Analytical Study on the Effect of Bracings in Turbine Building Subjected to Lateral Loads

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Abstract- **Structural steel buildings are growing in popularity over the past decades and needless to say, steel structures are the primary choice when it comes to industrial structures. Steel has always been more preferred to concrete because of its efficiency and the property of ductility. Lateral loading on the steel structures are generally resisted by moment resisting and braced frames. Braced structures are considered to be more efficient as the number of floors and height of the building increases. Previous studies show the effectiveness of various bracings on steel as well as concrete. But the effectiveness of various configurations of bracings on irregular multi-storied buildings is not studied deeply. The present study aims to investigate the seismic performance of a turbine building which houses components vital to generation of electricity. Analytical model of the turbine building is developed using structural analysis and design software, STAAD.Pro. Seismic performance of multi-storey steel turbine building for different configurations of bracings (namely X, V and inverted V) is investigated using equivalent static analysis and time history analysis method to compare the seismic performance.**

Keywords- Steel, configuration, bracing, turbine building, time history

I. INTRODUCTION

Over the last few decades, steel structure plays an important role in the construction industry. It is necessary to design a structure to perform well under seismic loads. Behavior of a structure during an earthquake critically depends on its geometry and overall configuration. Buildings with simple and regular configuration perform much better in the event of an earthquake compared to buildings with irregular configurations. Shear capacity of the structure can be increased by introducing steel bracings in the structural system. There are "n" numbers of possibilities to arrange steel bracings namely X, V, inverted V type bracings etc.

The study involves equivalent static analysis and time history analysis for a turbine building which houses components vital to generation of electricity. The turbine building is an enclosed metal and girder structure that houses: Turbine, generator and the support lubrication and cooling systems, Condensate-feed water systems, supply water to the steam generator, Circulating water to and from condenser, Electrical switchgear rooms that supply electrical power to plant components, Demineralized water system that supplies clean water for cooling plant components, and Control Room. Outside the building are the transformers that either supply power to the plant for startup or that supply power to the grid for distribution for residential purposes. The analytical model of a turbine building is developed using structural analysis and design software, STAAD.Pro. Equivalent static and Time history analysis is done to evaluate the performance of the building. In this method mathematical model of building are subjected to accelerations from earthquake records that represent the expected earthquake. The design output of the different configuration of bracings in turbine building is evaluated to have a comparative study of their seismic performance.

II. OBJECTIVE OF THE STUDY

The main objectives of the present study is

a) To model the multistory steel turbine building using the analysis and design software STAAD.Pro

b) To investigate the seismic performance of a multi-storey steel turbine building with different bracing arrangements such as X, V and inverted V, using Equivalent Static analysis method and Time History analysis method.

III. MODEL DETAILS

Turbine Building dimension in plan is 44.5m X 114.48m and the height of the building above ground is 44.5m. The three-dimensional centerline finite element model is generated based on the coordinates identified from the structural arrangement drawing in meters shown in Fig 1. In this integrated finite element model, BEAM elements and PLATE elements are used appropriately to idealize the structural behavior of the physical structure in the model under various loading conditions. All the structural elements that contribute towards the structural stiffness are modeled. The floor slabs of the structure are modeled for simulating diaphragm effect of slabs in their in-plane direction. Entire structure is composed of integrated three dimensional structure comprising of floors, roofs, walls, beams and columns forming regular orthogonal frames tied together to act as one unit.

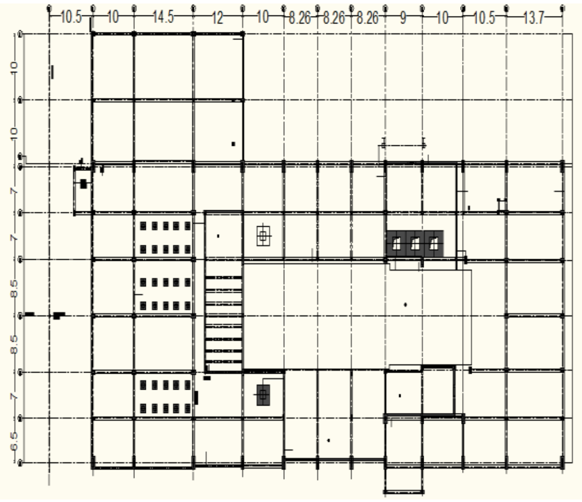


Fig 1.Plan at tie beams

The mathematical model of Turbine Building involves integrated assembly of beams, columns, slabs with fixed supports at the foundation level. The stiffness modeling involves discretization of the structure using three dimensional elastic beam elements for beams and columns in the structure and plate elements for walls/slabs. Floor Slabs (< 200 mm thickness) are modeled without density to function as diaphragms distributing lateral forces. Stiffness calculations are based on gross section properties of the concrete sections, defined properties for rolled steel sections [IS: 808-1989] and derived properties for built-up steel sections.

Two different patterns for location of braced bays have been used, including one with adjacent braced bays and the other with non-adjacent braced bays. The entire structure is modeled to study the effectiveness of the different configuration of bracings. The various bracings that are adapted to study are X, V and inverted V bracings. These are arranged both in alternate bays and adjacent bays. Configurations adapted:

Alternate X bracings, Alternate V bracings, Alternate inverted V bracings, Adjacent X bracings, Adjacent V bracings, Adjacent inverted V bracings and it is shown in Fig 2 and Fig 3.

Angle sections used: ISA150X150X12, ISA90X90X8, ISA90X90X8

Steel Beams used: ISMB 600, ISMC400, ISMC300

TABLE I. Elastic properties of the materials

Sl No	Material	Elastic Modulus (kN/m^2)	Poisson's Ratio	Coefficient of thermal expansion (mm/mm/^{0}C)
1.	Normal density reinforced concrete (M35 Grade)	2.958 x 107 calculated using $5000\sqrt{f_{ck}}$	0.2	9.5 x 10^{-6} based on IS:456-2000
2.	Structural steel	2 x 10^8 based on IS:800-2007	0.3	12 x 10^{-6} based on IS:800-2007

TABLE II. Unit weight of the materials used

Sl No.	Material	Unit weight (kN/m^3)
1	Reinforced Concrete	25
2	Plain Cement Concrete	24
3	Structural steel	78.5
4	Bulk Unit weight of the soil	17
5	40 mm thick Hardonate flooring	24
6	Corrugated galvalume sheets with central insulation	0.25 kN/m^2
7	Brickwork/Concrete block masonry	20/24
8	0.8 mm thick Troughed metal sheets (trough size 44x130mm)	8.16 kg/m^2

The mathematical modeling of the turbine building is done as follows

1) Cartesian co-ordinate system is used in modeling of Turbine Building

2) Modeling of beams and column frames: 3-D line-models of framed regions like beam-column skeletons are done using beam elements.

3) Modeling of Walls, Slabs: This involves generating planar-geometry patterns like walls, floors & Raft as basic entities of solid-model using Plate Elements. FE mesh is generated by STAAD.Pro software by meshing these areas into finite-elements with 3-D plate element discretization.

The components that are not modeled in the finite element model of turbine building are brick walls, cladding walls, gantry girders, sag rods, cladding runner beams, etc. Grade slab at ground level is also not modeled as there is no structural connectivity envisaged between frame and grade slab.

The approximations that are made in modeling the turbine building is as described below.

(1) Small offset eccentricities <100mm between beam and columns, as well as in the longitudinal axes of the columns are neglected. Accordingly nodal co-ordinates are fixed.

(2) Offset eccentricities between center-lines of floor / roof slabs and beams are neglected. Both the elements are modeled near the center-line of slab elements.

(3) The non-structural components like brick walls, claddings, etc. are neglected in modeling, but their loading on the structure is accounted for.

The turbine building in a nuclear power plant is subjected to various types of loadings. Those loadings that are used for finding the seismic behavior of the structure is as follows:

Live load = 15kN/m^2

Piping load=5kN/m^2

Cable tray load=0.8kN/m^2

Ducting load=7.5kN/m

The loads are distributed at the floor levels as uniformly distributed loads

IV. ANALYSIS DONE

Two types of analysis procedure are carried out to determine the behavior of the structure under the effect of seismic loads. The analyses carried out are

A. Equivalent static analysis
B. Time history analysis

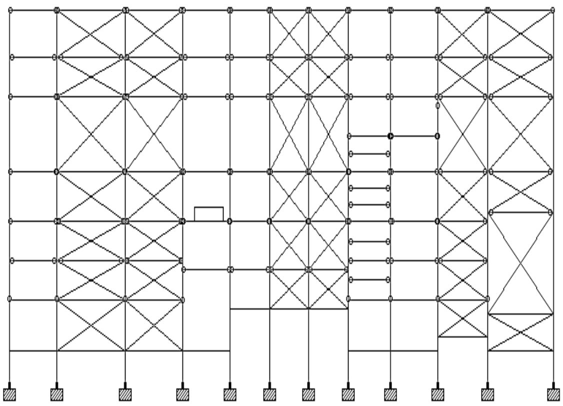
A. *Equivalent static analysis:*

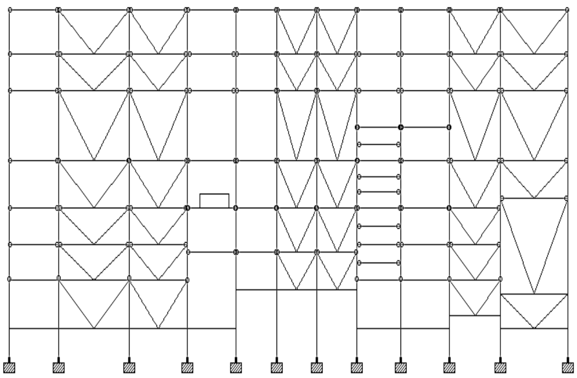
This procedure is carried according to IS 1893 (Part 1) 2002. First the design base shear is computed for the building and then it is distributed along the total height. Thus the lateral force at each floor level is distributed to individual lateral load resisting element. Here as the live load coming in each floor is greater than 3 KN/m^2 the seismic weight is taken as dead load plus 50% live load.

B. Time history analysis:

It is the most sophisticated method of dynamic analysis for buildings. In this method, the mathematical model of the building is subjected to accelerations from earthquake records that represent the expected earthquake at the base of the structure. The method consists of a step by step direct integration over a time interval; the equations of motion are solved with the displacements, velocities, and accelerations of the previous step serving as initial functions. The time history data of El Centro earthquake is adopted for the time history analysis.

The above mentioned methods of differing complexity are adopted in the analysis of structure are shown in table III.





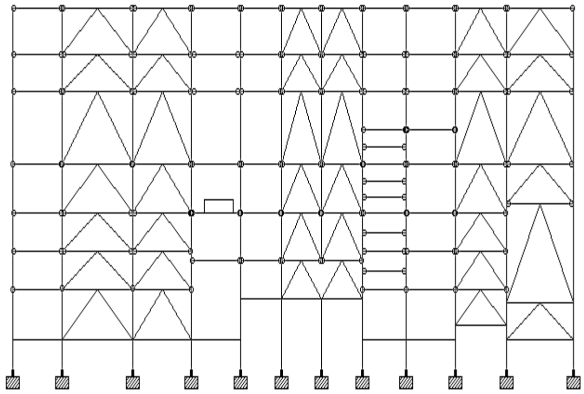
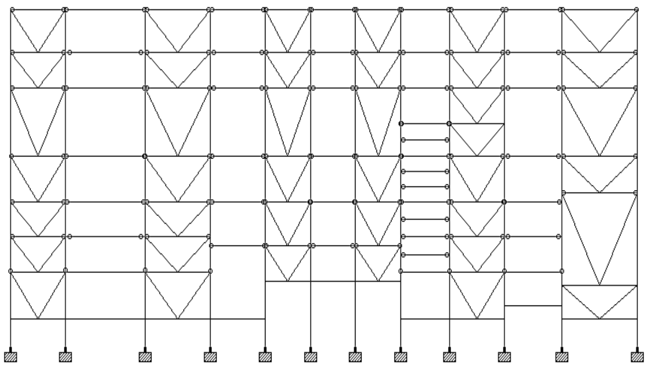
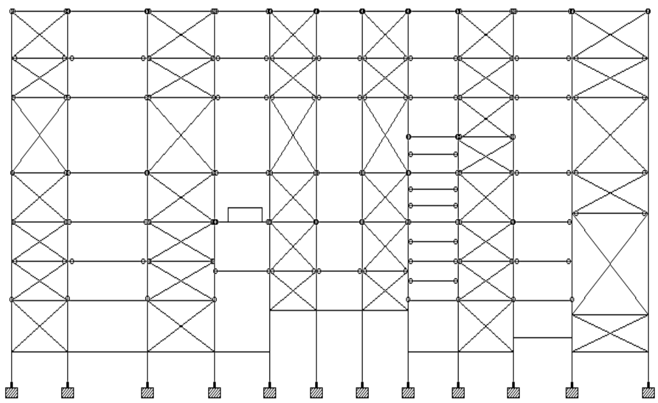


Fig 2. Adjacent configuration of bracings

TABLE III. TYPES OF ANALYSIS AND THEIR COMPLEXITY

Analysis type	*Usual name*	*Dynamic effect*	*Non linearity*
Linear static	Equivalent static analysis	No	No
Nonlinear dynamic	Time history analysis	Yes	Yes





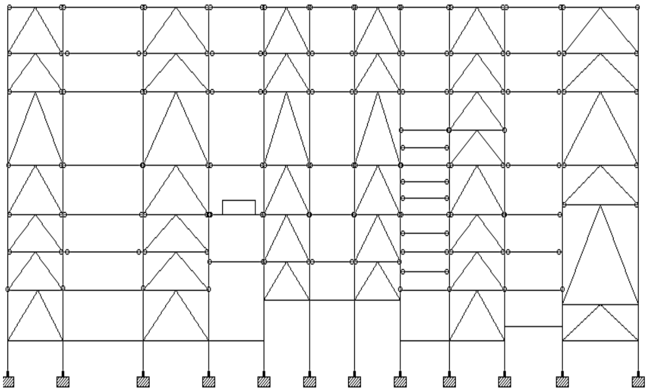


Fig 3. Alternate configuration of bracings

V. RESULTS AND CONCLUSION

The results that are observed by doing equivalent static analysis and time history analysis on the multistoried turbine building are tabulated in tables 3 to 5 and the figures 4 to 6 shows the effectiveness of the various configurations of the bracings that are taken to study.

1) Fig 4. shows the overall displacement of the structure analyzed using the equivalent static analysis method.

2) Fig 5 shows the overall displacement of the structure analyzed using time history analysis method.

3) Fig 6 shows the comparison of the overall displacement of the structure studied using equivalent static and time history analysis methods.

4) Table 4 shows the maximum displacement obtained by the six configurations of bracings in turbine building using equivalent static analysis.

5) Table 5 shows the maximum displacement obtained by the six configurations of bracings in turbine building using time history analysis

6) Table 6 shows the comparison of maximum displacement of six configurations of bracings using static and time history analyses

TABLE IV. COMPARISON OF DISPLACEMENT BY STATIC ANALYSIS

Sl. No	Configurations	Displacement(mm)
1	alternate X	28.224
2	alternate V	31.08
3	alternate inverted V	30.184
4	adjacent X	26.678
5	adjacent V	30.033
6	adjacent inverted V	29.567

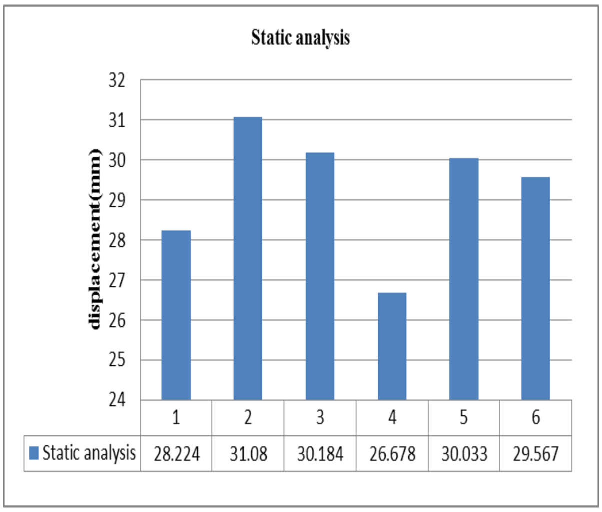


Fig 4. Overall displacement of various configurations by static analysis

TABLE V. COMPARISON OF DISPLACEMENT BY TIME HISTORY ANALYSIS

Sl.No	Configuration	Displacement (mm)
1	alternate X	66.485
2	alternate V	72.756
3	alternate inverted V	70.195
4	adjacent X	64.792
5	adjacent V	69.698
6	adjacent inverted V	68.35

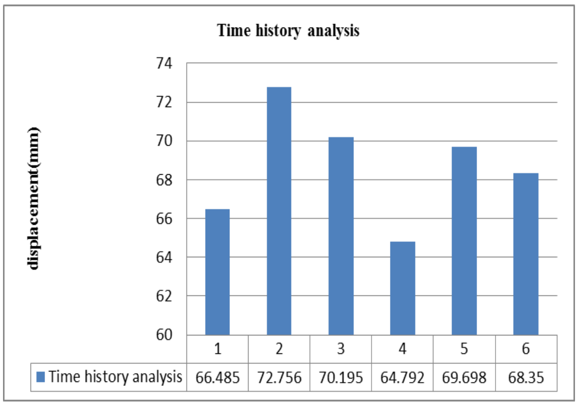


Fig 5. Overall displacement of various configurations by time history

TABLEV. COMPARISON OF DISPLACEMENT BY STATIC AND TIME HISTORY ANALYSIS

Sl. No	Configuration	Displacement(mm)	
		Static analysis	Time history analysis
1	alternate X	28.224	66.485
2	alternate V	31.08	72.756
3	alternate inverted V	30.184	70.195
4	adjacent X	26.678	64.792
5	adjacent V	30.033	69.698
6	adjacent inverted V	29.567	68.35

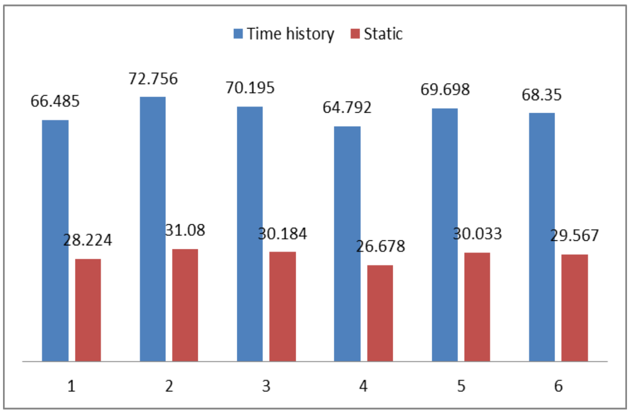


Fig 6. Comparison of overall deflection of various configuration by Static and time history analysis

The overall displacement of the structure due to seismic loading is observed in both equivalent static and time history analysis and the results are compared. From that, it is clear that the X bracings with adjacent configuration show less displacement as compared with alternate configuration of X bracings in turbine building and has greater stiffness compared with the other two configurations of V and inverted V bracings. For an irregular structure which is seismically loaded, the better configuration of bracings should be adjacent and it is that the type of bracings should be X bracings. The least effectiveness against seismic loading is shown by V bracings in both static and time history analyses.

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