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SEISMIC ANALYSIS OF VERTICAL IRREGULAR STEEL STRUCTURE WITH SEISMIC RESILIENCES

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Abstract

The application of steel in multistorey buildings plays a vital role. Steel has self-weight, so it has less force to damage itself under seismic shaking. In vertical irregular Multistorey building is more prone to earthquake load. Therefore, high-grade steel material is most suitable for such a structure. This Research paper is to find out the seismic behavior of vertical irregular steel structures with various seismic resilience. Setback vertical irregular Multistorey steel structures will consider for the Nonlinear Time-history analysis. Severe time history data of zone -V is considered for the analysis. Built-up steel sections will use for primary beams and columns. sections of primary members are designed accordingly to the requirement of loadings conditions. This evaluation will consider a comparison of the basic model with the Seismic resilience model. In which different seismic resilience will apply to buildings and check seismic behavior. That seismic residences are Fluid Viscous dampers, Elastomer bearing base isolations systems, and Inverted V bracing compare all the results. The multistorey pre-engineered steel structure will evaluate by analytical by using software SAP 2000 v23. Nonlinear time history analysis is suitable for these multistorey complex structures. Peak ground acceleration (PGA) data will be required for the evaluations. This analytical process will obtain important aspects of results such as base shear, story drift, relative displacements, etc.

Keywords: Multistorey steel structure, geometric vertical irregularities, Seismic Resilience, and Nonlinear time history analysis.

1. INTRODUCTION

Earthquake is one of the most uncertain and disastrous natural hazards. It affects multiple hazards to a community, potentially inflicting large economic, property, and population loss. There are so many parameters for risk assessment of earthquakes. Vertical irregular is one parameter of the building which evaluates seismic effects. Vertical irregularities are building characteristics that demand more compounded designs due to the different seismic demands experienced. An example of a vertical irregularity is buildings with soft stories. This can be further categorized into the different types of irregularities as well as their severity for a more refined assessment tool. Steel is a material with high-quality control, which aids in Capacity Design. The sequence of formation of plastic hinges is important in the capacity design, so it is necessary to accurately predict the actual yield stress. If the actual strength of members is higher than their design strength, plastic hinges would be developed in other members first. To avoid such a situation, some codes introduce a factor of safety, which is the ratio of the expected yield strength to the specified minimum yield strength for various grades of steel. This factor helps to ensure that members or connections that must withstand the development of plastic hinges in other members have sufficient strength.

1.1 Vertical Irregularity

Vertical irregularity results from the uneven distribution of mass, strength, and stiffness along the elevation of a building structure. Mass irregularity results from a sudden change in mass between adjacent floors, such as a mechanical plant on the roof of a structure. Stiffness irregularity comes from a sudden change in stiffness between adjacent floors, such as setbacks in the elevation of a multistorey building. IS 1893 (Part1): 2016 gives details about vertical irregularities in the structure.

a) Vertical stiffness irregularity
b) Weight (mass) irregularity
c) Vertical geometric irregularity
d) In-plane discontinuity
e) Out-of-plane offsets
f) Discontinuity in capacity (weak story)
g) Torsional sensitivity
h) Non-orthogonal systems

Fig 1.1 Model of Vertical Irregular Steel Structure

1.2 Passive Control Devices

Passive control was among the first control scheme to mitigate vibrations in civil engineering structures such as buildings and long bridges with a high level of seismic safety. This type of control does not require power to operate and therefore passive systems are non-controllable in the sense that is not possible to change the control forces or the device behavior during the earthquake excitation. Although the passive nature can be seen as a limitation to the adaptability of the control system, is also a source of reliability since passive systems are not affected by possible power outages during the seismic event but also because they have low maintenance requirements. Therefore, these systems are perceived as a reliable, economical, and easy-to-realize technique to enhance structural safety and integrity, protecting structural and nonstructural elements and building contents from considerably large earthquakes. Passive devices are designed to dissipate or transfer the seismic energy transmitted to the structure and/or isolate the structure from external loadings to minimize structural and non-structural damage. Seismic isolation and passive energy dissipation/transfer are generally recognized as the most effective and relatively inexpensive anti-seismic protective systems.

Inverted V-bracing

Inverted-V-braced frames are one type of Concentrically Braced Frame (CBF), This type of structural system utilizes steel braces to provide the stiffness and strength needed to dissipate earthquake energy. This system helps to increase ductility and energy dissipation capability of all types of structures in modern codes, design provision for a new type of braced frame, labeled the Special Concentrically Braced Frame (SCBF), Within these provisions, the performance of Special Inverted-V-Braced Frames (SIVBF) was improved from that of ordinary Inverted-V-Braced Frames (IVBF) by limiting width/thickness ratios, requiring closer spacing of stitches, and providing special design and detailing of end connections for the bracing members. However, SIVBFs still evince a typical braced frame design problem. Upon continued lateral displacement, the compression brace buckles, and its axial capacity reduces while that of the tension brace continues to increase. This produces an unbalanced vertical force on the intersecting beam, resulting in a structural system that tends to concentrate inter-story drift in a single story. To resist undesirable deterioration of the frame's lateral strength, the provisions require that the beam possess adequate strength to resist this potentially significant post-buckling force redistribution in combination with appropriate gravity loads. This shows in very strong beams, much stronger than would be required for ordinary loads.

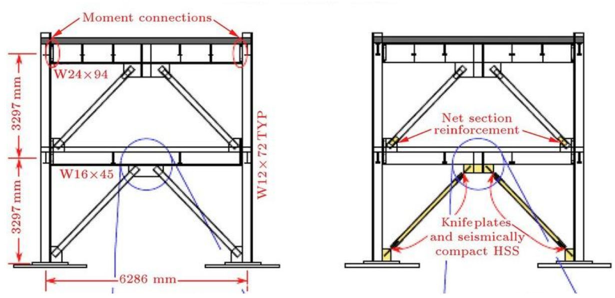


Fig 1.2 Inverted V Bracing in Frame Structure

Fluid Viscous Dampers

Fluid viscous dampers or seismic dampers are hydraulic devices that, when stroked, dissipate the energy placed on a structure by seismic events, wind buffering, or thermal motion. Substantial stress reduction – greatly enhanced damping lowers both stress and deflection to complete a structure. This allows the structure to remain elastic. Easy to model with existing codes – these dampers are completely vicious in output and will simply and efficiently raise structural damping to 20%-50% of critical, versus 1%-3% for a typical non-damping design. Allows designers to make economic structures by utilizing smaller structural elements and less complex foundations while enhancing the dynamic performance of the structure. The easily installed passive dampers are extremely fiducial with no dependence on outside energy sources. No Maintenance is ever required. Taylor Devices' exclusive modular design uses an optimum number of moving parts. The patented seal has a history of over 50+ years of successful performance on demanding applications.

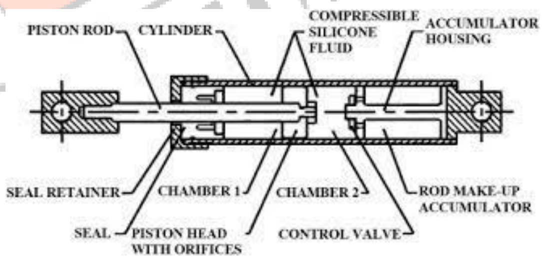


Fig 1.3 Fluid Viscous Damper model

Base Isolation System

An isolation system should be able to support a structure while providing additional horizontal flexibility and energy dissipation. The three functions could be concentrated into a single device or could be provided using different components. Various parameters to be considered in the choice of an isolation system, apart from its general ability to shift the vibration period and add dumping to the structure are

a) Deformability under frequent quasi-static load (i.e., initial stiffness),
b) yielding force and displacement
c) the capacity of self-centering after deformation and
d) the vertical stiffness.

There are two basic types of isolation systems. One is the elastomeric bearings and another is sliding isolation systems. The elastomeric bearings with low horizontal stiffness shift the fundamental period of structure to avoid resonance with excitations.

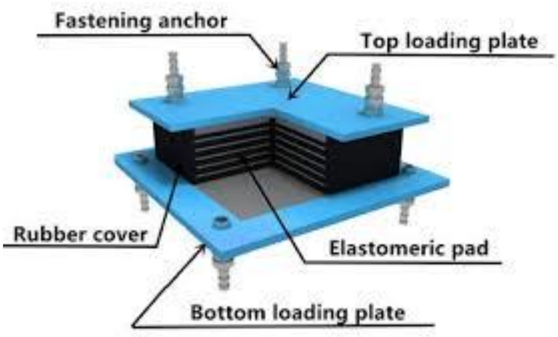


Fig 1.4 Elastomer Bearing Base Isolation Model

2. BACKGROUND AND LITERATURE

Various research paperwork is done related to this topic. Most researchers consider only one passive system. In this research paper evaluation of the vertical irregular structure by using various types of only one passive control device is used.

Pranab Kumar Das *et.al.*,(2020) studied the various type of irregularities in multistorey structures. Buildings with asymmetry and various classes of irregularity are found to be major causes of collapses of structure, property loss, and casualties during earthquakes. Although a considerable research effort was directed at asymmetric buildings, well-accepted information for multistory asymmetric structures is still yet to be framed.

Arjit Verma et.al., (2019) In this paper a nonlinear dynamic analysis of a multi-storied building was carried out considering the different seismic intensities which occurred in the seismically active state of Uttarakhand. The building under consideration is modelled using finite element-based software SAP 2000 v.14.0.0. The response parameters used in the seismic analysis are period, base shear, modal mass participation, lateral displacement, and storey drift. From the study, it is concluded that the time-history analysis method fortified the safety of multi-story buildings when it is subjected to seismic excitations.

Md Mahmud SAZZAD *et.al.*, (2019) This study has investigated the vulnerable effect of irregular profiles in steel frame buildings. To attain the behavior of each frame, the linear time history analysis method has been adopted for the present study. FEMA356 standard is used here for linear time history analysis. Investigations on different frames exhibit that a regular profile with symmetry in mass is more efficient while using overhanging mass is detrimental considering the time-dependent displacements and accelerations.

Anthony Quansah *et.al.*, (2017) stated that vertical irregularity tends to hurt the seismic effect on structures, but currently, there is a lack of appropriate research on the use of isolation techniques to reduce the seismic effect and issues related to a weak story. This paper focuses on analyzing isolated vertical irregular structures in both mass distribution and stiffness distribution scenarios. Discussion on the influence of shear forces distribution pattern, damping coefficients, and other parameters which affected the irregular distribution of story mass and stiffness is made.

3. METHODOLOGY

Nonlinear time history analysis is used to further evaluate these models of Vertical irregular structure. In SAP2000 v23. Four models are analyzed in this research work. Modeling of the structure is done in SAP2000. The followings are geometric properties of the basic model:

1	Building	G+15
2	Building Type	Commercial Building
3	Material	345 MPa Grade Steel
4	Geometric	Setback Building
5	Section Details	Built-up steel section
6	Height of Floor	4 m
7	Building Dimension	Up to 5th floor (7x7 Bay) 6 - 10th Floor (5x5 Bay) 11-15th Floor (3x3 Bay)
8	Bay Width	5 m

Table 1. Geometric Details of Buildings

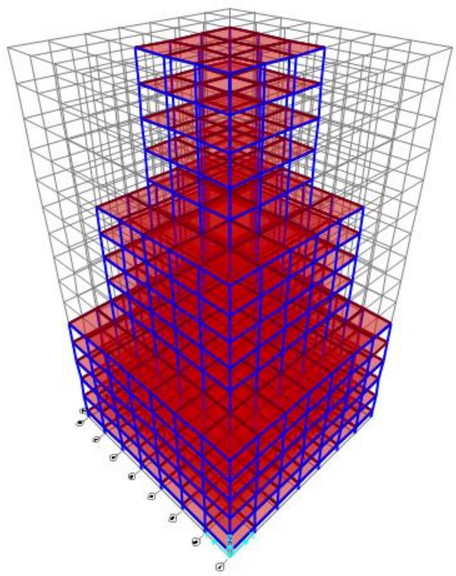


Fig 3.1 Structure model in SAP2000 v23

Static load such as dead load, live load is used the check the structure is safe in design as per the given built-up section to beam and column of the structure.

1	Dead Load	Self-Weight
2	Live Load	4 KN/Sq.m
3	Floor Finish load	1.2 KN/Sq.m
4	Time History Data	Bhuj

Table 2. Details of Static loads

3.1 Nonlinear Time History Analysis

The dynamic time history is preferred for analysis, as existing structures have similarities and output refers to displacement and base shears. The severe Indian EQ has been selected for the analysis as Bhuj EQ has similar wave propagation in coastal structures.

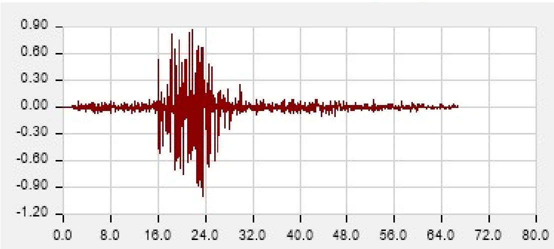


Fig 3.2 Time history graph of Bhuj

Using this dynamic load evaluate 4 models. Apply mass source on the floor for distributed EQ load. For model-1 means vertical irregular structure with a fixed base. Apply the EQ load and perform a nonlinear analysis. For model-2 fluid viscous damper properties are assigned to the structure For model-3 steel rod is used for inverted V bracing. for model-4 elastomeric bearing base isolation is provided. Stiffness values is provided is as per standard norms.

4. RESULTS & DISCUSSION

After completing the Nonlinear time history analysis of the structure for all 4 models. In which comparing the results of all models with the basic model we have got the following results for the Base Shear, Displacement, Storey Drift & Bending Moments.

1. Base Shear: Base shear is got at the base of the structure due to the Time history load of both sides getting the different values for X and Y directions. Model-1 has the highest values of the base shear. Model-4 has the lowest value of base shear.

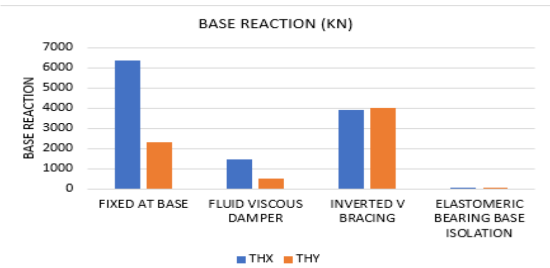
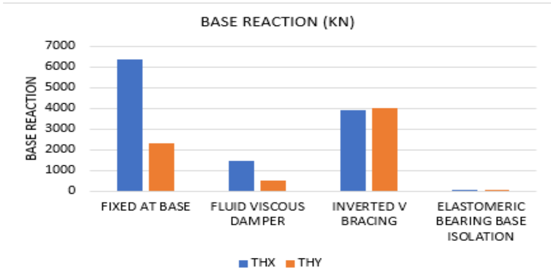


Fig 4.1 Comparison Graph of Base Reaction

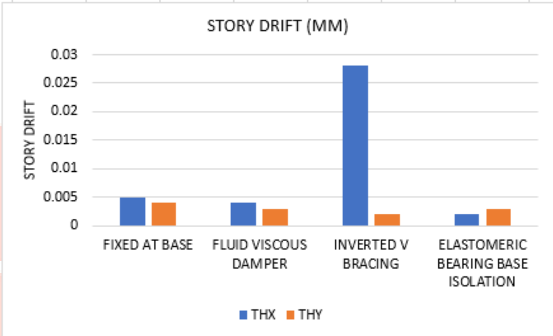
2. Joint Displacement: Joint Displacement is got at a high peak of the structure due to the Time history load of both sides getting the different values for X



and Y direction. Model-1 has the highest values of the base shear. Model-4 has the lowest value of base shea

Fig 4.2 Comparison Graph of Joint Displacement

3. Storey Drift: Storey Drift is calculated as displacement with respect to storey height. time history load of both sides got the different values for X and Y direction. Model-1 has the highest



values of the base shear. Model-4 has the lowest value of base shear.

Fig 4.3 Comparison Graph of Storey Drift

4. Bending Moment: Bending Moment is got at the base of the structure. time history load of both sides got the different values for X and Y direction. Model-3 has the highest values of the base shear. Model-4 has the lowest value of base shear.

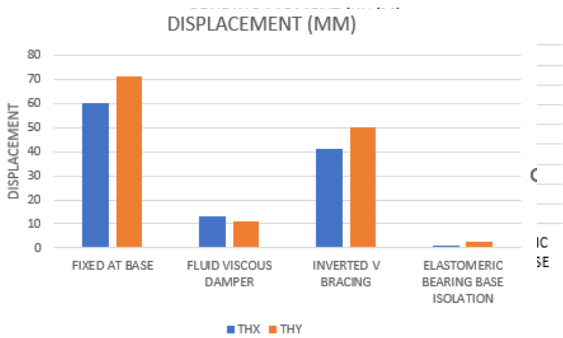


Fig 4.4 Comparison Graph of Bending Moment

5. CONCLUSION

- Seismic Analysis Multistorey Steel Buildings with geometric irregular without any resilience show variation in the results base reaction and Joint displacement in a structure where the area of the floor is changed
- Vertical irregular structure with Inverted V bracing base shear and displacement has fewer values as compared to model-1. But bending moments and storey drift have greater value.
- Vertical Irregular structure with Viscous fluid Dampers effects on Bending moments generated on the base of the structure. It makes the structure more ductile.
- Vertical Irregular structure with Elastomers bearings base isolation reduces base shear, lateral displacement and storey drift of structure as compared to model-1
- From all consolidated results it concluded that the Efficiency of the vertical irregular steel structure is increased in model-4, Structure with base isolation, base isolation is suitable of structure in zone-V

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