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PARAMETRIC STUDY ON MULTI-STOREY RC BUILDING WITH BELT TRUSS SYSTEM: A REVIEW

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Abstract- *Due to the advances in structural systems nowadays building became light weight, and slenderness is increased. Which is the reason why the lateral loads are required to be considered. These lateral loads are wind and earthquake load. For resistance of this lateral loads in tall buildings, identification of proper structural system is must. For lateral resistance of tall buildings, there are many structural systems. In tall buildings, the stiffness of the building becomes more important. Thus, the belt truss outrigger system is used in tall building to provide sufficient lateral stiffness. Outrigger and belt truss system is one of the structural system which controls the excessive drift due to lateral load. The risk of structural and non-structural damage can be lowered during wind or earthquake load by using this system. In this review work the behaviour of building having belt truss and outrigger system and change in its parameters are studied from different research works.*

Keywords- *Belt Truss System, Outriggers, Tall Building, Optimum Position, Response Spectrum Method*

I. INTRODUCTION

From the establishment of civilization, tall towers and buildings have enthralled mankind. Contemporary tall buildings begin to development in the 1880 has mostly for commercial and residential building purposes [1]. Due to quick increment of population and for it limited space available tends to increase tall buildings. Tall buildings are generally built based on commercial or residential purposes. Vertical, horizontal or torsion type of loads give various effects on building. The primary function of the structural elements is to resist the gravity loading from the weight of the building and its contents and secondary function of the vertical structural elements is to resist the wind and earthquakes whose magnitude will be varied from the epicenter to epicentral distance whose magnitude obtained in the IS 1893 2002 code book [1]. As height of structure increases its displacement, story shear, story drift of the building decreases. To restrain those parameter in the building under seismic and wind load, suitable method to be taken to reduce those effect [1].

The design of tall and slender structures is controlled by three governing factors, strength (material capacity), stiffness (drift) and serviceability (motion perception and accelerations), produced by the action of lateral loading, such as wind [2]. By the advances in structural design/systems and high strength materials, building weight has reduced, in turn increasing the slenderness, which necessitates taking into account majorly the lateral loads such as wind and earthquake [3]. Specifically, for the tall buildings, as the slenderness, and flexibility increases, buildings are severely affected from the lateral loads resulting from wind and earthquake [3]. Hence, it becomes more necessary to identify the proper structural system for resisting the lateral loads depending upon the height of the building [3]. There are many structural systems that can be used for the lateral resistance of tall buildings like Braced frame systems, Rigid frame systems, Outrigger systems, Shear-walled frame systems [3]. Figure 1 shows the outrigger and belt truss system.

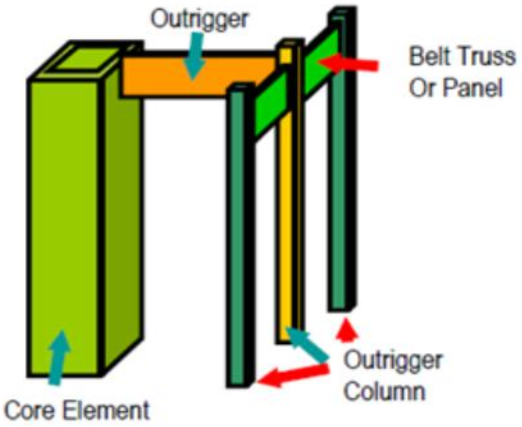

Figure 1.Outrigger and belt truss [2]

During the last few decades several buildings have been built utilizing belt truss and outrigger system for the lateral loads transfer (throughout the world) [4]. The efficiency of the building structure may be improved by the use of horizontal belt trusses that tie the frame to the core (Schueller 1977) [5].

II. LITERATURE REVIEW

A. Optimization of Outrigger Locations in Steel Tall Buildings as Subjected to Earthquake Loads; 15 WCEE Lisboa 2012

Abbas Haghollahi, Mohsen Besharat Ferdous, Mehdi Kasiri; "Optimization of Outrigger Locations in Steel Tall Buildings as Subjected to Earthquake Loads**".**In this paper, author derived the location of the outrigger, which is optimum, by response spectrum analysis and nonlinear time-history analysis. Then this both results were compared. They prepared two models of 20 and 25 storey models. Against seven ground motions response spectrum and time-history analysis was carried out. This study utilized 3D high rise steel frame braced models with 20 and 25 storey with outrigger and belt truss system. Space between frames at direction X and Y is 5 m and 5.5 m respectively. The braced system of the building model is prepared with double diagonals in an "X" configuration. SAP 2000 was used for analysis of this building model.

This paper concludes that optimum location of outrigger and belt truss resulted from response spectrum analysis for 20 storey model is storey 10 and for 25 storey model is storey 14. And for optimum location of time-history analysis is storey 14 for 20 storey model and storey 16 for 25 storey models.

B. Optimum Position of Outrigger System for Tall Vertical Irregularity Structures; IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), e-ISSN: 2278-1684, p-ISSN: 2320-334X, vol. 12, no. 2, pp. 54-63, March-April 2015

K Shivacharan, Chandrakala S, Karthik N M; "Optimum Position of Outrigger System for Tall Vertical Irregularity Structures".In this research paper, the use of outrigger and belt truss placed at different location subjected to wind and earthquake load is studied. The design of wind load was calculated based on IS 875 (Part 3) and the earthquake load obtained using IS 1893 (Part-1): 2002. They conducted linear static analysis to examine the behaviour of vertical irregularities of outrigger structure in ETABS. In it the vertical irregularities structures with 30 stories 7X7bay from 1st to 10th floor 5x5bay from 11th to 20th floor, 3x3bay from 21st to 30th floor with outriggers and belt truss at different stories were analysed. Maximum Storey Shear and Axial Load of different columns were observed for the structure with first and second location of the outrigger.

In this study, it is concluded that provision of second outrigger with 0.67h gives the reduction of 12.78% in deflection and 11.5% in drift. It is also concluded that the optimum location of the outrigger is near about 0.5 times of buildings height.

C. Behaviour of Outrigger Beams in High Rise Buildings Under Earthquake Loads; Australian Earthquake Engineering Society, Melbourne, 2009

N. Herath, N. Haritos, T. Ngo & P. Mendis; "Behaviour of Outrigger Beams in High Rise Buildings Under Earthquake Loads".In this study researchers aims to derive the optimum outrigger location in tall buildings under earthquake loads. They investigated 50 storey building and three different peak ground accelerations to peak ground velocity ratios in each category of earthquake. Response parameters such as lateral displacement and inter story drift were considered to determine the behaviour of the building by conducting response spectrum analysis on it. The height of each storey in building considered is 3.75m and all wall piers are identical with a uniform wall thickness of 450mm over the entire height. The STRAND 7 finite element package was used to simulate the model and two-dimensional analysis was conducted to identify the behaviour of the structure under earthquake loads.

It has been shown from this study that the structure is optimized when the outrigger is placed between 22-24 levels. Therefore, it was concluded that the optimum location of the structure is between 0.44-0.48 times its height (taken from the bottom of the building).

D. The Use of Outrigger and Belt Truss System for High-rise Concrete Buildings; Dimensi Teknik Sipil, ISSN 1410-9530, vol. 3, no. 1, pp. 36-41, 2001

Po Seng Kian, Frits TorangSiahaan; "The Use of Outrigger and Belt Truss System for High-rise Concrete BuildingsIn this paper, the use of belt truss system with outrigger for high rise concrete building subjected to earthquake and wind load were studied. In it two-dimensional, 40-storey building with 6 m central shear wall and 12 m bays on either side was considered. The typical floor height was 3.5 m and total height of 140 m. The beams, columns, shear walls and outriggers were assumed as concrete structure. For two-dimensional model total of 8 different arrangements of outriggers analysed using GT-Strudl software program. For Three-dimensional model was of 60 storey and it was analysed by using ETABS software. For it 5 different models were prepared in ETABS.

It is stated that for two-dimensional model, single outrigger provided at the middle of the structure height reduces the maximum displacement by 56 %, while providing first outrigger at the top and second outrigger at the middle of the structure height reduces displacement by 65%. For three-dimensional structural model subjected to the earthquake load, about 18% reduction in lateral displacement can be achieved with optimum location of the outrigger truss at the top and 33rd level.

E. Optimum Position of Outrigger System for High-Rise Reinforced Concrete Buildings Under Wind and Earthquake Loadings;American Journal of Engineering Research (AJER) e-ISSN: 2320-0847 p-ISSN: 2320-0936, vol. 2, no. 8, pp. 76-89, 2013.

P.M.B. Raj Kiran Nanduri, B.Suresh, MD. Ihtesham Hussain; "Optimum Position of Outrigger System for High-Rise Reinforced Concrete Buildings Under Wind And Earthquake Loadings".In this study optimum location of outrigger, its behaviour and efficiency of every outrigger when three outriggers are used in the building is studied. Nine 30−storey three dimensional models of outrigger and belt truss system, subjected to wind and earthquake load are analysed. In it techniques for using belt trusses and basements as "virtual" outriggers in tall buildings have been proposed. ETABS program is used in this study. All the building models analysed in the study have 30 storey with constant storey height of 3 meters. R.C.C. structure is taken into consideration and the analysis is done as per the Indian standards. There are 7 bays in both direction at spacing of 5.5 m.

It concluded that maximum drift at the top of structure when only core is employed is around 50.63 mm and this is reduced by suitably selecting the lateral system. The placing of outrigger at top storey as a cap truss is 48.20 mm and 47.63 mm with and without belt truss respectively. It also shows that using second outrigger with cap truss gives the reduction of 18.55% and 23.01% with and without belt truss. The optimum location of second outrigger is middle height of the building. Figure 2 and Figure 3 shows the result derived by analysis of above building.

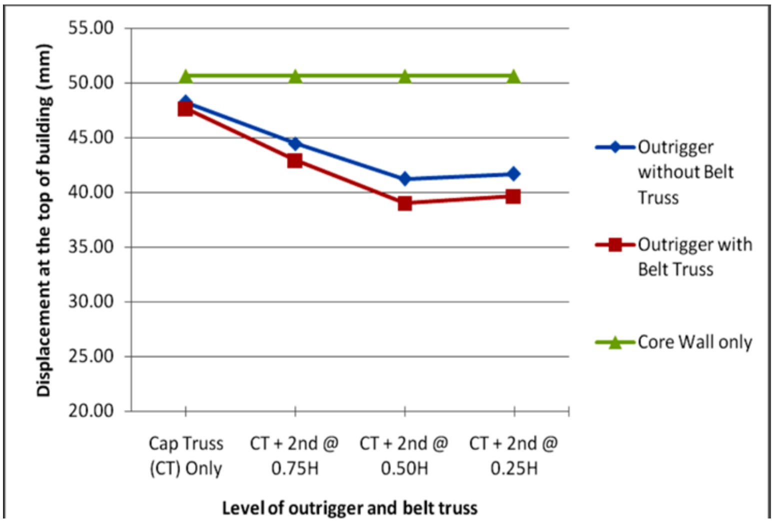

Figure 2.Lateral Displacement of the top storey as a function of level of outrigger and belt truss

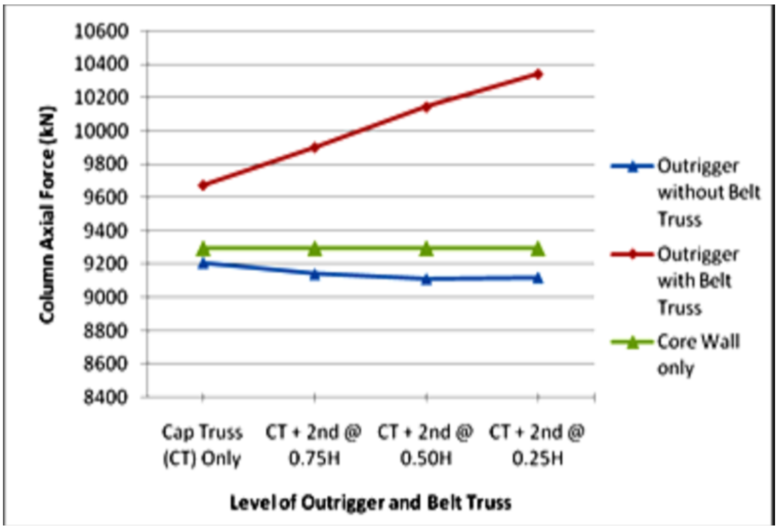

Figure 3.Compression forces in column for different levels of outrigger and belt truss

F. Deflection Control in Composite Building by Using Belt Truss and Outriggers Systems; International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, vol. 4, no. 12, pp. 414-419, 2010

S. Fawzia and T. Fatima; "Deflection Control in Composite Building by Using Belt Truss and Outriggers Systems". In this paper author investigated that how deflection control in the 60-storey composite building having belt truss and outrigger system can be done which is subjected to wind load. In it three-dimensional Finite Element Analysis were performed with one, two and three outrigger levels. In this paper, the model is 60 storey with floor to floor height of 3.5 m making total height of the building as 210m with braced core frame and simple construction is adopted for this building based on definition provided in Australian standards. Steel sections are chosen from ASI design capacity tables.

In this paper, it is concluded that the introduction of two and three outrigger levels in considered composite structure results in a further 8% and 9% deflection reduction respectively. A comparable fashion can be seen in the reduction of inter-storey drifts as in displacements.

G. A Study on Behavior of Structural Systems for Tall Buildings Subjected to Lateral Loads; International Journal of Scientific Development and Research (IJSDR) ISSN: 2455-2631, vol. 2, no. 7, July 2017

Yogendra BhojujiMeshram, S.B. Sohani; "A Study on Behavior of Structural Systems for Tall Buildings Subjected to Lateral Loads". In this research, the concept of high rise building, which includes basic design considerations, and lateral loads of tall buildings, were studied. Then the results for different shear wall and outrigger positions were analysed and conclusions were made as to which condition buildings taken in the consideration are most stable. The derivation of various parameters such as displacement, drift, base shear and time period were studied.

In this study the analysis of g+20,30,40 multi storey steel building is done against earthquake and wind loads as per Indian standard codes of practice IS 1893(Part 1):2002 and IS 875(Part 3):1987. Nagpur was the building location taken by author for earthquake and wind loads application. In it building is subjected to self-weight, dead load, live load as per IS 875(Part 1, Part 2):1987. Author carried out dynamic analysis using response spectrum method. For the analysis ETAB 2016 software were used.

It is observed that X type of belt truss system is suitable for all type of models in this study. It is concluded that shear wall provision is effective for 20 storey building. For 30 and 40 storey building X type belt truss outrigger system is more effective.

H. Optimized Use of Multi-Outriggers System to Stiffen Tall Buildings; The 14th World Conference on Earthquake Engineering, Beijing, China, Oct 2007

Z. Bayati, M. Mahdikhani, A. Rahaei; "Optimized Use of Multi-Outriggers System to Stiffen Tall Buildings". In this paper, the results of an investigation on drift reduction in uniform belted structures having rigid outriggers, through the analysis of a sample structure built in Tehran's Vanak Park is presented. Author modelled an 80-story steel-framed building and investigated for the effectiveness of belt trusses as virtual outriggers. Designs with conventional outriggers and virtual outriggers was compared. The floor-to-floor height in this building is 4 meters. The building has three sets of 4-story outriggers between Levels 77 and 73 (at the top) second between Levels 46 and 50; and third between Levels 21 and 25. The analysis of building was done as a three-dimensional elastic structure, using the ETABS program.

The results of this study show that the lateral displacement at the top of the building due to wind loading was 70 cm for the design with conventional outriggers and 95 cm for the design with belt trusses as virtual outriggers. when the analysis of structure was done with no outriggers at all, the displacement increased to 275 cm. and when the structure with virtual outriggers was analysed with a ten-fold increase in the in-plane stiffness of the floor slabs at the top and bottom of each belt truss, displacement decreased to 80 cm. When, in addition, the belt truss member sizes were increased ten-fold, the displacement decreased further to 65 cm.

III. CONCLUSION

From the above literature we conclude that
1) Optimum position for the first belt truss outrigger in structure is near about 0.50 times of its height.
2) For second and third outriggers, top floor and basement are optimum location for the structure.
3) For belt truss system X-type belt truss is most suitable for most of the structures.
4) Belt truss system is effective for all type of composite, steel and concrete structures.

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