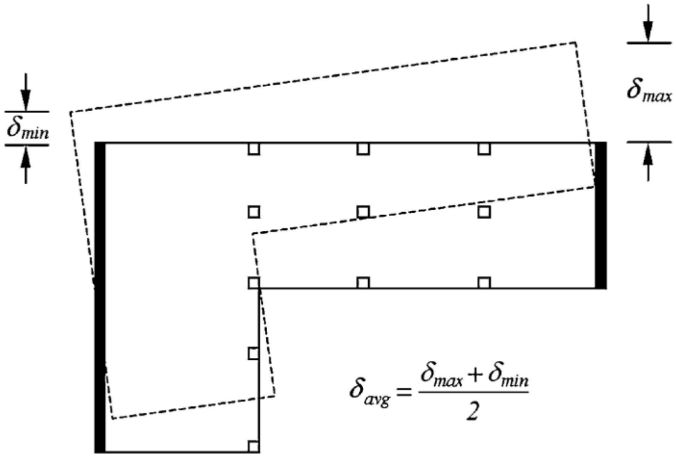


Fig 3 Extreme and average displacements

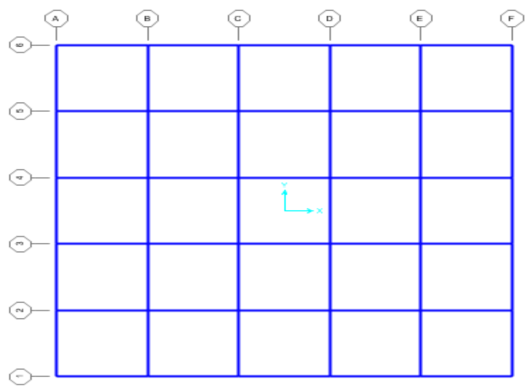


Fig 4 Typical Floor Plans Of 3 Storey And 9 Storey Building

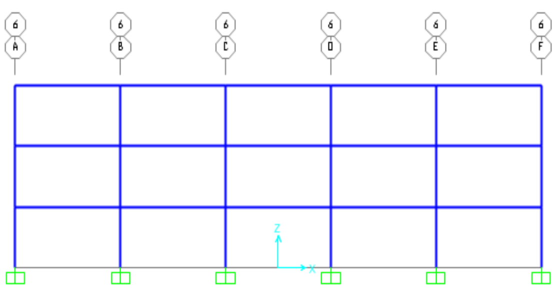


Fig 5 Elevation of 3 Storey Building

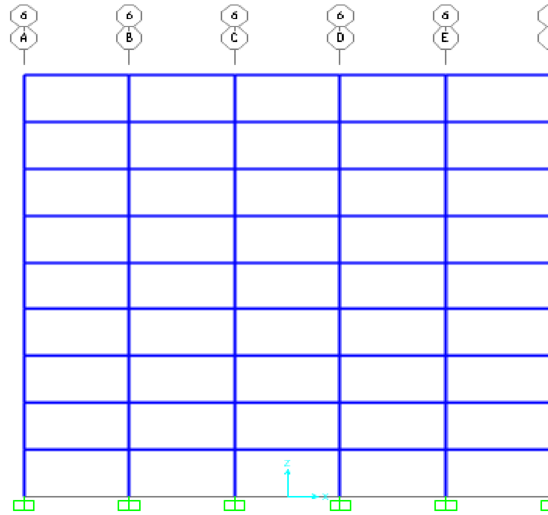


Fig 6 Elevation of 9 Storey Building

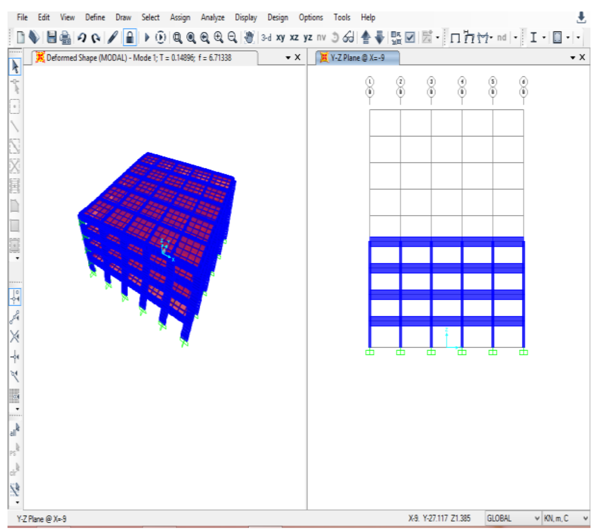


Fig 7 SAP 2000 Mode 1 G+3

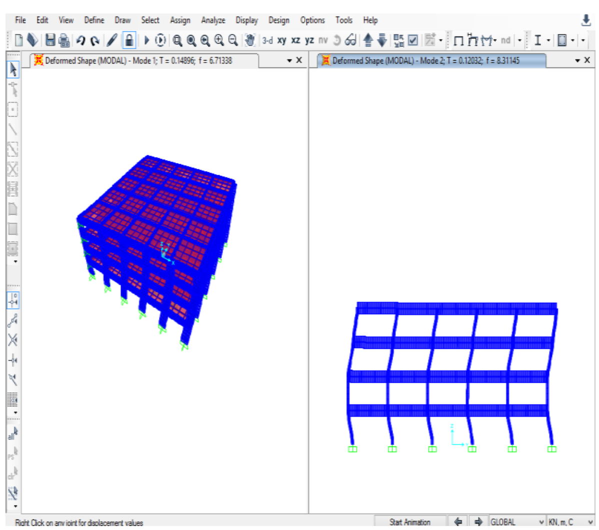


Fig 8 SAP 2000 Mode 2 G+3

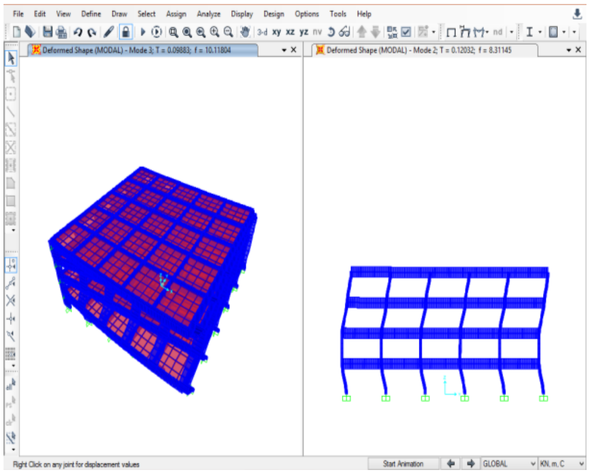


Fig 9 SAP 2000 Mode 3 G+3

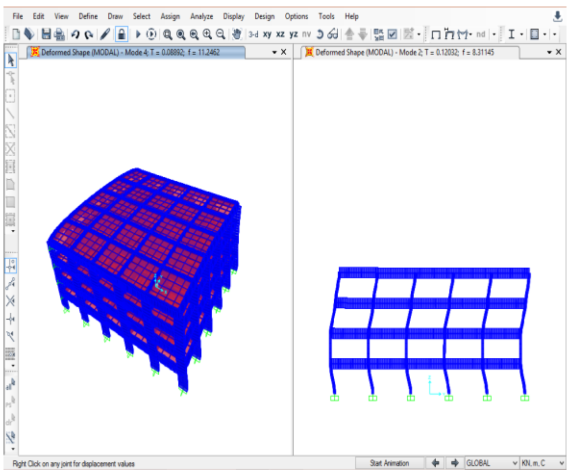


Fig 10 SAP 2000 Mode 4 G+3

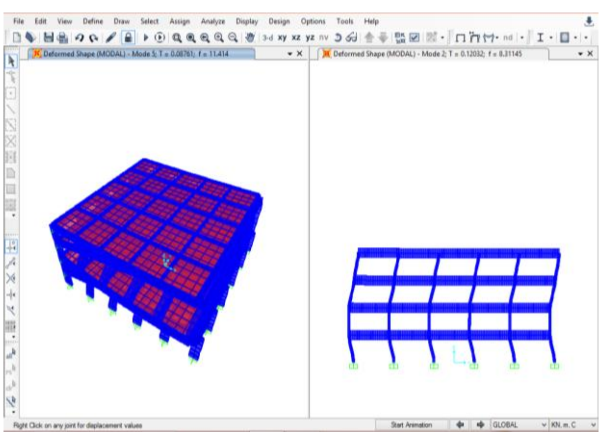


Fig 11 SAP 2000 Mode 5 G+3

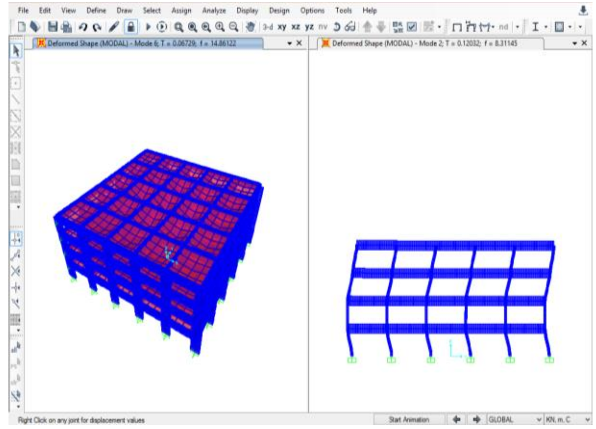


Fig 12 SAP 2000 Mode 6 G+3

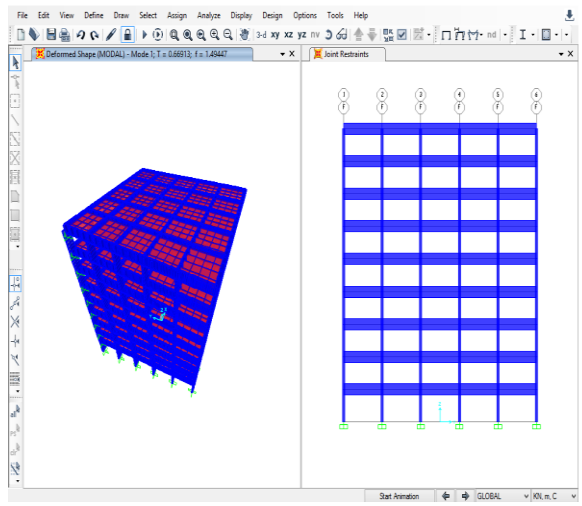


Fig 13 SAP 2000 Mode 1 G+9

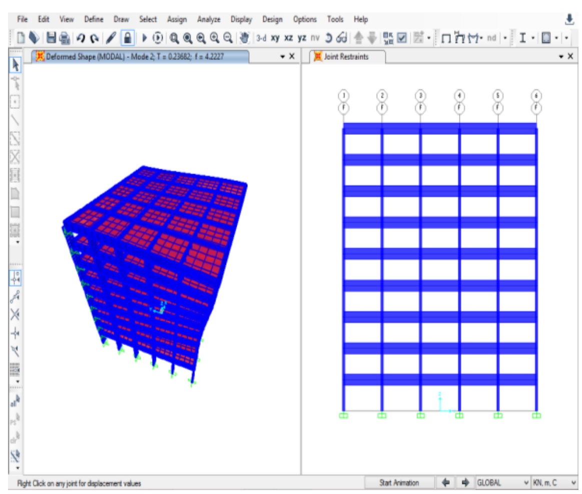


Fig 14 SAP 2000 Mode 2 G+9

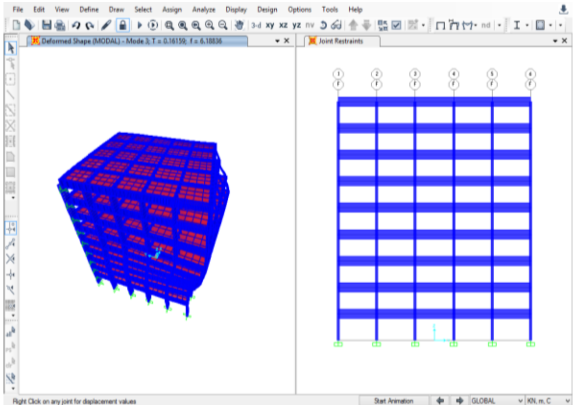


Fig 15 SAP 2000 Mode 3 G+9

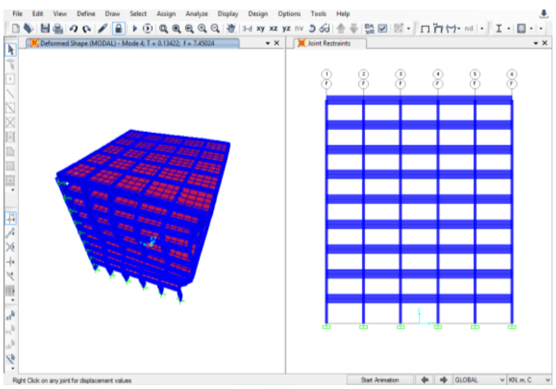


Fig 16 SAP 2000 Mode 4 G+9

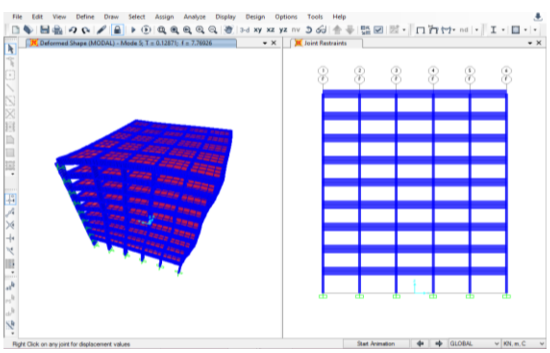


Fig 17 SAP 2000 Mode 5 G+9

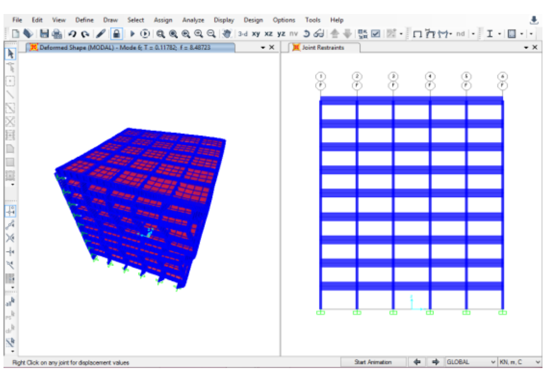


Fig 18 SAP 2000 Mode 6 G+9

III. RESULT AND DISCUSSION

This research is carried out to check the effect of torsional irregularity, mass irregularity and plan irregularity of the building.

The analysis is carried out with Response Spectrum and Time History methods. The results are obtained, tabulated and later the results of response spectrum and time history are compared. The results are obtained for base shear, storey drift.

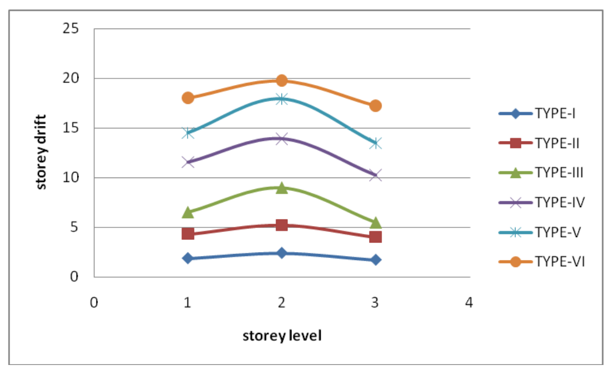
3.1 Response spectrum:-

3-Storey

Storey drift:

Table 1: Storey drift

STOREY	TYPE-I	TYPE-II	TYPE-III	TYPE-IV	TYPE-V	TYPE-VI
STOREY 1	1.868	4.291	6.525	11.567	14.493	18.012
STOREY 2	2.405	5.178	8.96	13.953	17.916	19.75
STOREY 3	1.71	4.007	5.503	10.253	13.471	17.236



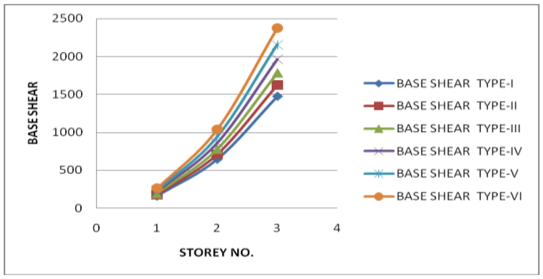
Graph 1: Storey drift

The max storey drift is 19.75 in type VI.

Base shear:

Table 2: Base shear

STOREY NO.	TYPE-I	TYPE-II	TYPE-III	TYPE-IV	TYPE-V	TYPE-VI
1	161.16	177.276	195.0036	214.504	235.9544	259.5498
2	644.64	709.104	780.0144	858.0158	943.8174	1038.199
3	1474.14	1621.554	1783.709	1962.08	2158.288	2374.117
	2279.94	2507.934	2758.727	3034.6	3338.06	3671.866



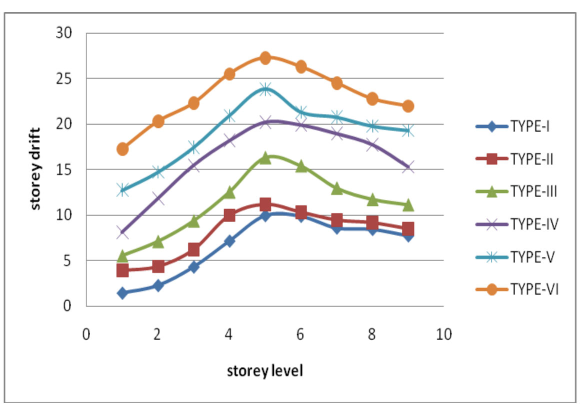
Graph 2: Base shear The max Base shearis2374 in type VI.

9 Storey

Storey drift:

Table 3: Storey drift

STOREY NO.	TYPE-I	TYPE-II	TYPE-III	TYPE-IV	TYPE-V	TYPE-VI
1	1.467	3.942	5.495	8.135	12.718	17.241
2	2.295	4.376	7.071	11.816	14.708	20.286
3	4.33	6.227	9.342	15.462	17.417	22.302
4	7.179	9.986	12.523	18.149	20.899	25.522
5	9.967	11.211	16.321	20.179	23.826	27.291
6	9.896	10.35	15.406	19.871	21.295	26.301
7	8.607	9.49	12.96	18.926	20.734	24.525
8	8.456	9.191	11.721	17.718	19.749	22.767
9	7.75	8.532	11.12	15.296	19.282	21.984



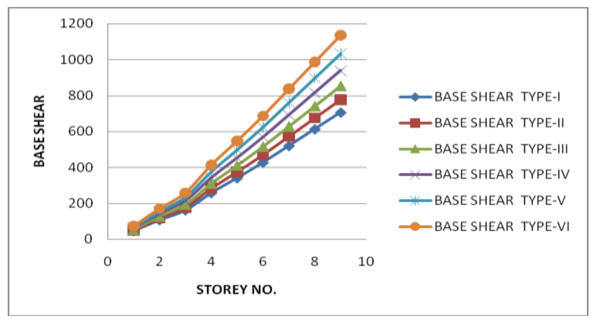
Graph 3: Storey drift

The max storey drift is 27.291 in type VI.

Base shear:

Table 4: Base shear

STOREY NO.	TYPE-I	TYPE-II	TYPE-III	TYPE-IV	TYPE-V	TYPE-VI
1	44.9064	49.39704	54.33674	59.77042	65.74746	72.32221
2	105.8508	116.4359	128.0795	140.8874	154.9762	170.4738
3	160.38	176.418	194.0598	213.4658	234.8124	258.2936
4	256.608	282.2688	310.4957	341.5452	375.6998	413.2698
5	340.0056	374.0062	411.4068	452.5475	497.8022	547.5824
6	426.6108	469.2719	516.1991	567.819	624.6009	687.061
7	519.6312	571.5943	628.7538	691.6291	760.792	836.8712
8	612.6516	673.9168	741.3084	815.4393	896.9832	986.6815
9	705.672	776.2392	853.8631	939.2494	1033.174	1136.492
	3172.3164	3489.548	3838.503	4222.353	4644.588	5109.047



Graph 4: Base shear The max Base shearis1136.492in type VI.

V. CONCLUSION AND SCOPE OF STUDY

In this project modeling of multistoried building with plan irregularity is done. In accordance with ASCE-07 for simulation purpose finite element analysis SAP 2000 is used following conclusions are formed after studying 6 types of SEISMIC moment resisting frame Building with low rise building (3 STORIES)and high rise building`(9 STORIES)

BASE SHEAR

The base shear of building in 3 storey and 9 storey is increased from 10% to 25% as the SEISMIC moment resisting frame is shifted from first bay to last bay this is due to increase in torsional moment in the building.

STOREY DRIFT

The storey drift is observed maximum at the top storey for 3 storey and 9 storey because base shear is observed highest at top storey. The storey drift is increased from 15% to 25% from first bay to last bay this is due to increase in torsional moment in the building

TORSION

The torsional moment increased from first bay to last bay. The torsional moment increased due to base shear increased from first bay to last bay. The torsional amplification factor observed 50 to 60 which gives presence of torsional irregularity in structures. In ths paper the plan irregular model with different type of seismeic moment resisting frame are compared for time historey analysis and response spectrum analysis .It is observed that the base shear and displacement of building is increased due to seismeic moment resisting frame provided and hence storey drift is increased.

SCOPE OF STUDY

- The study can be extended for mass regular and irregular building with plinth beams and shear walls.
- The study can be extended for mass regular and irregular building resting on soft soils.
- The study can be extended for mass regular and irregular building with lateral resisting load building systems.

REFERENCES

[1] AISC 360-10 (American institute of Steel construction's) Specification for structural Steel buildings.

[2] Alinia, M. M. and Dastfan, M. (2006). "Behaviour of thin steel plate shear walls regarding frame members". *Journal of Constructional Steel Research* 62 (2006) 730–738.

[3] Anantwad, S. ,Wakchaure, . M. R. ,Nikam, R. (2012). "Effect of Plan Irregularity on High-rise Structures."*IJAIR*,143-147.

[4] Athanassiadou, C.J., (2008). "SEISMIC performance of R/C plane frames irregular in elevation."*Engineering Structures* 30 (2008):1250–1261.

[5] ASCE 7-10. Minimum design loads for buildings and other structures. USA: American Society of Civil Engineers, Structural Engineering Institute; 2010.

[6] Basu, D. and Gopalakrishnan, N. (2008). "Analysis for preliminary design of a class of torsionally coupled buildings with horizontal setbacks." *Engineering Structures* 30 (2008) 1272–1291.

[7] Basu, D. and Giri, S. (2015). "Accidental eccentricity in multistorey buildings Due to torsional ground motion." *springer.*

[8] Bazeos, N. (2008). "Comparison of three SEISMIC design methods for plane steel frames". *Soil Seismics and earthquake engineering* 29 (2008) 553-562.

[9] Bensalah, M.D.,Bensaibi, M.,Modaressi, A. (2012).*"*Assessment of the Torsion Effect In Asymmetric Buildings Under SEISMIC Load".

[10] Chopra, A.K.andGoel, R. K. (1991). "Evaluation Of Torsional Provisions In SEISMIC Codes."*Journal of Structural Engineering*, Vol. 117, No. 12, December, 1991.

[11] Climent, A. B., Morillas, L., Margarit, D. E. (2014). "Inelastic torsional SEISMIC response of nominally symmetric reinforced concrete frame structures: Shaking table tests."*Engineering Structures* 80 (2014) 109–117.

[12] DeBock, D.J.,Liel, A.B.,Haselton, C.B.,Hooper, J.D.,Richard, A.J. (2013)."Importance of SEISMIC design accidental torsion requirements for building collapse capacity." *Engineering Structures.*

[13] Dimopoulos, A. I., Bazeos, N., Beskos, D. E. (2012). "SEISMIC yield displacements of plane moment resisting and x-braced steel frames". *Soil Seismics and earthquake engineering* 41(2012) 128-140.

[14] Fragiacomo, M., Amadio, C., Macorini, L. (2004). "SEISMIC response of steel frames under repeated earthquake groundmotions". *Engineering Structures* 26 (2004) 2021–2035.

[15] Georgoussis, G.,Tsompano, A., Makarios, T.(2015). "Approximate SEISMIC analysis of multi-storey buildings with mass and stiffness irregularities." *Procedia Engineering* 125 (2015) 959 – 966.