Seismic Behavior of Steel Staggered Truss in Building

Ms. Sayali Sastare[1], Prof.P.K.Pasnur[2]
[2] Lectuer
[1, 2] JSPM's ICOER ,Wagholi , Pune, India.

Abstract- *The staggered-truss system (STS) is a concept in structural steel framing for multi-story and high-rise buildings. Staggered truss system is a prospective steel structure system for multi-story and high-rise buildings. The staggered-truss systems (STS) 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 system is known to be appropriate for use in residential buildings such as apartments, dormitory and hotels. As columns are located only on the exterior faces of the building, large clear span and open areas can be created. The interaction of the floors, trusses, and columns makes the structure perform as a single unit, there by 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. These column free areas can be utilized for ballrooms, concourses and other large areas. One added benefit of the staggered-truss framing system is that it is highly efficient for resistance to the lateral loading caused by wind and earthquake. The stiffness of the system provides the desired drift control for wind and earthquake loadings. The staggered-truss framing system is one of the quickest available methods to use during winter construction. The floor system not only carries the direct vertical loads, but in addition, has to act as a diaphragm to transfer the horizontal shear forces between stories through truss diagonals. Because of this double use concept this system results in a lighter structure and provides more column-free space than a conventional beam-column framed structure.*

Keywords- Staggered Truss System (STS), Seismic Behaviour, Storey Displacement, Storey drift.

I. INTRODUCTION

The staggered-truss framing system, originally developed at MIT in USA, has been used as the major structural system for certain buildings for some time. 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 arrangement of story-high trusses in a vertically staggered pattern at alternate column lines can be used to provide large column-free areas for room layouts as illustrated in Fig. 1.1. The staggered-truss framing system is one of the only framing systems that can be used to allow column-free areas on the order of 60 ft. by 70 ft. Furthermore, this system is normally economical, simple to fabricate and erect, and as a result, often cheaper than other framing systems. One added benefit of the staggered-truss framing system is that it is highly efficient for resistance to the lateral loading caused by wind and earthquake. The stiffness of the system provides the desired drift control for wind and earthquake loadings. Moreover, the system can provide a significant amount of energy absorption capacity and ductile deformation capability for high-seismic applications. When conditions are proper, it can yield great economy and maximum architectural and planning flexibility. It also commonly offers the most cost-efficient possibilities, given the project's scheduling considerations. The staggered-truss framing system is one of the quickest available methods to use during winter construction. Erection and enclosure of the buildings are not affected by prolonged sub-freezing weather. Steel framing, including spandrel beams and precast floors, are projected to be erected at the rate of one floor every five days. 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 and grouting, all "wet" trades are normally eliminated. Savings also occur at the foundations. The vertical loads concentrated at a few columns normally exceed the uplift forces generated by the lateral loads and, as a result, uplift anchors are often not required. The reduced number of columns also results in less foundation formwork, less concrete, and reduced construction time. When used, precast plank is lighter then cast-in-place concrete, the building is lighter, the seismic forces are smaller, and the foundations are reduced. The fire resistance of the system is also good for two reasons. First, the steel is localized to the trusses, which only occur at every 58 to 70 ft 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 achieved through proper construction of the wall. Also, the elements of the trusses are by design compact sections and thus will require a minimum of spray-on fireproofing thickness.

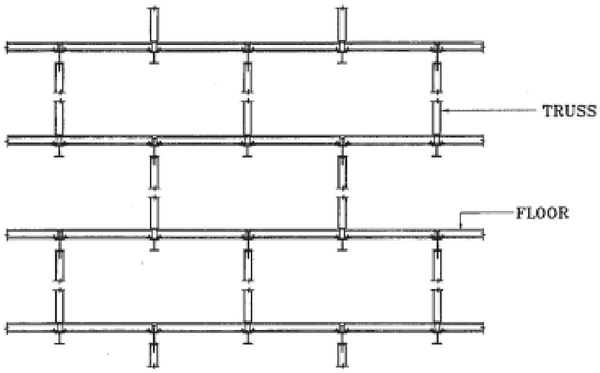


Fig. 1.1Staggered-truss system-vertical stacking arrangement.

A staggered-truss frame is designed with steel framing members and concrete floors. Most often, the floor system is precast concrete hollow-core plank. Other options, including concrete supported on metal deck with steel beams or joists, can be used. The trusses are manufactured from various steels. Early buildings were designed with chords made of wide-flange sections and diagonal and vertical members made of channels. The channels were placed toe-to-toe, welded with separator plates to form a tubular shape. Later projects used hollow structural sections (HSS) for vertical and diagonal members.

Advantages of Staggered Truss:

i. 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.
ii. 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.
iii. Columns are oriented with their strong axis resisting lateral forces in the longitudinal direction of the building.
iv. Maximum live load reductions may be realized because tributary areas may be adjusted to suit code requirements.
v. 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.
vi. 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.
vii. High strength steels may be used to advantage, because all truss members and columns are subjected, for all practical purposes, to axial loads only.
viii. 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.
ix. 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.
x. 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 place.

Following are the few picture of staggered truss used in building.

Fig .1.2 Staggered truss used in hotel

Fig .1.3Staggered truss placed on floor

II. METHODOLOGY

2.1 Selection of Earthquake Zone

Pune lies very close to the seismically active zone around koyna dam, about 100km south of the city and has been rated in zone III. This zone is classified as moderate damage risk zone. The IS code design zone factor of 0.16 for zone III. The importance factor and response reduction factor is 1.2 and 5 respectively for building.

2.2 No. of Storey

8 Storey building have been use in these study.

2.3 Role of ETABs

Extended Three-Dimensional Analysis of Building System (ETABs) is a kind of software generally used for structural analysis of multi-storey building or any structure. ETABs features are contain powerful graphical interface coupled with unmatched modelling, analytical, and design procedures, all integrated used in common data base.

2.4 Response spectrum method :

Response spectrum analysis is method to estimate the structural response to short, non deterministic, transient, dynamic event.

This concepts provide a conceptual basis for using response spectra based on single mass system for analyzing multi stoery buildings.

We can use response spectra of single degree of freedom for computing the deflected shape, storey acceleration, forces and moment.

III. MATERIAL DESCRIPTION

A staggered-truss frame is designed with concrete framing members and concrete floors. The beams and columns are designed as per IS code. Early buildings were designed with chords made of wide-flange sections and diagonal and vertical members made of channels. The channels were placed toe-to-toe. The properties of concrete members result from both its chemical composition and its method of manufacture. Standard properties of concrete and steel are given in Table 2.1.

Table 2.1 : Material Properties

Sr. No.	Property	Value
1	Density of Concrete	2400 Kg/m^3
2	Density of Steel	7850 Kg/m^3
3	Yield Strength	250 N/mm^2
4	Young's Modulus	2.1 x 10^5
5	Poisson's Ratio	0.3

IV. MODELLING OF STRUCTURE

Following structure are studied for the analysis.

(A)MODEL I: Structure without Steel Staggered Truss (STS)

In this type of structure, the structure is created normal frame i.e without using steel staggered truss system (STS).The G +7 storey building is created for analysis

Table 4.1: Properties Of Model I Structur

Sr.no.	Description	Values
1	Dimension	24 X 21m
2	Number of storey	8
3	Height of each storey	3 m
4	Type of floor	concrete
5	column	650 x 650 mm
6	beam	300 x 600 mm
7	Thickness of floor	0.15 m

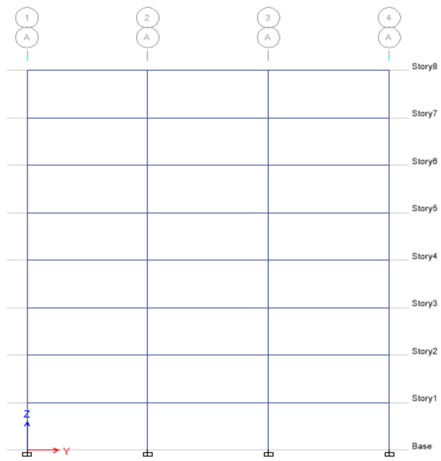


Fig.4.1: Elevation of Model I

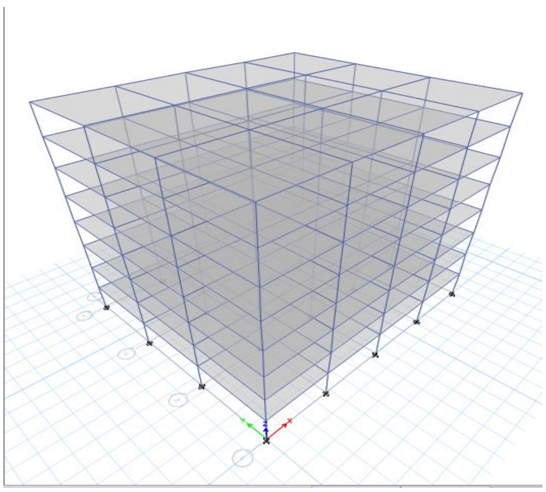


Fig.4.2: 3D View of Model I

(B)**MODEL II: Structure With Steel Staggered Truss (STS)**

In this type of structure, the structure is created using steel staggered truss system (STS). The G +7 storey building is created. In this model steel staggered truss are placed alternatively on the floor.

Table 4.2: Properties of model II structure

Sr.no.	Description	Values
1	Dimension	24 X 21m
2	Number of storey	8
3	Height of each storey	3 m
4	Type of floor	concrete
5	Column	650 x 650 mm
6	Beam	300 x 600 mm
7	Chords	ISLB200
8	Thickness of floor	0.15 m

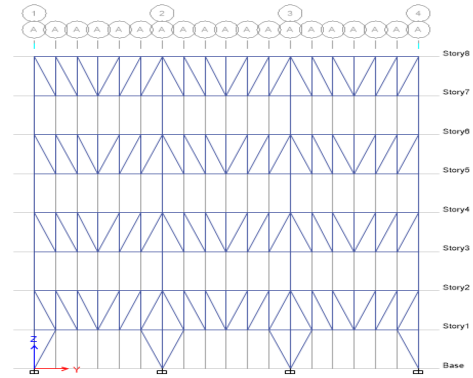


Fig. 4.3: Elevation of Model II

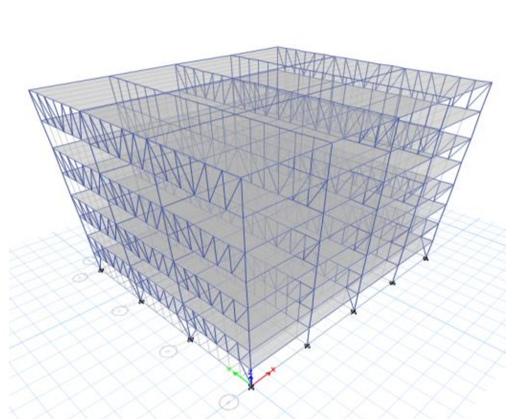


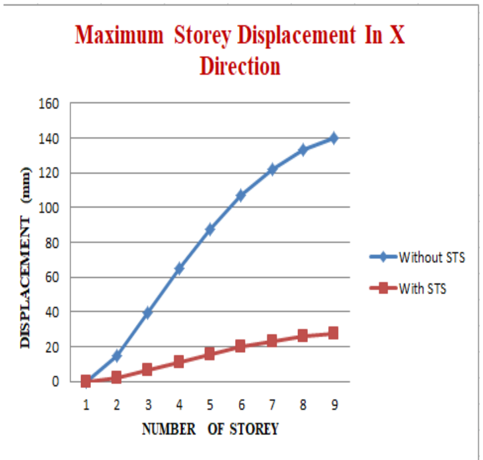
Fig. 4.4: 3D View of Model II

V. RESULT AND DISCUSSIONS

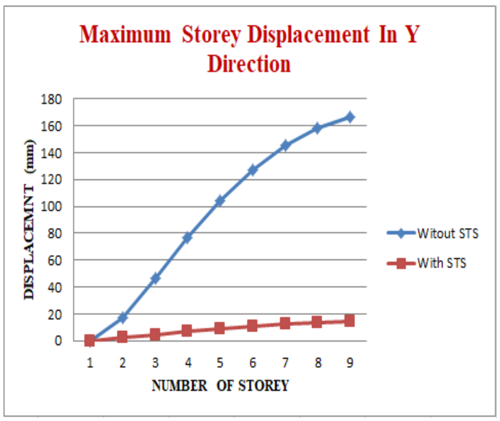
In this study two models of eight storey one model of normal frame and one model of steel staggered truss system has been designed and their seismic performances has evaluated by response spectrum analysis.

A) Storey Displacement

In case of storey displacement in both X direction& Y direction without steel staggered truss building shows maximum displacement. And the minimum storey displacement occurred in with steel staggered building.



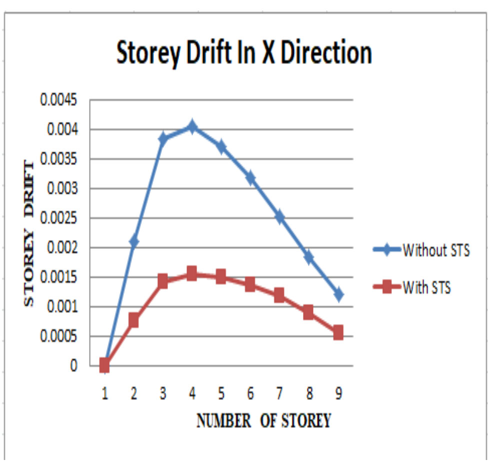
Graph 5.1: Maximum Displacement In X Direction



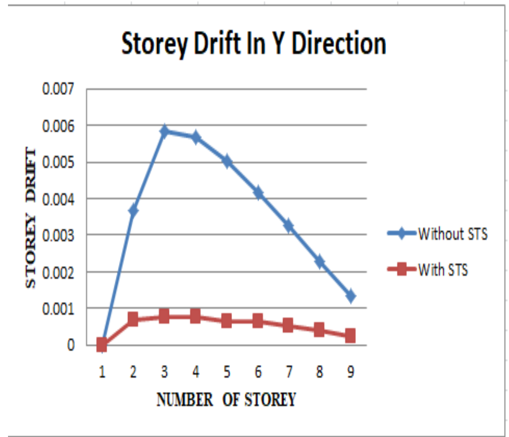
Graph 5.2: Maximum Displacement In Y Direction

B)Storey Drift

The distribution of storey drift ratio over building height become non uniform over building height increases. The storey drift ratio is higher in normal building than steel staggered truss system building for all lateral load cases. The storey drift ratio for steel staggered truss system is lower compared to normal building.



Graph 5.3: Storey Drift In X Direction



Graph 5.4: Storey Drift In Y Direction

VI. CONCLUSION

In this paper, an attempt is made to assess the seismic behaviour of steel staggered truss (STS) in the building. The seismic analysis of steel staggered truss system(STS) has been completed and form the result it is clear that steel staggered truss model building have maximum strength than the without steel staggered truss building. This structure has minimum value of storey displacement in both X and Y direction. The maximum value of storey displacement observed in without steel staggered truss building (STS).The storey drift ratio is less in steel staggered truss system(STS) than the normal building. Stiffer the frame storey drift ratio is less.

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