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International Journal for Modern Trends in Science and Technology, 8(06):06-16, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0806002
Available online at: http://www.ijmtst.com/vol8issue06.html

Analysis and Design Multi-storey Steel Staggered-Truss System RC Slab Using ETABs

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To Cite this Article
Durgadas Ashok Rude and Harshvardhan Rangari. Analysis and Design Multi-storey Steel Staggered-Truss System RC Slab Using ETABs. International Journal for Modern Trends in Science and Technology 2022, 8(06), pp. 06-16. https://doi.org/10.46501/IJMTST0806002

Article Info
Received: 22 April 2022; Accepted: 25 May 2022; Published: 27 May 2022.

ABSTRACT

A staggered Truss System (STS) is a prospective steel structure system for high-rise buildings and a steel staggered truss framing system is one of the effective design techniques to improve the efficiency in building construction. Besides, cost reductions arise from a reduction in steel tonnage. Staggered truss system is a prospective steel structure system for multi-story and high-rise buildings. The staggered truss framing system arose from the use of system design techniques to improve efficiency in building construction. Staggered truss systems have proved to be effective in integrating the structural and mechanical requirements. In addition, cost reductions arising from reduced steel tonnage and reduced building volume may be achieved from the use of these framing methods. The purpose of this project is analytical investigation on the behavior of an 8-storey steel staggered-truss system using the ETABS software. The parameters such as the structural truss type, arrangement of the trusses are varied, and their influences on seismic behaviors of the system are studied. And based on the test results, some indices of seismic behaviors of the system, such as yield load, deformation and strength are analyzed.

KEYWORDS- ETABs, Staggered Truss System, Multi Storey Building, Seismic

1. INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The staggered-truss system (STS) is a new concept in structural steel framing for high-rise buildings, which was developed in Massachusetts Institute of Technology in 1960s. This system is efficient for mid rise apartments, hotels, motels, dormitories, hospitals, and other structures for which a low floor to-floor height is desirable. The staggered truss system is a type of structural steel framing used in high-rise buildings. The system consists of a series of story-high trusses spanning the total width between two rows of exterior columns and arranged in a staggered pattern on adjacent column lines. Staggered truss system is a prospective steel structure system for multi-story and high-rise buildings. The staggered truss framing system arose from the use of system design techniques to improve efficiency in building construction. Staggered truss systems have proved to be effective in integrating the structural and mechanical requirements. In addition, cost reductions arising from reduced steel tonnage and reduced building volume may be achieved from the use of these framing methods. The staggered arrangement of the storey-high trusses placed at alternate levels on adjacent column lines allows an interior floor space of twice the column spacing to be available for freedom of floor arrangements. To resist gravity loads, the floor system may be considered to be a series of simple spans or continuous for two column spacing. As a continuous system, the floor members rest on the top chord of one truss and extend to the bottom chords of the two adjacent trusses. The purpose of this project is analytical investigation on the behavior of an 8-storey steel staggered-truss system using the ETABS software. The parameters such as the structural truss type, arrangement of the trusses are varied, and their influences on seismic behaviors of the system are studied. And based on the test results, some indices of seismic behaviors of the system, such as yield load, deformation and strength are analyzed. Previous researches on steel staggered-truss system concentrated on the theoretical analyses, and the experimental studies on the seismic behaviors of it have never been reported. So in this project an analytical investigation on seismic behaviors of an 8-storey steel staggered-truss system is carried out. It is done using ETABS software. Both the material and geometric nonlinearity are considered in the method.

1.2 STEEL STAGGERED TRUSS SYSTEM

The staggered truss system was developed in the USA by the Massachusetts Institute of Technology (MIT) in the 1960s. This was a new concept in the structural steel framing system for high-rise buildings. For achieving a large column-free area columns are located only at the exterior face of the building. A staggered truss system is not considered as a basic seismic force-resisting system so some research work should be carried out in the future for the system to be accepted as a standard structural system. For STS guidelines are given in "Design Guide 14" by AISC (American Institute of Steel Construction) but there is no guideline given by Indian standard. For achieving a large column-free area twice than column spacing the STS should be provided at an alternate floor level. A staggered truss system was generally suitable for rectangular buildings. A staggered truss system should be provided in a shorter direction. For the connectivity between two corridors, one central opening is provided called an open truss or vierndeel truss. Previous researches on steel staggered-truss system carried out only for open truss, angle of incline truss, comparison between staggered truss system and moment-resisting system, comparison between staggered truss and open web truss. But the use of the concrete shear wall in STS may be a new direction of research work.

[Fig.1.1: ETABs Interface of Staggered Truss System]

1.2.1 OVERVIEW

THE STAGGERED TRUSS system is a new concept in structural steel framing for high rise buildings. The system consists of a series of story-high trusses spanning the total width between two rows of exterior columns and arranged in a staggered pattern on adjacent column lines. The staggered truss system for steel framing is an efficient structural system for high rise apartments, hotels, motels, dormitories, and hospitals. The arrangement of story-high trusses in a staggered pattern at alternate column lines provides large column-free areas for room layouts. The interaction of the floors, trusses, and columns makes the structure perform as a single unit, thereby taking maximum advantage of the strength and rigidity of all the components simultaneously. Each component performs its particular function, totally dependent upon the others for its performance. The staggered truss system of steel framing has become an economical system for high rise, high density occupancy buildings.The staggered truss system is a type of structural steel framing used in high-rise buildings. The system consists of a series of story-high trusses spanning the total width between two rows of exterior columns and arranged in a staggered pattern on adjacent column lines. The staggered truss system for steel framing is an efficient structural system for high-rise apartments, hotels, motels, dormitories, and hospitals. The arrangement of story-high trusses in a staggered pattern at alternate column lines provide large column-free areas for room layouts. These column free areas can be utilized for ballrooms, concourses, and other large areas. The staggered truss structural system consists of story-high steel trusses placed on alternating column lines on each floor so that the long axis of one truss is always between the trusses on the floor below. The system staggers trusses on a 12' module, meaning that on any given floor the trusses were 24' apart. The interaction of the floors, trusses, and columns makes the structure perform as a single unit, thereby taking maximum advantage of the strength and rigidity of all the components simultaneously. Each component performs its particular function, totally dependent upon the others for its performance. The total frame behaves as a cantilever beam when subjected to lateral loads. All columns are placed on the exterior wall of the building and function as the flanges of the beam, while the trusses which span the total transverse width between columns function as the web of the cantilever beam.

While earlier staggered truss systems utilized channels for web diagonals and verticals, today most of the trusses are designed with hollow structural sections (HSS) for vertical and diagonal members because they are more structurally efficient and easier to fabricate. The trusses are fabricated with camber to compensate for dead load and are transported to the site, stored and then erected—generally in one piece. Fabrication of this type of structure requires certified welders and overhead cranes capable of lifting 10 to 15-ton trusses and columns for projects up to 20 stories. Fabrication involves the following components: Columns, Spandrel Beams, Trusses, Secondary Columns & Beams and the Floor System.

1.2.2 ADVANTAGES

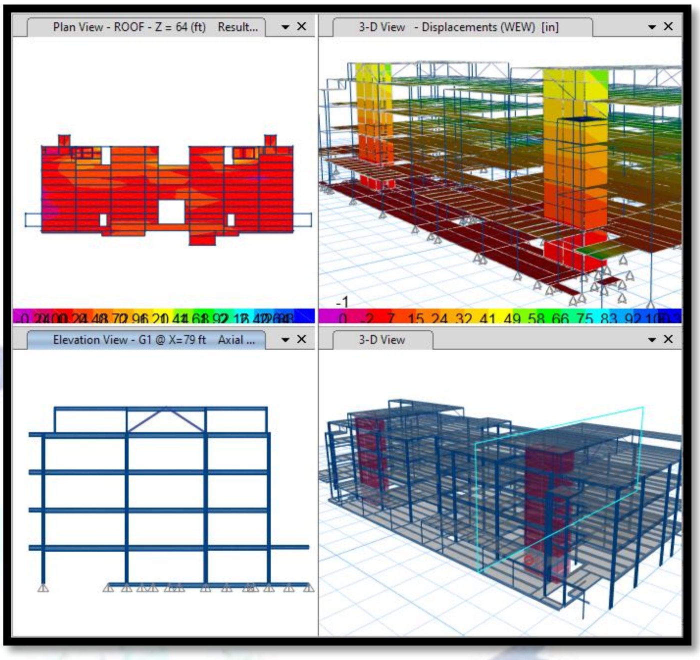
- Large clear span open areas for ballrooms, or other wide concourse are possible at the first floor level, because columns are located only on the exterior faces of the building. This allows for spaces as much as 60 feet in each direction with columns often only appearing on the perimeter of a structure. This also increases design flexibility especially for atrium placement and open space floor plans.
- Floor spans may be short bay lengths, while providing two column bay spacing for room arrangements. This results in low floor-to-floor heights. Typically, an 8'-8" floor-to-floor height is achieved.
- Columns have minimum bending moments due to gravity and wind loads, because of the cantilever action of the double-planar system of framing.
- Columns are oriented with their strong axis resisting lateral forces in the longitudinal direction of the building.
- Maximum live load reductions may be realized because tributary areas may be adjusted to suit code requirements.
- Foundations are on column lines only and may consist of two strip footings. Because the vertical loads are concentrated at a few column points, less foundation formwork is required.
- Drift is small, because the total frame is acting as a stiff truss with direct axial loads only acting in most structural members. Secondary bending occurs only in the chords of the trusses.
- High strength steels may be used to advantage, because all truss members and columns are subjected, for all practical purposes, to axial loads only.
- A lightweight steel structure is achieved by the use of high strength steels and an efficient framing system. Since this reduces the weight of the superstructure, there is a substantial cost savings in foundation work.
- Faster to erect than comparable concrete structures. Once two floors are erected, window installation can start and stay right behind the steel and floor erection. No time is lost in waiting for other trades, such as bricklayers, to start work. Except for foundations, topping slab, and grouting, all "wet" trades are eliminated.
- Fire resistance; steel is localized to the trusses, which only occur at every 58-to-70-feet on a floor, so the fireproofing operation can be completed efficiently. Furthermore, the trusses are typically placed within demising walls and it is possible that the necessary fire rating can be entirely by enclosing the trusses with gypsum wallboard. Finally, if spray-on protection is desired, the applied thickness can be kept to a minimum due to the compact nature of the truss elements.

1.3 INTERFACE OF ETABs

ETABS is a special purpose computer program developed specifically for building systems. The concept of special purpose programs for building type structures was introduced more than 35 years ago [R. W. Clough, et al., 1963]. However, the need for special purpose programs, such as ETABS, has never been more evident as Structural Engineers put nonlinear static and dynamic analysis into practice and use the greater computer power available today to create larger, more complex analytical models. With ETABS, creating and modifying a model, executing the analysis, design, and optimizing the design are all done through a single interface that is completely integrated within Microsoft Windows. Graphical displays of the results, including real-time display of time-history displacements, are easily produced. Printed output, to a printer or to a file, for selected elements or for all elements, is also easily produced. This program provides a quantum leap forward in the way models are created, modified, analyzed and designed. The analytical capabilities of ETABS are just as powerful, representing the latest research in numerical techniques and solution algorithms.

ETABS is available in two versions, ETABS Plus and ETABS Nonlinear. Both versions are comprised of the following modules integrated into and controlled by a single Windows-based graphical user interface:

- Drafting module for model generation.
- Seismic and wind load generation module.
- Gravity load distribution module for the distribution of vertical loads to columns and beams when plate bending floor elements are not provided as a part of the floor system.
- Output display and report generation module.
- Steel frame design module (column, beam and brace).
- Concrete frame design module (column and beam).
- Composite beam design module.
- Shear wall design module.



[Fig.1.2: Working Interface of ETABs]

ETABS Plus also includes the finite-element-based linear static and dynamic analysis module, while ETABS Nonlinear includes the finite-element-based nonlinear static and dynamic analysis module. ETABS is an engineering software product that caters to multi-story building analysis and design. Modeling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure.

- ETABS allows user for Graphic input and modification for the sake of easy and quick model creation for any type of structure.
- Creation of 3D model with the utilization of plan views and elevations, 3D model of any kind of complex structure can be created easily.

The ETABS is a well-known engineering software that helps in modeling tools and templates, analyzes the methods. Provide solutions and are based on code-based load prescription. It helps with understanding the static and dynamic analysis of shear wall building and multi-story structures. ETABS offers a single user interface to perform modeling, analysis, design, and reporting. There is no limit to the number of model windows, model manipulation views, and data views.

2. LITERATURE REVIEW

[1] Maleki and Mahjoubi (2010): a simple finite element model is introduced in this paper for seismic retention wall analysis. In the behavior of near-wall soil, wall flexibility and elastic free field soil reaction, the model includes nonlinearity. In relation to acceptable accuracy, the benefits of this model are simplicity and flexibility. Analysis was carried out on several soil-wall systems by applying real earthquake records using nonlinear time-history analysis. New distributions of seismic soil pressure are proposed for different soil and boundary conditions based on the results of these analyzes. The soil-wall structure can experience significant displacement in an earthquake. If the soil's wall and free field displacement are equivalent, the wall will have no impact on the pressures of free field soil. This is generally not the case, however, and the distinction in soil and wall displacements generates stress in the soil, particularly near the wall. Therefore, in terms of the distinction between free field soil and wall displacements, the horizontal stresses in the soil behind the wall can be written. With nonlinear springs connected to the wall representing the interfacing soil, this phenomenon can be modelled.

[2] A 3-D finite element dynamic computer program called ANSYS was discussed by Garavand et al. (2010) to study the soil structure interaction retaining wall. The information of the assessment is based on the 1995 Kobe earthquake report and the findings were checked with the damage caused by some retaining walls in the earthquake. Soil-structure surface nonlinearity, surface-to-surface contact element is used. The reinforcement concrete also operates nonlinear under the dynamic loads and material used. Hence the results of classic methods such as Coulomb and Rankine compared to nonlinear dynamic assessment outcomes. Two types of boundaries were applied to simulate the unbounded nature of the soil medium and the corresponding responses were compared. These boundaries are:

- Viscous border (dashpot): viscous dampers are mounted on the model's side wall. Damping coefficients were given in normal and perpendicular directions at a particular node where viscous dampers are attached.
- Boundary of the Kelvin component (spring and dashpot): Kelvin components are also used at the boundary. The Kelvin element's stiffness and damping constant was assessed.

[3] Alireza Ahmdnia et al (2011), studied on basement walls, is an essential component of tall buildings. These walls should be intended to resist the static and seismically induced lateral earth pressures. Since there is no guideline specific to seismic design of basement walls, developers use the Coulomb concept to discover the static active lateral thrust from soil to wall and the Mononobe and Okabe (M-O) method to discover the complete active lateral thrust during seismic loading (static and earthquake-induced). For a long time, structural and geotechnical engineers depended on the use of the famous MononobeOkabe (M-O) technique to determine the lateral seismic stress acting on the wall. First, a 24.3 m deep and 150 m wide layer of soil is created and put into balance under the forces of gravity. Then part of the upper soil layer is excavated in lifts to a depth of 11.7 m and a width of 30 m. As each lift has been excavated, lateral pressure (shoring) is applied to retain the soil.Then the basement wall is built, re-establishing worldwide balance. In the next stage, the shoring pressures will be removed and the load transferred from the ground to the basement wall. Modelling the flexural conduct of the walls with yield times equivalent to the corresponding moment resistance.

[4] Bhattacharjee et al The goal of this undertaking is to analyses and design layout a multistory building [G+21 (3 dimensional body)] mistreatment STAAD professional. the making plans involves load calculations manually and reading the whole structure through STAAD expert. the planning methods employed in STAAD-pro analysis square measure limit country style conformist to Indian Everyday Code of look at. STAAD. seasoned alternatives a progressive interface, image equipment, effective analysis and fashion engines with advanced finite element and dynamic evaluation abilties. From version generation, evaluation and fashion to image and end result verification, STAAD. seasoned is that the professional’s opportunity. ab initio we generally tend to began with the analysis of easy a pair of dimensional frames and manually checked the accuracy of the software device with our consequences. The effects attempted to be terribly accurate. we generally tend to analyzed and d esigned a G+7 degree building together with basement [2-D body] ab initio for all capability load combos [useless, stay, and unstable loads]. STAAD. seasoned encompasses a terribly interactive interface that permits the customers to draw the frame and inpu t the load values and dimensions. Then in keeping with the favored criteria appointed it analyses the structure and styles the individuals with reinforcement details for RCC frames. we tend to continuing with our paintings with a few extra multistory 2-D and 3-D frames beneath varied load combinations. Our final paintings became the right analysis and style of a G+21 3-D RCC frame beneath numerous load mixtures. we generally tend to thought of a 3-D RCC frame with the dimensions of four bays. The coordinate axis consisted of G+ floors. the whole numbers of beams in every floor were twenty-eight and consequently the numbers of columns have been sixteen. the bottom floor peak became 4m and the rest of the 5 floors had a top of 3.6 m. The structure became subjected to self weight, dead load, stay load, wind load and risky loads underneath the burden case info of STAAD.pro. The seismic load esteems were produced by STAAD.Pro taking into consideration the given seismic powers at totally extraordinary statures and carefully perpetual by the determinations of IS 875.unstable burden computations were finished after IS 1893 - 2000.The materials were explicit and cross-segments of the shaft and section individuals were delegated. The backings at the base of the structure were conjointly explicit as attached. The codes of training to be pursued were conjointly explicit for style reason with elective fundamental subtleties. At that point STAAD.Pro was acclimated break down the structure and style the individuals. inside the post-handling mode, when finishing of the arranging, we can take a shot at the structure and concentrate the twisting minute and shear drive esteems with the created graphs. we will in general may check the avoidance of differed individuals underneath the given stacking blends. the arranging of the structure relies on the base needs as recommended inside the Indian ordinary Codes. The base needs relating the auxiliary wellbeing of structures square measure being covered by strategy for parturition down le ast style hundreds that should be expected for dead hundreds, mandatory hundreds, and elective outer hundreds, the structure would be required modern. Severe adjustment to stacking norms advised amid this code, it's trusted, can ensure the basic wellbeing of the structures that square measure being planned. Structure and basic parts were typically planned by Limit State system. refined and skyscraper structures might want frightfully time taking and bulky computations abuse run of the mill manual ways. STAAD.Pro gives US a brisk, productive, simple to utilize and address stage for breaking down.

[5] Comparative Study of Staggered Truss System With and Without Shear Wall Dharmin B Mistry , Vimlesh V Agrawal , Vishal B Patel [2021]- A staggered Truss System (STS) is a prospective steel structure system for high-rise buildings and a steel staggered truss framing system is one of the effective design techniques to improve the efficiency in building construction. Besides, cost reductions arise from a reduction in steel tonnage. The purpose of this study is to carry out a comparative analysis of staggered truss systems with and without a shear wall for 8, 9, and 10-storey buildings using the ETAB software. In this analysis, time histories are used. For the analysis, these structures are modeled in ETABS software and various displacement data are achieved for different types of structures. After analysis of the models, some outcomes were observed and it was concluded that the staggered truss system with the shear wall has lower displacement values compare to the staggered truss system in the x and y-direction. In the y-direction, displacement was 64% to 85% less and in the x-direction, it was 3% to 62% less than the conventional staggered truss system. So, after analyzing the data it was concluded that a staggered truss system with the shear wall is more efficient than the staggered truss system.

3. PROPOSED METHODOLOGY

3.1 MODELING USING ETABs

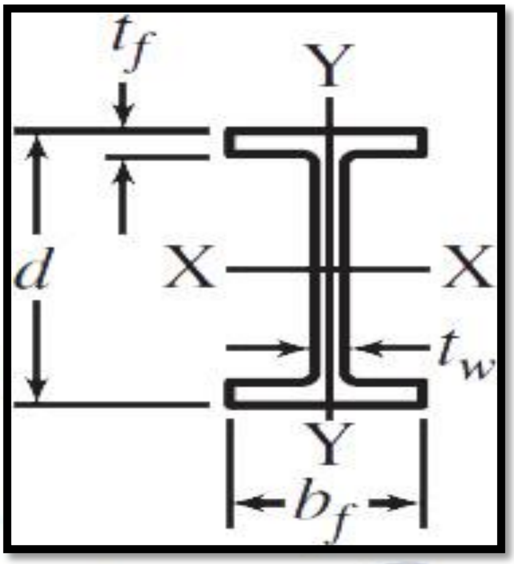
The innovative and revolutionary new ETABS is the ultimate integrated software package for the structural analysis and design of buildings. The latest ETABS offers unmatched 3D object based modeling and visualization tools, blazingly fast linear and nonlinear analytical power, sophisticated and comprehensive design capabilities for a wide-range of materials, and insightful graphic displays, reports, and schematic drawings that allow users to quickly and easily decipher and understand analysis and design results. From the start of design conception through the production of schematic drawings, ETABS integrates every aspect of the engineering design process. Creation of models has never been easier - intuitive drawing commands allow for the rapid generation of floor and elevation framing.

A. Analytical Model-

The structure has been stimulated in three dimensional steel staggered truss systems with similar spans and varying type of trusses. The columns are fixed at the base. Eight full-scale FE models with plan dimensions of 24X16.8m are constructed for parametric analyses. All the models are composed of five parallel frames with spacing of 6m and each planar frame consists of storey high trusses with span of 16.8m, arranged alternately in vertical direction. But the truss type and arrangement of the ground floor trusses are different with each other. The steel sections which are used for the framing of staggered truss system are wide parallel flange beams (WPB). The model of typical I section is shown in Figure 4.1. These are doubly symmetric shapes, generally used as beams or columns. Beams or columns under the standard have nominal flange width same as depth up to nominal beam depth 300 mm. The sectional properties of steel sections are given in below in Table 4.2. Beam depth larger than 300 mm have nominal flange width 300 to 400 mm. Columns have flange two numbers of hybrid trusses at each of the second, fourth and sixth floors, and two each at the third and fifth floors. The arrangement of trusses at top floor is same as that of the first floor. The truss properties are mentioned in Table 4.3. widths more than the depths. Beams and column section are manufactured with heavy, medium and light flange and web thickness. Beams and columns are designated by nominal depth and nominal flange width and mass in kg/m.

Table 4.2: Sectional Properties of Steel Sections

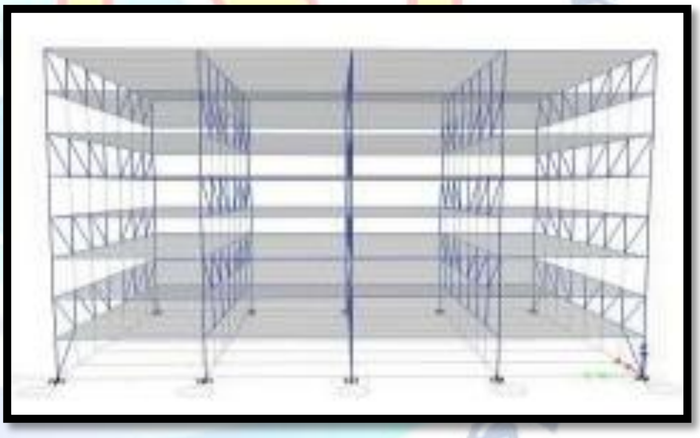
Designations	Mass (Kg/m)	Depth (D) mm	Width (B) mm	Web (t) mm	Flange (T) mm
Column WPB 400×400 Beam	191.10	368	391	15.0	24.2
ISMB 600 Chords	103.7	600	210	12.0	20.8
ISLB 600	99.5	600	210	10.5	15.5



[Fig.4.1: Parallel flange section]

B. MODEL 1-

Structure with three hybrid trusses at first floor. In this type of structure the first floor consists of hybrid trusses at first, third and fifth frames and open-web trusses at the second and fourth frames as shown in Figure 4.2. There are



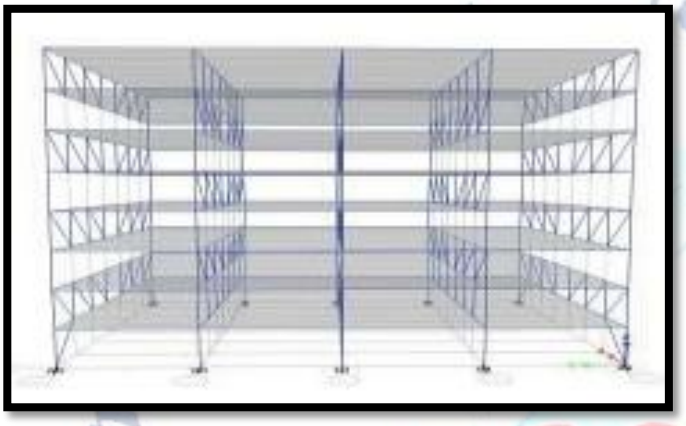
[Fig.4.2: Model 1]

Table 4.3: Properties of Model 1

Name	Model 1
Dimension	24X16.8 m
Type of truss	Hybrid truss
Number of storeys	8 m
Height of each storey	3 m
Column	WPB 400X400
Beam	ISMB 600
Chords	ISLB 600
Type of floor	Concrete
Thickness of floor	0.10 m

C. MODEL 2-

Structure with three open trusses at first floor In this type of structure the first, third, fifth and seventh floors consist of open-web trusses at first, third and fifth frames as shown in Figure 4.3. Also there are two numbers of open-web trusses at each of the second, fourth and sixth floors. The properties of truss are mentioned in Table 4.4.



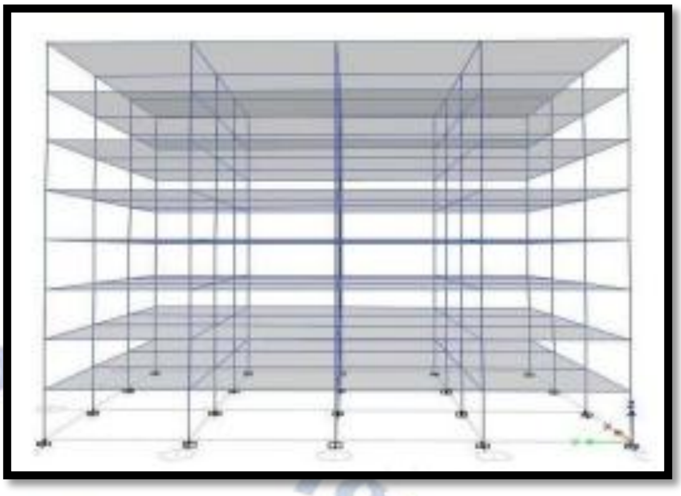
[Fig.4.3: Model 2]

Table 4.4: Properties of Model 2

Name	Model 2
Dimension	24X16.8 m
Type of truss	Open-web truss
Number of storeys	8 m
Height of each storey	3 m
Column	WPB 400X400
Beam	ISMB 600
Chords	ISLB 600
Type of floor	Concrete
Thickness of floor	0.10 m

D. MODEL 3-

Normal framed structure. This structure is modeled with normal frame as shown in Figure 4.4. There are four and five columns in x and y directions respectively. The columns in x direction are placed with a spacing of 5.6m each. The truss properties are mentioned in Table 4.5.



[Fig. 4.4: Model 3]

Table 4.5: Properties of Model 3

Name	Model 3
Dimension	24X16.8 m
Type of truss	Normal Frame
Number of storeys	8 m
Height of each storey	3 m
Column	WPB 400X400
Beam	ISMB 600
Type of floor	Concrete
Thickness of floor	0.10

4. RESULTS AND DISCUSSIONS

In this study two models of eight storey steel staggered truss system and one model of normal frame has been designed and their seismic performances has evaluated by time history analysis.

4.1 STOREY DISPLACEMENT

According to the analytical results the staggered truss system with hybrid truss and open web truss showed superior seismic load resisting capacity in the longitudinal direction of the building than the normal frame. The storey displacements of three models in both X and Y directions are shown below in the Table 5.1 and Table 5.2.

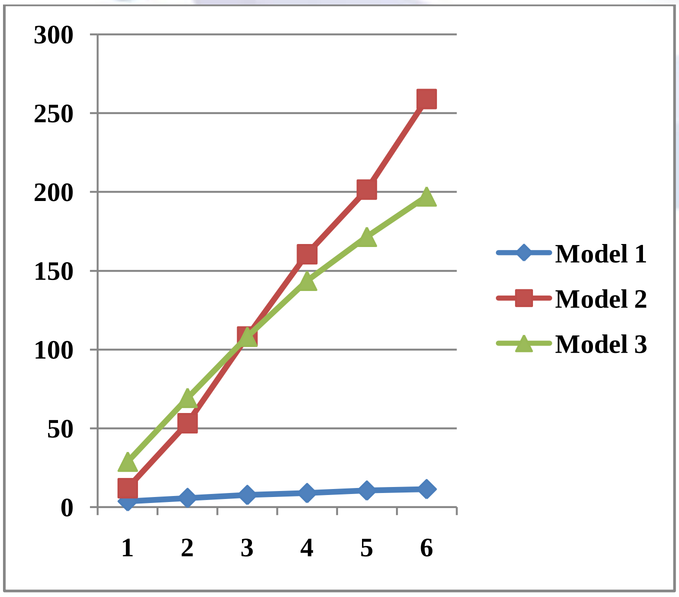
Table 5.1 Storey Displacement In X Direction

Storey	Model 1 (mm)	Model 3 (mm)	Model 3 (mm)
1	3.6	12.1	28.8
2	5.7	53.3	69.3
3	7.6	108.3	108.1
4	8.8	160.5	143.6
5	10.4	201.5	171.5
6	11.3	258.9	197.1
7	12.4	355.7	216.1
8	12.9	464.7	227.8

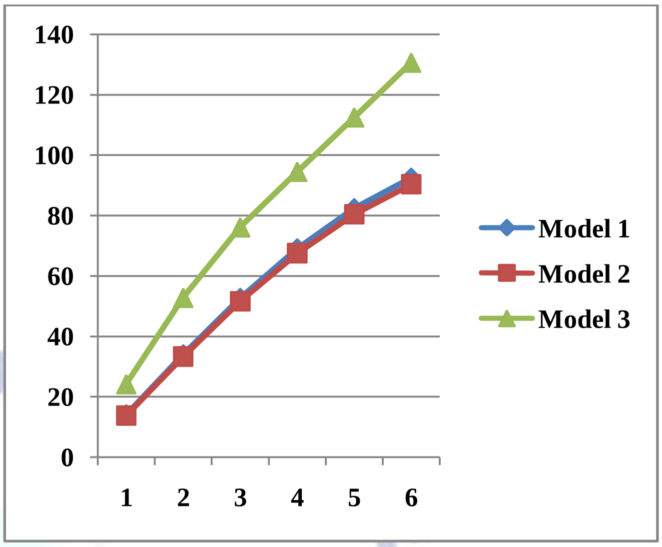
Table 5.2 Storey Displacement In Y Direction

Storey	Model 1 (mm)	Model 3 (mm)	Model 3 (mm)
1	14.1	13.8	24.2
2	34	33.3	52.8
3	52.7	51.6	76.1
4	69.1	67.5	94.5
5	82.4	80.4	112.5
6	92.5	90.3	130.6
7	99.4	97.1	143.6
8	103.1	100.9	156.8

In the case of longitudinal direction the model with hybrid truss showed the maximum seismic load resisting capacity with least storey displacement. The storey displacement in X and Y directions are shown in Figure 5.1 and Figure 5.2 respectively.



[Fig. 5.1: Storey displacement in X direction]



[Fig. 5.2: Storey displacement in Y direction]

4.2 STOREY SHEAR

The storey shear in the models shows an increasing manner in the values according to the height of building. The storey shear in X direction for model 2 have the least value and the model with normal frame have the highest value of storey shear. The graphical representation of storey shears of three models in X and Y direction are shown in Figure 5.3 and Figure 5.4 respectively. At the same time the value of storey shear in Y direction for models framed with hybrid trusses and open web truss shows almost the same value. While comparing the three models it could be concluded that the normal framed structure has the highest value of storey shear.

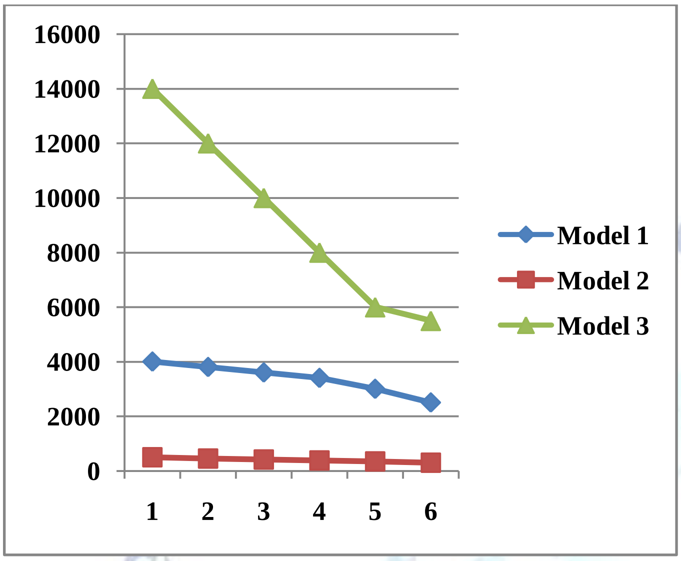
Table 5.3 Storey Shear In X Direction

Storey	Model 1 (KN)	Model 3 (KN)	Model 3 (KN)
1	4000	500	14000
2	3800	450	12000
3	3600	420	10000
4	3400	380	8000
5	3000	350	6000
6	2500	300	5500
7	2000	280	4000
8	1500	250	3000

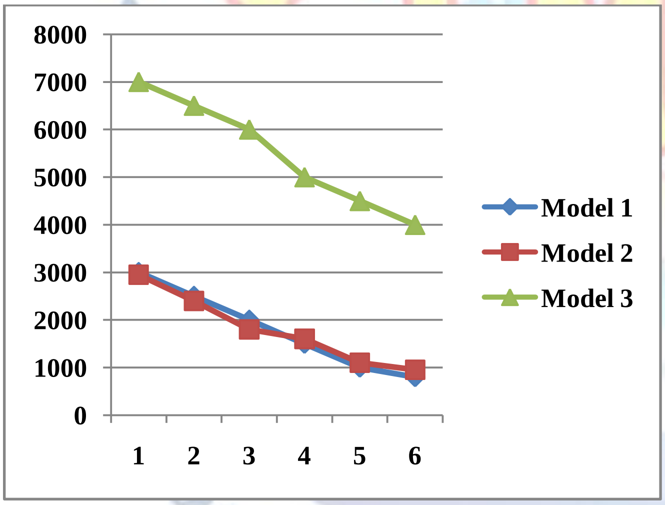
Table 5.4 Storey Shear In Y Direction

Storey	Model 1 (KN)	Model 3 (KN)	Model 3 (KN)
1	3000	2950	7000
2	2500	2400	6500
3	2000	1800	6000
4	1500	1600	5000
5	1000	1100	4500
6	800	950	4000

7	500	650	3800
8	200	280	3000



[Fig. 5.3: Storey displacement in X direction]



[Fig. 5.4: Storey displacement in Y direction]

5. CONCLUSION

The seismic analysis of steel staggered truss system has been completed and from the results it is clear that among the three structures modeled, the structure with hybrid truss have maximum strength. This structure has the minimum value of lateral displacement in both X and Y directions. The maximum value of lateral displacement and maximum value of storey shear is observed for the structure with normal frame. The storey shear in Y direction for Model 1 and Model 2 have almost the same value. The storey shear of the structure with normal frame has been observed as decreasing as the height of the building increases.

ACKNOWLEDGMENTS

The authors would like to express an acknowledgement to the Faculty of Civil Engineering Department and management of V.M Institute of Engineering and Technology, Nagpur, Maharashtra, India, for providing the facilities such as the Structural laboratory and advanced Structural laboratory to accomplish this study. The author also wishes to acknowledge cooperation given by laboratory technician from Faculty of Civil Engineering, V.M Institute of Engineering and Technology, Nagpur, Maharashtra, India, to complete this study

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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