Comparative Study of Wind Analysis of Highrise Building With The Effect of Outrigger And Shear Wall Structural System

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Abstract- *In recent high-rise buildings, a coupled wall system is adopted to resist lateral loads caused by wind or seismic. But as height of building increases, the structural stiffness plays significant role and the provision of outrigger system is benefited to give adequate stiffness to the structure against such lateral forces.*

This study presents the c results of shear wall and outrigger structural system for high-rise building of height 108 m subjected to lateral wind load. The analysis includes different building models with shear wall system, and outrigger system. By using Gust factor method as per IS: 875 (Part-3)-1987, the lateral wind load is calculated by considering dynamic 'along wind' response. Hence the aim of this study is to analyze and compare different models by changing the location of outrigger. Comparison of analysis results is made in terms of top storey displacement, axial forces.

Keywords- High rise building,wind analysis using gust factor, shear wall, outrigger a ETAB2016.

I. INTRODUCTION

High rise structures are more preferred now a day, due to tremendous growth of urban population and scarcity of available land. Structural analysis and design of high rise building is governed by lateral loads caused by seismic or wind. As height of structure increases, a lateral load becomes predominant. Interior structural system or exterior structural system provides lateral load resistance of the structure. The growth of high rise building is facilitated by enhancement in construction industry, effective materials, internal and external structural systems and advancement in analysis and design methods. Governing factor for structural design of high rise building is the lateral loads caused by wind or earthquake. It should to be noted that the assigned structural system is such that the structural components are used efficiently while ascertaining the design requirements. Various load resisting structural systems or philosophies which are usually incorporated in multi-storied structures are discussed here. The various structural systems are;

1. Rigid frame systems
2. Braced frame and shear-walled frame systems
3. Braced frame systems
4. Shear-walled frame systems
5. Outrigger systems
6. Framed-tube systems
7. Braced-tube systems
8. Bundled-tube systems

Motion perception or vibration is the third engineering difficulty creating in the structure‟s resistance to bending and shear. If building sway increases, structural system loses human comfort criteria or it may observe that the nonstructural components such as glass fascia may crack which causes expensive destruction to the building, also causing harm to the pedestrians.

II. LITARATURE REVIEW

Smith, B. S. and Alex Coull (1991) [1] investigated the optimum outrigger location by taking into account the tentative structures whose outriggers were flexurally rigid. It is seen that, structural system with single outrigger should be positioned at around midheight of the building, the outrigger should be positioned at approximately at 1/3rd and 2/3rd of height in case of structure with two outrigger system and it should be positioned roughly at 1/4th, 1/2, 3/4th of height in case of structure with three outrigger system, and so on.

Z. Bayati, M. Mahdikhani and A. Rahaei (2008)[2]studied on reduction in displacement for uniform belted structures having rigid outrigger by means of the analysis done on sample structure constructed in Vanak Park in Tehran. From analysis results it can be seen that, the seismic response of the building can efficiently reduce by using optimized multi outrigger system. Furthermore, it shows that the dimensions of the structural elements and foundation can decreases by multi outrigger system.

Po Seng Kian, Frits Torang Siahaan (2001) [3] studies that for high-rise building, the usefulness of outrigger belt truss system under wind or seismic lateral load. Analysis is done for eight 2-D models of outrigger belt truss system having 40-storey subjected to wind load and five 3-D models having 60-storey subjected to seismic load. Analysis results are compared to ascertain lateral displacement corresponds to the different positions of outrigger system.

Abbas Haghollahi, Mohsen Besharat Ferdous, and Mehdi Kasiri (2012)[4]studied present the comparison of optimum outrigger locations for response spectrum and nonlinear time-history analysis. For response spectrum and time-history analyses, 20 and 25 storey models have been investigated and carried out against seven ground motions. The aim of this study is to ascertain optimized location of outrigger with nonlinear time history is different from response spectrum analyses and it has been located in upper levels.

Khushbu Jani, Paresh V. Patel (2012) [5] carried out analysis and design of diagrid steel building having 36-storey. Analysis and design of structural member is conducted by using ETAB software. All structural elements are designed by taking into account all load combinations as per IS 875:2007. For analysis and design of structure dynamic along wind and across wind are considered. Likewise, for fifty, sixty, seventy and eighty storey high diagrid building, analysis and design is carried out.

III. SCOPE AND OBJECTIVE OF WORK

The present study aims to establish optimum location of outrigger and storey displacement in high-rise buildings. Taking into account the dynamic effects by using gust factor method of wind analysis as per IS 875 (Part 3)-1987. The 3D modeling and analysis has been considered using structural analysis and design software ETABS-16 and the results such as storey displacement, column's axial forces and material consumption are acquired and compared with different building models.

OBJECTIVE OF WORK:

1. Creating 3D building models with different storey module by varying the outrigger locations.
2. The main objective of this study is to investigate the behavior of structure for different lateral load resisting system i.e. outrigger and- shear wall under wind analysis.
3. To ascertain the optimum position of outrigger.
4. To obtain and compare the analysis results in the form of storey displacement, axial forces, for different building models with shear wall and outrigger structural systems.

IV. METHODOLOGY OF WORK

4.1 GENERAL

The present work represents the comparative study of wind analysis of high rise building with diagrid and outrigger structural systems using gust factor approach. For analysis 2 basic building models are considered in which building with shear wall (without outrigger), building with outrigger structural system are included. Each building model is further modeled by providing different locations of outrigger in case of outrigger structural systems. While there is no variation in model with shear wall structure. The performance of lateral load is made by imposing the lateral wind load having wind intensity low at bottom and goes on increasing at top to the building models by using gust factor methods per IS 875-1987 (part 3). At each floor level, the obtained wind load is applied to each of building models.

DYNAMIC WIND ANALYSIS

Dynamic wind analysis is required for high rise, slender and long span structures. Large dynamic motions with oscillations produced due to fluctuating forces on the structure caused by wind gust. Damping of structure and Frequency of vibration are the two parameters on which severity of dynamic motion depends. In both along wind and across wind direction, the motions are produced.

4.2 OUTRIGGER & BELT TRUSS STRUCTURAL SYSTEM

The structural configuration of an outrigger system includes central core tied to the exterior periphery column by means of rigid triangulated truss member names as outrigger truss. The central core can be of steel braced element or reinforced concrete core wall, and mainly situated at central location of building with outrigger connected to the exterior columns of building. The outrigger system consists of combined shear walls with outriggers that are capable to restrict inter-storey displacement subjected to wind as well as seismic loads and also reduces moment of central core and its dimension.

In outrigger and belt truss mechanism, the function of core wall is to resist lateral forces and weighty part of the loading is carried by the perimetral columns by means of axial load due to which windward columns subjected to tension and leeward columns subjected to compression. Former literature have represented that the outrigger and belt truss system can give extra lateral stiffness up to 25 to 30 % (Taranath 1988) or decreases lateral displacement of about 25 to 32 % (iyengar 1995). It is possible to directly connect each and every perimetral column to the outrigger; hence belt truss system along with outrigger is frequently implemented to tie all perimetral columns around the building.

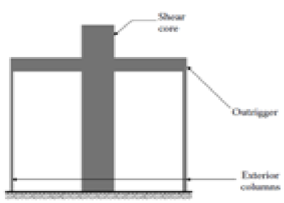


Fig. centrally located core with outrigger and belt wall structure

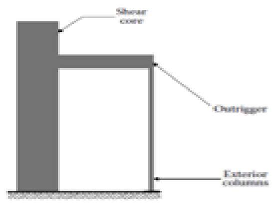


Fig. offset core with outrigger and belt wall structure

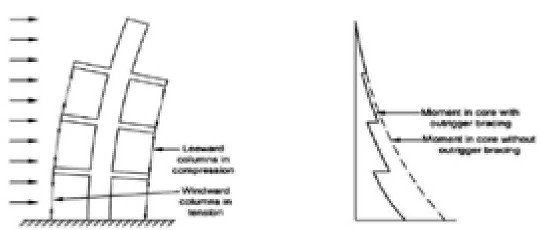


Fig. Outrigger structural system subjected to lateral load (b) Resultant core moment.

The usual structural performance of the outrigger and belt truss system is not complex. When structure is subjected to horizontal loads, the columns connected to the outrigger resist the rotation of the central core, hence moments and the lateral deflection in the core becomes lesser as compared to core alone set apart resisted the loading [The exterior moment is then opposed by core bending alone as well as by exterior columns through axial tension and compression. Due to which, structural effective depth is enhanced when it moves as vertical cantilever fixed at base by means of windward columns subjected to tension and leeward columns subjected to compression. Hereafter the remaining columns which are not connected to the ends of the outrigger, also mobilize to attend in withstanding the outriggers. This can be done by providing a deep spandrel beam, or triangulated truss which is known as belt truss placed at the periphery column corresponds to outrigger level.

The depth of outrigger and belt truss can be taken as one or two stories deep to make it sufficiently stiff in flexural and shear. Diagonal members extending over multiple floors can also be adopted as an outrigger . It has to remember that in outrigger system, the flexural stiffness of the structure is significantly increases whereas its shear resistance does not increase which is further taken by central core.

Optimum Location of Outrigger Structural System

There are more options for locating the two outriggers in different positions.

Deflection reduction in building near to the optimum values may be attained with outriggers located completely diverse from optimum locations. Hence, there is some freedom to engineers and architect while ascertaining the optimum locations of outriggers. However, it is appropriate to locate one outrigger roughly at half of building height.

The outrigger should be positioned approximately at 1/3rd and 2/3rd of height in case of structure with two outrigger system. And outrigger should be positioned roughly at 1/4th, 1/2, 3/4th of height in case of structure with three outrigger system, and so on. Generally, the outrigger located at 1/(n+1), 2/(n+2) up to n/(n+1) of height to achieve satisfactory results for an n-outrigger structure.

V. MODELING AND ANALYSIS OF STRUCTURE

In the present study, two different structural systems viz, shear wall and Outrigger is taken into consideration. The analysis of building does not exhibit a specific existing structure that has been built. Nevertheless, the building configuration is set to satisfy the aspect ratio to perform dynamic wind analysis. The building models with shear wall and outrigger is modeled and analyzed using the structural software ETABS and the results are compared.

ETABS SOFTWARE

ETABS is most comprehensive software for modeling, analysis and design of building. The ETABS program comprised of finite element based linear static and dynamic analysis, nonlinear static and dynamic analysis of buildings, static and dynamic P-delta analysis, pushover analysis, response spectrum analysis, time History Analysis, construction sequence loading analysis. In this work, the effort is made to investigate the performance of the shear wall and outrigger structural system under dynamic response. At the end of analysis, the top storey displacement, column axial forces, and material comparison of different building models are gained in the analysis.

MS-EXCEL SOFTWARE

After analyzing the different structural models by including gravity as well as lateral loads with different load combinations, the excel sheet is used to show different graphs represents difference between top storey displacement, axial forces in the column, material comparison.

Structural Configuration :

- Number of stories : 30 Stories
- Height of storey : 3.6 m
- Height of structure : 108 m
- Plan dimension : 18m x 18m

Material Properties:

- Grade of concrete : M30
- Grade of steel reinforcement : Fe500
- Grade of steel section : Fe345

Structural Parameter:

-Floor level column: 1000mmx1000mm(steel column)
450mmx450mm(concrete column)

-Ground level column : 1000mm x 1000mm (concrete column)

-Floor level beam : ISWB 600 & builtupsection (diagrid)
ISMB 500 & ISWB 600 (outrigger)

- Floor beam : 230mmx600mm
(outrigger)

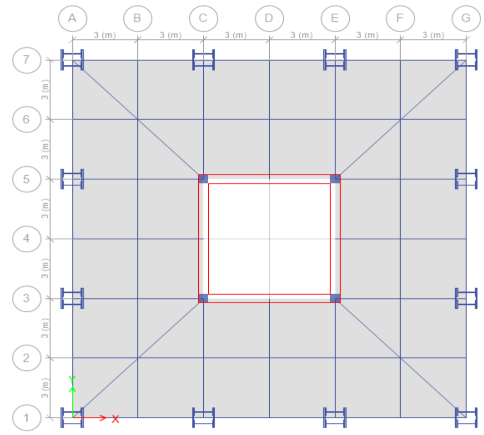
-Slab Thickness : 130mm

-Outrigger beam : 2ISA 200mm x 200mm x 25mm
(Double angle section)

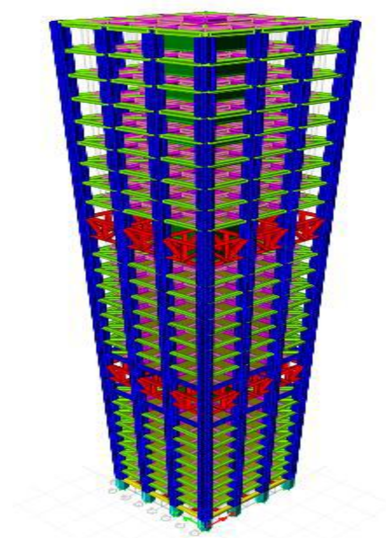
-Outrigger belt truss : 2ISA 200mm x 200mm x 25mm
(Double angle section)

-Core wall Thickness : 450mm

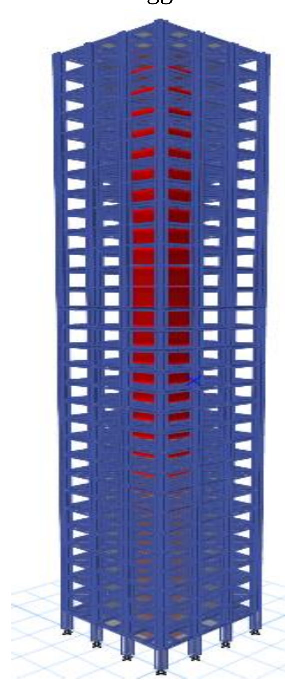
-Wall Thickness : 230mm



PLAN FOR SHEAR WALL AND OUTRIGGER



Building With Two Outrigger At 0.33H And 0.66H



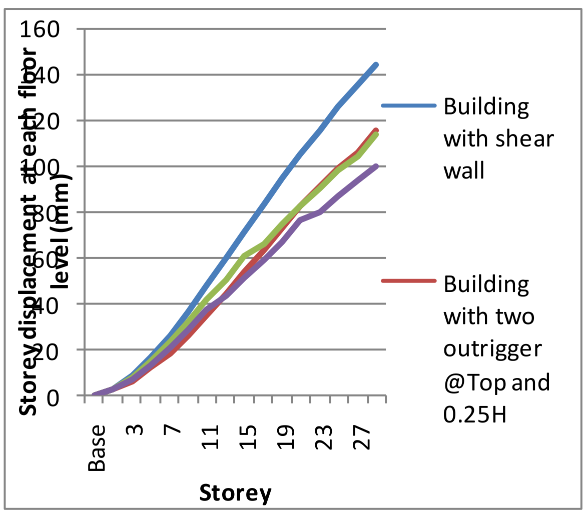
Building With Shear Wall

VI. RESULT AND DISCUSSION

In this section, analysis results of the building structures with two outriggers at various locations and shear wall , considered for the dynamic response of wind are presented.

Top storey displacement (mm) Top storey displacement is one of the relevant stiffness design criteria in any high rise structural system. Permissible value of top storey displacement should be limited to the ratio Height/500. The important parameter oversee throughout the complete analysis is displacement at the top of the structure. The following table gives the results for top storey displacement for the structural models having two outriggers at different locations.

Structural system	Top storey displacement(mm)
Building with shear wall	148.582
Building with two outrigger @Top &0.25H	116.551
Building with two outrigger @Top &0.5H	114.609
Building with two outrigger @0.33H &0.66H	103.224



Storey displacement of each storey level for outrigger structure with three different outrigger locations are tabulated in table . it can be observed, as compared to shear wall structure the top storey displacement of building with two outrigger at top and 0.25H is reduced by of about 21.55 %, the top storey displacement of building with two outrigger at top and 0.5H is reduced by of about 22.86 %, and the top storey displacement of building with two outrigger at 0.33H and 0.66H is reduced by of about 30.52 %.

From table it can be seen that by introducing outriggers, the top storey displacement reduces of about 30.52 % for 0.33H and 0.66H location of outrigger as compared to the building without outrigger (i.e building with shear wall only). In high rise building, provision of outrigger at optimum location increases the shear rigidity of the structure, subsequently the structural stiffness also increases which gives the resistance to deflection under lateral loads and hence top storey displacement will be less.

Axial Force (KN) The axial force results in structure provided with two outriggers at different locations are tabulated in table given below

Structural system	Axial force in column (KN)
Building with shear wall	12601.99
Building with two outrigger @Top &0.25H	11641.62
Building with two outrigger @Top &0.5H	11618.66
Building with two outrigger @0.33H &0.66H	11537.76

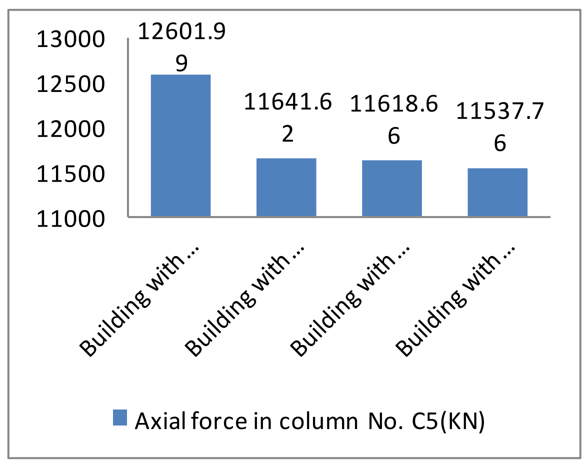


Table and fig. shows the axial force (kN) in column for building models consisting of two outriggers at different locations. It can be observed that the value of axial force in column C5 is higher (11641.62kN) for building model with outrigger location is at top and 0.25H as compared to another two outrigger models. Provision of outrigger in the highrise structure decreases the displacement of the building as well as axial force in the column reduces by 7.62% for the building model to with outrigger location is at top & 0.25H; for the building with outrigger location is at top & 0.5H, the axial force reduces by 7.82%; and for the building with outrigger location is at 0.33H &0.66H, the axial force reduces by 8.44% as compared with the building model without an outrigger (12601.99 kN) By introducing the outrigger the stresses in the columns are reduced as compared to building without an outrigger system. Also due to provision of outriggers, the forces get evenly distributed and hence the column axial forces are also reduced.

VII. CONCLUSIONS

In the current study, an effort is made to investigate the behavior of outrigger system and shear wall in high rise building of about 108m height subjected to trapezoidal distribution of wind loads. The following conclusions can be made based on the analysis results

1. The provision of outrigger with belt truss system in high rise buildings enhance the structural stiffness and make the structural system effective under lateral load as well as they are effective in reducing the lateral displacement.
2. The study shows that the performance of outrigger structural systems considerably affected by optimum location of outrigger system. Hence from analysis results, it may be conclude that the optimum location of outrigger structure is at 0.33H and 0.66H that is one third and two third of height to which corresponding top storey displacement is getting less.
3. By introducing the outrigger the stresses in the columns are reduced as compared to building without an outrigger system. Also due to provision of outriggers, the forces get evenly distributed and hence the column axial forces are also reduced.

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