Research Paper Engineering

A Study on Staggered Truss Frame Steel Structural System

Sivaji Atturi Post Graduate Student in Computer Aided Structural Engineering

E. Arunakanthi Associate Professor, Department of Civil Engineering

ABSTRACT

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 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. A numerical studies will be perform on steel building with different number of diagonal chords of a truss before or after vierendeel and also comparing by varying vierendeel panel width to investigate the performance of staggered structural system using SAP2000 software. P-Delta analysis is done for all critical load combinations for each model and results are to be analyzed. The time history analysis is carried out to study the response of buildings using Bhuj earthquake data.

KEYWORDS : staggered truss system, story-high trusses, diagonal chords, P-Delta analysis, critical load combinations

INTRODUCTION:

When designing a structure in today's market, speed of construction, design flexibility, material costs, aesthetics, and availability of materials are just some of the many issues that must be addressed when making the initial decision as to what is the best way to frame out a proposed structure. Considering the optimal material to accommodate all of these issues is essential. For the multi-story residential market, structural steel has become more of a viable and popular option in recent years. A number of competitive steel systems offer the advantages of competing systems, but also have the ability to meet tighter schedule requirements and increase design flexibility in the process.

The Staggered truss system is a type of structural steel framing used in high-rise buildings 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.

LITERATURE REVIEW:

The staggered truss system came about due to sponsored research at Massachusetts Institute of Technology's Departments of Architecture and Civil Engineering in the 1960s by U.S. Steel. The research attempted to achieve the same floor-to-floor height with steel as you could with flat plate concrete. The system was presented at the 1966 AISC Conference. Additional benefits discovered were high resistance to wind loads and versatility of floor layout with large column-free areas.

It has been used with on a number of LeMessurier Consultants work in hotels including Lafayette Place Hotel in Boston and the Aladdin Hotel in Las Vegas. Other locations that use this system include the Resorts International Hotel in Atlantic City, New Jersey, Embassy Suites hotel in New York City, Baruch College Academic Center in New York City, Trump Taj-Mahal in Atlantic City NJ, and the Renaissance Hotel in Nashville TN.

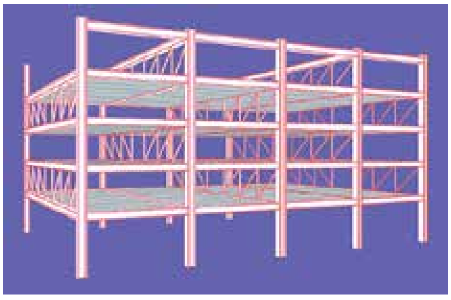


Figure 1: Typical 3-D model of standard staggered trusses supporting hollow core slabs

MATERIAL DESCRIPTION:

A staggered-truss frame is designed with steel framing members and concrete floors. M40 grade of concrete is considered. Steel properties are Yield strength is 250 N/mm^2, Density is 7850 Kg/m^3, Young's Modulus is 2.1x105 N/mm^2, Shear Modulus is 80769N/mm^2 and Poisson's Ratio is 0.3.

SECTION PROPERTIES:

Standard section recommended by the Indian standards code book IS 800: 2007 are considered. The steel sections which are used for the framing of staggered truss system are Heavy Weight Beams (ISHB-450). These are used as columns, Medium Weight Beams (ISMB-600) are used as top truss chord members, bottom truss chord members and spandrels, and Light Weight Beams (ISLB-600) are used as Truss Diagonals, Truss Verticals, Truss Hangers, and Truss Posts.

MODELING:

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. Full-scale FE models with plan dimensions of 42X27m are constructed for parametric analyses. All the models are composed of seven parallel frames with spacing of 7m and each planar frame consists of storey-high trusses with span of 27m, arranged alternately in vertical direction. But diagonal chords in trusses and Vierendeel panel width are varied.

The arrangement of staggered truss building system can be done by using two types of bays one is odd bay and another is even bay arranged alternatively one by one vertically

CASE-1:

In this type, 8 - storey buildings with varying the number of chords of the truss with different Vierendeel panel width is analyzed under critical load combinations height of each storey is considered 3meters. Total 6 models (consists of number of panels before or after Vierendeel are 1 or 2 or 4 or 6 or 8 or 10) are modeled and analyzed for each Vierendeel width of the truss, the Vierendeel widths taken are 2 meters, 3 meters, 4 meters, 5 meters, hence a total of 24 models are created.

CASE-2:

In this type, 8 - storey buildings with height of each storey is considered 3 meters. Total 9 models are modeled and analyzed for different Vierendeel width of the truss, the Vierendeel widths are taken as 2 meters, 2.5 meters, 3 meters, 3.5 meters, 4 meters, 4.5 meters, 5 meters, 5.5 meters, 6 meters, with same the number of diagonal chords of the truss i.e., 4 numbers on before and after the Vierendeel panel is analyzed under critical load combinations and also under time history analysis.

ANALYSIS:
Structural analysis is the determination of the effects of loads on physical structures and their components. Structures subject to this type of analysis include all that must withstand loads, such as buildings, bridges, vehicles, machinery, furniture, attire, soil strata, prostheses and biological tissue. Structural analysis incorporates the fields of applied mechanics, materials science and applied mathematics to compute a structure's deformations, internal forces, stresses, support reactions, accelerations, and stability. The results of the analysis are used to verify a structure's fitness for use, often saving physical tests. Structural analysis is thus a key part of the engineering design of structures.

P-DELTA:
Its effect, also known as geometric nonlinearity, involves the equilibrium and compatibility relationships of a structural system loaded about its deflected configuration. Of particular concern is the application of gravity load on laterally displaced multi-story building structures. This condition magnifies story drift and certain mechanical behaviors while reducing deformation capacity.

P-Delta effect typically involves large external forces upon relatively small displacements. If deformations become sufficiently large as to break from linear compatibility relationships, then Large-Displacement and Large-Deformation analyses become necessary.

DYNAMIC ACTIONS ON STRUCTURE:
Dynamic actions are caused on buildings by both wind and earthquakes. But, design for wind forces and for earthquake effects are distinctly different. The intuitive philosophy of structural design uses force as the basis, which is consistent in wind design, wherein the building is subjected to a pressure on its exposed surface area; this is force-type loading. However, in earthquake design, the building is subjected to random motion of the ground at its base, which induces inertia forces in the building that in turn cause stresses; this is displacement-type loading. Another way of expressing this difference is through the load-deformation curve of the building – the demand on the building is force (i.e., vertical axis) in force-type loading imposed by wind pressure, and displacement (i.e., horizontal axis) in displacement-type loading imposed by earthquake shaking.

TIME HISTORY ANALYSIS:
The Time History Response of a structure is simply the response (motion or force) of the structure evaluated as a function of time including inertial effects. The time history analysis in SAP2000 or ETABS allows base displacements as loading type. Again, the Base Acceleration loading type uses a text file for input. The base acceleration is very similar to the base displacement and represents putting the structure through some varying ground acceleration over time. Logically, the base acceleration is just the second derivatives of the base displacements. Similarly, the accelerations can act in the x, y, and z directions and again they can be any combination of all or some of these directions.

The 26 January 2001 Gujarat Earthquake (moment magnitude 7.9) occurred near the Rann of Kachchh in northwestern India. The Gujarat earthquake demonstrates again the devastation wrought on buildings that are subjected to a major earthquake.

RESULTS AND DISCUSSIONS:
In this study two models cases of eight storey steel staggered truss system has been designed and their performances has evaluated by P-delta and time history analysis.

All the models mentioned in the model-case1 are analyzed under 49 load combinations and also under time history analysis. The displacement in x, y direction, deflection in z direction, storey shear, bending, axial force, and base shear are compared with each and every model

The critical load combinations among 49 load combinations are:

LC6 = 1.7(DL + LL - WLx)

LC7 = 1.7(DL + LL - WLy)

LC11 = 1.2DL + 0.5LL -2.5WLx

LC13 = 1.2DL + 0.5LL -2.5WLy

LC20 = 1.7(DL + LL - EQx - 0.3EQy)

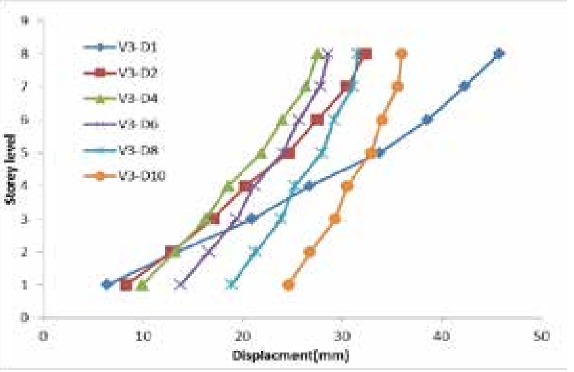
LC24 = 1.7(DL + LL - 0.3EQx – EQy)

LC36 = 1.2DL + 0.5LL -2.5(EQx - 0.3EQy)

LC40 = 1.2DL + 0.5LL -2.5(0.3EQx - EQy)

TABLE-1

Maximum Lateral Displacement (mm) in Y Direction for LC40 with Vierendeel Width 3mts

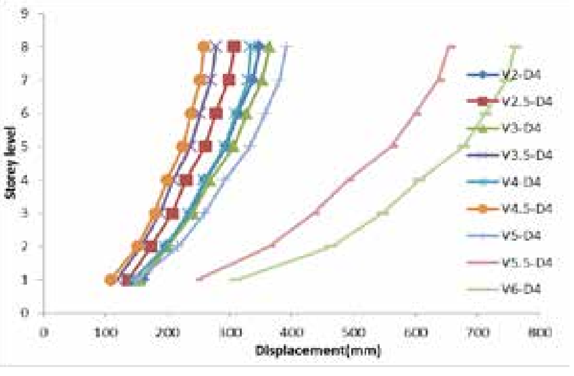


V refer to vierendeel width and D refers to the number of diagonal truss chords on one side

From the results it to be decided that number of diagonal chords of the truss before or after the vierendeel panel having 3 to 5 diagonal have less displacement, deflection, when compared with others, and shear, bending, axial force increases slightly with the increase in number of diagonals.

Therefore in the model-case-2 we use above results that is we consider number of diagonal before or after the vierendeel panel to be 4 as constant and now by varying the width of the vierendeel panel as 2, 2.5, 3, 3.5, 4, 5, 5.5, 6m under critical load combinations and Bhuj time history analysis the graphs and tables have been drawn below.

TABLE-2
Maximum Lateral Displacement (mm) in Y Direction for THA-2



From the results it has been observed that with which the increase in vierendeel panel width deflections displacement increases, but the storey shear, bending moment and axial force also increases slightly.

CONCLUSIONS:
After the complete analysis of the structures it has been concluded that number of diagonal chords of the truss before or after the vierendeel panel having 3 to 5 diagonal have less displacement, deflection,

shear, bending and axial force. And the vierendeel panel width will be considered according to the requirement and but it should be better to adopt least value as per requirement.

The diagonal chord angle should be maintained 40^0 to 50^0 for the effective performance of the structure.

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