Investigation of Seismology Achievement For Height Tower Construction With Cantilevered And Conveyor Frame Structure

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Abstract- *The cantilevered structure has become one of the most done a lot of research and effective systems that can be employed to build up the lateral load initiatives are being taken of a multi - story building. The ascent to the skyscraper has a slimming effect. Core wall structure with connections of diagonally projections beam, outriggers has been a very effective structural system decreasing the drift that is related to lateral load and leading to stability of structure. The position modification of the surfboard, in addition to the inflatable dinghy along the belt structural member, will be the primary focus of this study. Outrigger and belt trusses are given in a variety of locations, including H/3, 2H/3, and the top position from the base. A multi-outrigger mechanism is utilized for the construction of the 60-story structure. Also compared and determined the best design for the outrigger and belt truss by using X, V, and inverted V bracing. When doing a response spectrum analysis for a Normal Building (NB) or a Symmetric Setback Building (SSB) with 30 or 60 stories, the outriggers and belt truss construction must be taken into consideration. When conducting responsive wavelet transform, the ETABS software is typically used. When determining the appropriate location and shape of braced outriggers and belt truss, the maximum story drift, top storey displacement, base shear, and time period are all parameters that are taken into consideration. When the outriggers were placed in the most advantageous positions, there was a 7–8 percentage point reduction in the maximum amount of top story displacement and maximum story drift. It has been discovered that outriggers with X-shaped bracing are effective.*

Keywords- dampers, Tall building of RC frames, storey drifts, lateral displacements, base shear in the building.

I. INTRODUCTION

Tall buildings have essentially become a need of the present populations tends in the world, which led to an increase in the demand of tall structures. There is a limited amount of land accessible in cities, thus higher buildings are preferred. High rise buildings have been known to possess a high risk towards lateral loads due to its slender nature which has inspired structural engineers to come up with inventive solutions to these effects. Therefore, When the height of a building increases, the lateral load turns out to be enormously important. As a result, the structural system that counter attacks gravity loads becomes less significant than the lateral load resisting system. With the use of modern structural systems and high-strength materials, buildings are lighter, slenderer and more resistant to wind and earthquake. Specially for the high rise buildings, currently many structural systems can be used for the lateral load resistance (Sitapara & Gore, 2016).

1.1WORKINGPRINCIPLEOFOUTRIGGERS

When the structure is expose to lateral loading, the axial force generated in the external columns, specifically tensile force in the windward columns and compressive force in the leeward ones, reduces the rotation of the core such that flexural stiffness of the girder and the axial stiffness of the perimeter vertical columns determine the effectiveness of the out rigger system (Sitapara & Gore,2016). Furthermore ,in addition to deep spandrel girders, which act as belts around the entire building, it is possible to assemble the other outlying columns to support in restraining the outriggers, providing an increase in stiffness of up to 25-30%(Sitapara &Gore, 2016).

The outrigger system is one type of structural system which is formed from a cantilever-shaped horizontal member connected to a structure’s inner core and outer columns so through the connection, the moment arm of the core will be increased which leads to higher lateral stiffness of the system (Chung &Sunu, 2015).

1.2 Procedure of Optimum Topology and size Design for Outrigger and Belt-Truss System

Generally, in the reviewed articles, the adopted procedures of optimum topology and size design of the outrigger and belt truss system were as follows: firstly, identifying the variables which should be optimized; secondly, modeling the structure, thirdly, formulating optimization problem according to chosen criteria, where the objective function. Constraints and boundaries should be defined; and finally, solving the problem by using an appropriate searching technique to obtain the optimum solution (see Figure 2). However, the detailed application of these procedures is different between the initial and final design stages. That is because each of these stages requires different details and level of accuracy. The differences are mainly reflected in the adopted assumptions in modeling techniques and in the selected searching technique.

These procedures will be explained and clarified in the next sections.

1.3. What are the Topology and Size of Outrigger and Belt-Truss System?

1. Topology. In general, the topology in structures refers to the material distribution within the structural elements (in continuum structures) or refers to spatial order and con nativity of the bars (in discrete structures such as trusses). However, the topology of the outrigger system, which is termed in this review, indicates to
(a) The topology of outrigger system in overall structure. which in its turn means (1) the locations and number of outriggers or/and belt truss and (ii) the various combinations of the system components (outrigger system configurations).
(b) The topology of components themselves: (i) out rigger topology truss shape, wall, etc.); (ii) belt truss topology (truss shape, wall, etc.) () interior structural system topology core topology, eg, steel trame braced core or shear wall core, etc and (1) exterior structural system topology (e.g., moment resisting frame, mega columns, etd).

2. Size. The outrigger and belt truss system size indicates the material amount of the specific material distributions (topology) of this system, i.e.. cross sections of outrigger system components.

Topologies and sections of outrigger system components are mutually interacting, which makes the optimum design of this system a complicated indeterminate process. In this paper, based on the aforementioned definitions of the topology and size of the outrigger and belt truss system, many studies and articles were reviewed. Therefore, it shouldbe noted that some of the reviewed arties did not adopt these definitions, and they studied topics such as outrigger locations, outrigger numbers, and other issues, without clearly stating that the considered issue is a topology or size problem.

II. LITERATURE REVIEW

İbrahim ÖzgürDedeoğlu et.al (2020) Conducted research on "Effectiveness of outrigger and belt truss systems on the seismic behavior of high-rise buildings" The outrigger systems, which is widely used with shear wall-framed systems at the tall buildings, increase the lateral stiffness of the structural bearing system and reduce the lateral drift of the structure under lateral loads. However, the traditional outrigger systems, besides these positive contributions, also create some limitations and problems affecting the modeling of the structure. Some of these; more interior space occupying as an architect, problems arising in the connection of outrigger and center core (especially when a concrete shear-wall core is used). On the other hand, the belt trusses known as "Virtual Outriggers" which have recently been used to build high-rise structures, have removed these problems. Unlike the traditional outrigger systems, belt trusses are formed between the outer columns. In this way belt trusses eliminate the problems arising from the direct connection of the outriggers to the center core and other problems associated with using outriggers. Extensive studies have been carried out on the examination of outrigger and belt truss systems used in high-rise buildings under static and dynamic loads. In this study, the linear earthquake responses of three structural models, which are shear wall-framed system, shear wall-framed system with traditional outriggers and shear wall-framed system with belt trusses, were performed by using modal time history analysis method. Lateral displacements and drifts of the structure, internal forces of the structural elements were obtained. These results of three structural models were compared with each other and the effectiveness of outrigger and belt truss systems were assessed. For earthquake input, three real earthquake records were selected. These records were scaled in accordance with the DD2 level earthquake design spectrum defined in Turkish Building Earthquake Standards (2018) and used in the analyses.

Akshay Khanorkar (2016) Conducted research on "Outrigger and Belt Truss System for Tall Building to Control Deflection: A Review" Accumulation of growing population especially in developing countries has resulted in an increased height of buildings, this need creating impact on structural development of tall building. As building increases in height there is effect of wind and earthquake forces, to increase stiffness of building against lateral load additional structural system such as belt truss and outriggers is required. This paper presents the review of various techniques and methods used to investigate uses of belt truss and outrigger system in a tall building. The various parameters like lateral displacement, storey drift, core moment and optimum position related to outrigger and belt truss are reviewed. The reviewed approach for the design and development of tall building using outrigger and belt truss is useful to provide a potential solution. The study in turn is useful for various research persons involved in design the tall buildings by using outrigger and belt truss system.

Mehrdad Abdi Moghadam et.al (2021) Conducted research on "SEISMIC PERFORMANCE OF STEEL TALL BUILDINGS WITH OUTRIGGER SYSTEM IN NEAR FAULT ZONES" As much as a building becomes taller, the stiffness of the structure plays a more important role than the other structural parameters of building. To reach the desirable stability for tall towers, it is necessary to increase the stiffness of structure. One of the best available ways to maintain the lack of stiffness is to use outrigger belt trusses between external columns. For high-rise buildings, particularly in the seismic active zones, this bracing system can be added to the structure. The main objective of this paper is to study the performance of a continuous three-story outrigger system which is used in a tall braced frame steel skeleton. For this purpose, three 30-story buildings with different configurations of outrigger systems have been selected and designed. The structural models have been designed according to the Iranian seismic code 2800 (3rd edition). For performing the non-linear time history analyses, the particular criterion for the selected strong earthquake records is the appearance of a coherent pulse or multiple pulse features in the velocity time history concerning with high amplitude factors and long period. The illustrated results of this research show that the response parameters of the studied structures subjected to near-field earthquake records are greater than those of far-field ones. Furthermore, the outrigger systems increase the base shear but decrease the drift and lateral deflection significantly. The reduction values in the lateral deflection are about 40% and 50% respectively for the model with single top outrigger and the model with mid and top outriggers, respect to the model without any outrigger under influencing of strong records. Furthermore, the other response parameters would remain in the acceptable performance domain. Yet, an intensive concentration of the axial stress resultants were resulted in the perimeter column elements which would be caused by the action of outrigger systems.

Tall building development has been rapidly increasing worldwide introducing challenges of controlling lateral deflection that need to be solved by structural engineers. In modern tall buildings, lateral loads induced by wind or earthquake are often resisted by a system of central resistant core. But when the building increases in height, the stiffness of the structure becomes more important and the use of outrigger beams between the shear core and external columns can provide sufficient lateral stiffness to the structure. It is also usual to mobilize other peripheral columns to assist in restraining the rotation of outriggers. This is achieved by tying the exterior columns with braced frames commonly referred to as a "belt truss" around the building. The outrigger and belt truss system is commonly used as one of the structural system to effectively control the excessive lateral deflection and storey drifts in high-rise buildings due to either wind or earthquake loads, so that the risk of structural and non-structural damages can be minimized (Bungale, 2010; Jahanshahi and Rahgozar, 2013; Nanduri et al., 2013; Stafford and Coull, 1991). The present paper attempts to further investigate the seismic behavior of outrigger and belt truss systems. We examine various alternative 3D models using SAP2000 software for a 40-storey steel building with central core braced with outrigger and without outrigger effects. Material properties for steel and concrete in the building are given in Table 1. The structural model with one and two outrigger levels has been analyzed against three sets of ground motion records. The aim of this study is to find and compare optimum outrigger locations in height using response spectrum analysis (RSA) and linear time history analysis (THA). Moreover, the reductions in lateral displacement are compared to model without any outrigger and belt truss system.

Emanuele Brunesi et.al (2015) Conducted research on "SEISMIC PERFORMANCE OF HIGH-RISE STEEL MRFs WITH OUTRIGGER AND BELT TRUSSES THROUGH NONLINEAR DYNAMIC FE SIMULATIONS" The work reported herein summarizes the results of a series of nonlinear dynamic FE analyses devoted to assess the main criticalities in the seismic response of high-rise steel MRFs with outrigger and belt trusses. Thirty- and sixty-storey planar frames, extracted from reference three-dimensional structures composed of an internal one-way braced core, are designed in accordance with European rules. The core consists of a CBF system, while outriggers are placed every fifteen stories to limit inter-storey drifts and second order effects. FE models able to account for material and geometric nonlinearities have been developed within an open source FE code, using inelastic force-based fiber elements to model structural members and equivalent nonlinear links to reproduce the behaviour of bolted beam-column joints and welded gusset-plate connections. Out-of-plane imperfections are explicitly included in the braces to allow for potential buckling mechanisms in both braces and gusset plates. NLTHAs have been performed, in comparison with response spectrum analysis, aiming to quantify the potential of such systems, when included in the lateral-force resisting system of modern high rise steel MRFs. Global and local performance have been investigated in terms of inter-storey drift and acceleration peak profiles and axial force-displacement curves and static-to-seismic load ratios in critical braces at different floor levels. Sensitivity to the structure height has been explored by comparing the response of the two prototype MRFs. Trends are discussed to show that, if accurately designed and detailed, these structural systems provide an optimum combination of stiffness and strength.

NishitKirit Shah et.al (2016) Conducted research on "Review on Behavior of Outrigger System in High Rise Building" In the modern society there is a huge demand of high rise buildings and with the evolution and continuous demand of taller buildings have created need for more and more unconventional and efficient structural systems. One such system is Outrigger System. The paper aims at summarizing in detail the concept and working principle of various configurations of Outriggers and the current trends in integration of Outriggers in tall structures. In addition to this various problems associated with the Outriggers are also discussed. A detailed scrutiny of literature available in the field of Outrigger system is carried out and the summary and gaps encountered in the study are listed in this paper. A relatively new concept of Virtual Outrigger is introduced in this paper. In which, using only the belt truss in the building in order to increase the performance of the building under the dynamic loads is studied. Emphasis is given to the various benefits of employing Virtual Outriggers instead of Conventional ones. Concept of Basements as Virtual outrigger is also reviewed in the paper.

Reihaneh Tavakoli et.al (2018) Conducted research on "The Best Location of Belt Truss System in Tall Buildings Using Multiple Criteria Subjected to Blast Loading" The main goal of this paper is to investigate the effect of blast phenomenon on structures to determine the best location of belt truss system in tall buildings. For this purpose, one of the exterior frames of a tall steel building, in which the belt truss is located, is considered. The steel frame model is subjected to two different charges of equivalent weight which are applied in two different standoff distances. In this research, the best location of the belt truss system is determined using OpenSees software based on the nonlinear dynamic analysis. The best location of the belt truss system for different types of loading is investigated both with and without considering the post-buckling effect for all members of the belt truss system. The results show that when blast charges are located in a 5-meter range from the building (R=5), post buckling effect of truss elements are more obvious than the case in which blast charges are located in a 10-meter range (R=10); this, in turn, causes the amount of base moment to be completely different when the belt truss is located in the first storey in comparison to the cases where the belt truss is located in any other stories. In addition, if the explosion occurs near the building when the base moment is considered as a criterion, the post buckling effect has a significant role.

III. METHODOLOGY

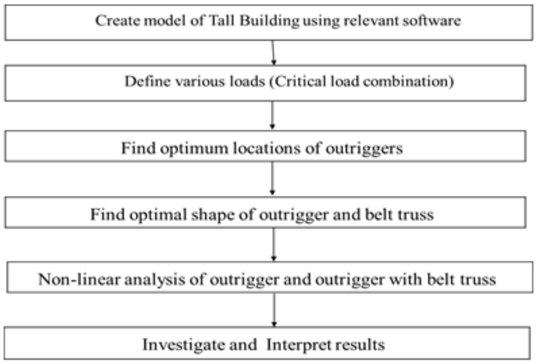


Fig.1 Methodology Process Work

3.1 SEISMICEVALUATIONMETHOD

Seismic Analysis of high rise building is required to carry out for the determination of seismic responses of building so as to understand the actual behavior of the structure so this can be done either by dynamic or simple equivalent static analysis this Linear static method can be used for regular structure with limited height, A Linear dynamic an analysis can be executed by response spectrum methods on on linear dynamic analysis

i.e. time History analysis is the only method to label the real performance of a building during seismic excitation (Fajfar, 2018).

3.2 Linear Dynamic Method

For the building whose response is dominated by more than one model, the Linear Dynamic Method is used to estimate the demand of the structure. There are two ways to carry out linear Dynamic Analysis–

a) Response Spectrum Method

This method can be used on structures where modes other than the basic one has amajorimpactonthestructure'sresponsesuchthattheresponseofasystemwithamultidegree of freedom (MDOF) is described as an overlay of modal response & then merged to determine global response. Usually the approach is used along with a response spectrum (Naessand Moan, 2013).

The load vectors for a predetermined number of modes are calculated using this procedure. To compute the relevant modal responses, these load vectors are being targeted at design center of mass. To produce entire response these modal response is integrated using the SRSS or CQC rule hence the modal response is estimated by combining results of static analysis of structures subjected to the relative modal load vector and dynamic analysis put through same ground motion, as stated in fundamentals of dynamics (Naess and Moan, 2013).

To produce the model response, A spectral ordinate generated from the dynamic analysis of the SDOF system multiplies the static MDOF output and the same approach is followed for the other modes, with the results derived using the SRSS or CQC rules so for the study of reaction spectrum, the spectral values for the design spectrum are vitally multiplied with the modal load vector and the modal peak response is obtained by static analysis (Naess and Moan, 2013). Classical Modal Analysis is the name given to this procedure.

Linear dynamic Analysis Steps:

i. Choose a design spectrum.
ii. Determine the vibration mode shapes and period to be added in analysis.
iii. For each of modes investigated, read the level of response from the spectrum for the period.
iv. Determine the percentage of each mode that corresponds to a single degree of freedom.
v. A response read on the curve.
vi. Combine the impacts of the modes to get the best possible reaction.
vii. Convert the total maximum response into shears and moments for use in structural design. Analyze the building in the same way for the consequent moments and shear.

b) Time History Method

Building reaction is calculated at separate time steps utilizing a discretized record of synthesis time history as the base motion in dynamic analysis employing time history analysis. Only maximum responses of parameters are chosen if three or more-time history analyses are done.

3.3 Non-Linear Static Analysis

This is the process of pushing a structure that accounts for material nonlinearity until it collapsestoy ie ld a pushover curve, which his then used to predict the target displacement at which the response quantity is recovered from a deformed modal.

1. Pushover Analysis

Pushover analysis is an approximate analysis method in which the structure is subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a target displacement is reached and Pushover analysis consists of a series of sequential elastic analyses, superimposed to approximate a force-displacement curve of the overall structure (Sermin Oguz 2005). A two or three dimensional model which includes bilinear or trilinear load-deformation diagrams of all lateral force resisting elements is first created and gravity loads are applied initially so predefined lateral load pattern which is distributed along the building height is then applied so the lateral forces are increased until some member's yield (Sermin Oguz 2005). The structural model is modified to account for the reduced stiffness of yielded members and lateral forces are again increased until additional members yield such that the process is continued until a control displacement at the top of building reaches a certain level of deformation or structure becomes unstable such that the roof displacement is plotted with base shear to get the global capacity curve (Sermin Oguz 2005).

2. Nonlinear Dynamic Analysis

This is the most precise way for determining a structure's seismic reaction. The structure is therefore sensitive to real ground movement, which is a picture of ground acceleration vs. time. To obtain ground motion record, the ground acceleration is calculated at a tiny time step. The structure reaction is then determined at each time instant, and the design demand is chosen from this time history's peak value. As a result, to obtain forces and displacement, an earthquake shaking represented by the history of ground motion must be subjected to a mathematical model which explicitly links the non-linear characteristics of individual components and building elements. Inelastic responses and internal calculated forces are reasonably similar to those predicted during the earthquake design. Time history analysis can be done using one of two ways.

a) Modal time history analysis (Non-linear)
b) Direct integration time history analysis (Non-linear)

IV. MODELLING AND ANALYSIS

4.1 PROBLEM STATEMENT

Response spectrum analysis of reinforced concrete building by author N.R. Chandak from the Journal/ Publication - The institution of Engineers (India) / Springer, Year - 2012. Response spectrum analysis of reinforced concrete 6 story building is compared by Indian Standard code and two other well-known codes (Uniform Building Code, Euro code 8). To evaluate seismic Response of the buildings, elastic analysis was performed by using Response spectrum method using computer program SAP2000. Periods, Base shear, lateral displacement and Inters Tory drift is calculated (Chandak, 2012).

4.2 MODEL DATA

The following are the details of the model used for validation.

G+5 story building
Column size - C1(1–3 stories) - 600 X 600
Column size - C1(4–6 stories) - 500 X 500
Column size - C2(1–3 stories) - 900 X 900
Column size - C2(4–6 stories) - 700 X 700
W1, W2 - 250 X 1750
Thickness of slab - 150
Beam size - 250 X 500
Grade of Concrete - M20
Grade of Steel - Fe415
Seismic zone - 4
Type of soil - II
Young's Modulus of Concrete - 28000 Mpa
Unit weight of Concrete - 25kN/m^3

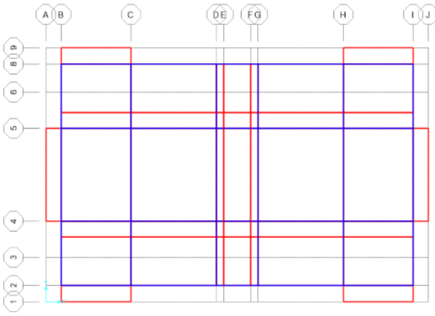


Fig.2 Plan of G+5 Building

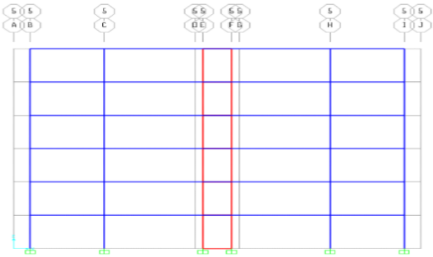


Fig.3 Elevation of G+5 Building with Fixed Base

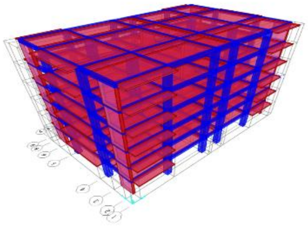


Fig.4 3D Model of Building

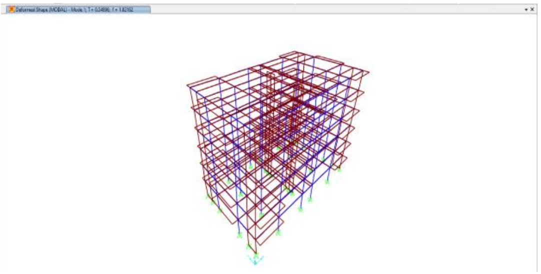


Fig.5 Deformed Shape (Modal) X axis

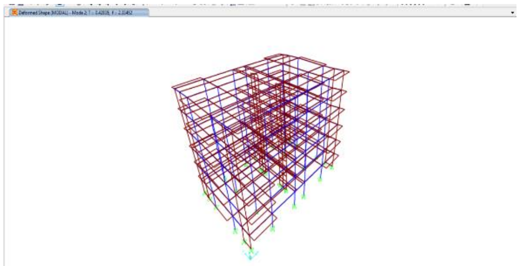


Fig.6 Deformed Shape (Modal) Y axis

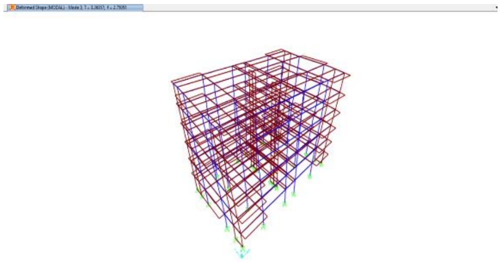


Figure 4. 1 Deformed Shape (Modal) Torsion

4.1 OUTRIGGER SYSTEM

Outriggers have been used for approximately four decades, their existence as a structural member has a much longer history. Outriggers have been used in the sailing ship industry for many years. They are used to resist wind. The slender mast provides the use of outriggers. As a comparison the core can be related to the mast, the outriggers are like the spreaders and the exterior columns are like the shrouds or stays.

- **Core and outrigger system**

In this system concrete core is connected to columns through beam. So in case of bending in shear wall plane section will remain plane but beams are going to be bending since it is flexible as a results there is warping in beam. So in first case moment of inertia will be equal to moment of inertia of column plus moment of inertia shear wall since MI of column is not large. In second case Provision of Outrigger i.e. horizontal rigid member of building which extends plane section which is perpendicular to neutral axis of the shear wall beyond shear wall and up to column as a results leeward side column subjected to tensile force and windward side column subjected to compressive force. Therefore, total moment of inertia of system wills increase equals MI of shear wall plus area times distance square of these columns. Resultant lateral load resistance will be increased significantly with provision of outrigger.

- **Core outrigger and belt truss system**

Further enhancement of outrigger system with addition of belt truss resists lateral load effectively. When shear wall is bending it will bend outrigger and outrigger is connected to belt which is all around building perimeter. So that belt will also bend in same way because it is rigid and usually we achieve this belt by making solid story which behaves like horizontal shear wall due to that it is engaging all these columns which are around the shear wall. Effective moment of inertia which is responsible for strength and stiffness that will increase tremendously. Not only we have to ensure that shear wall should yield at base but also we have to ensure that it should fixed at base.

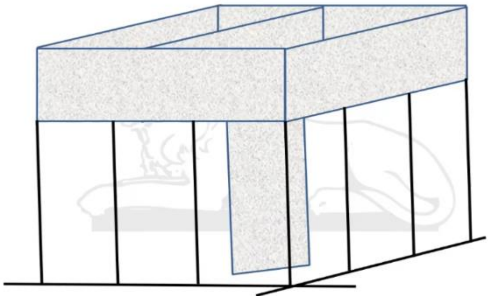


Fig.7 Outrigger with belt truss system

V. RESULTS

5.1 Modal Analysis Results

The following figure represents the modal analysis results for the validated model and model from paper.

Table. 1Time Period calculation

Modes	Time Period (Sec)		Error (%)
	Current Results	Literature Results	
1	0.548	0.548	0
2	0.43	0.45	4.44
3	0.363	0.363	0
4	0.172	0.172	0
5	0.122	0.126	3.17
6	0.107	0.108	.92
7	0.089	0.09	1.11

The comparative results for the validation work are shown below:

Table.1 Comparative results of validation work

Parameter studied	N. R. Chandak (From Literature)	Current Results	Error (%)
Base shear	3200 KN	3130 KN	2.18
Displacement	25 mm	24 mm	4

1. Response Spectrum Analysis Results

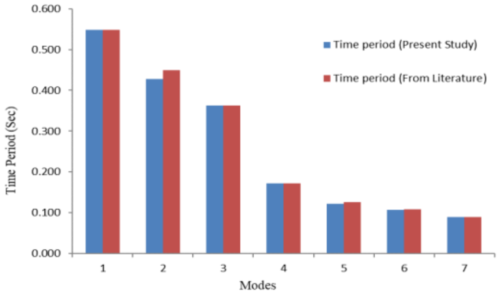


Fig.8 Modal analyses Result

The following Figure shows Inters Tory drifts for analyzed building.

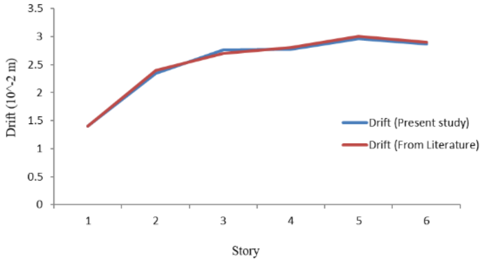


Fig.9 Drift for 6 story Building

2. PUSHOVER ANALYSIS RESULTS

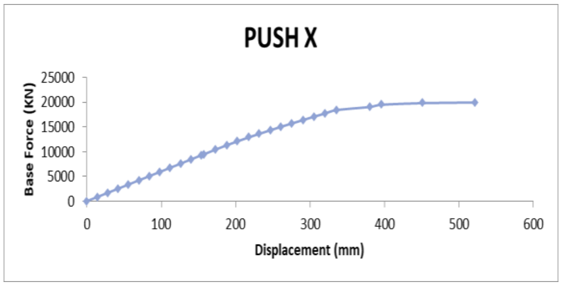
Table 8.1 and Table 8.2 shows nonlinear analysis results of actual building plan with provision of optimum outrigger location with optimal braced shape.

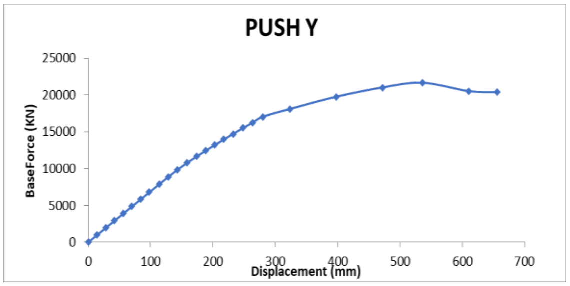
Table.3 Pushover analysis result

Parameter	PUSH X	PUSH Y
BASE SHEAR	20013 (KN)	21677.608 (KN)
TOP STORY DISPLACEMENT	36.453	37.652
MAXIMUM STORY DRIFT	0.000519	0.000612

Table.4 Modal analysis result

Modes	Time period (Sec)
Mode 1	3.33
Mode 2	2.668
Mode 3	2.367





VI. CONCLUSION

1. For NB 60 subjected to earthquake load, about 4.9% reduction in lateral displacement can be achieved with outrigger truss at top and H/3 level.
2. For NB 60 it is observed that 6.53% drift is controlled by providing outrigger at top and H/3 location.
3. Base shear shows minimum response value other than general structure at H/3 location for NB.
4. For SSB 60 subjected to earthquake load, about 6.85 % reduction in lateral displacement can be achieved with outrigger truss at top and 40 story(2H/3).
5. For SSB 60 it is observed that 7.39 % drift is controlled by providing outrigger at top and 2H/3 location.
6. For SSB 30 subjected to earthquake load, about 7.29 % reduction in lateral displacement can be achieved and 6.45 % drift is controlled by providing outrigger truss at 30 story level (H).
7. The use of outrigger and belt truss system in high rise building increases stiffness and makes structural form efficient under lateral load.
8. Outriggers provided with core wall are beneficial as compare to without core wall with considering top story displacement and time period.
9. Outriggers with belt truss is more effective for high rise building considering top story displacement and maximum story drift.
10. For NB 30 subjected to earthquake load, about 11.79 % reduction in lateral displacement can be achieved and 13.06 % drift is controlled by providing outrigger truss at H/3 level.
11. For 60 story building provision of two outriggers are efficient as compare to one outrigger system.

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