SEISMIC PERFORMANCE AND OPTIMIZATION OF MULTISTORYED BUILDING BY OUTRIGGER ALONG BELT TRUSS STRUCTURE

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Abstract - *The outrigger structure become most widely considered and efficient system which used to build up lateral load resistance performance of multistoried building. As rise in building causes slenderness. Core wall structure with connection of horizontally projected beam, outriggers been a very effective structural system reducing the drift which is due to lateral load and leads to stability of structure. The focal point of study is location optimization of outrigger as well as outrigger along belt truss structure. Response spectrum analysis is done for normal building of 30 and 60 story by taking outriggers and belt truss structure into account. The ETABS software is utilized for response spectrum analysis.*

Key Words: Lateral loads, Drift, Displacement, Base Shear, Belt truss structure, Outriggers

1.INTRODUCTION

The outrigger also belts truss structure perform very important role to counterattack the lateral loads arising in structure. External columns in this structure are attached to the central core wall with stiffened outriggers and belt truss at one or more than one level. The outrigger beam and belt truss structure resist lateral loads by tying the central core to the external columns at one or more levels with exceptionally rigid outriggers beam and belt truss structure. The belt truss attached to peripheral columns of building, while the main central core wall connected to peripheral column through outriggers. The core can be positioned in the center of the building such that with outriggers extending on both sides, to the building columns. The belt truss structure and outrigger efficiently regulate lateral load-induced excessive drift and reduce the harmful effects of structural as well as non-structural damage. Outriggers are rigid components that connect a core of structure to its exterior columns. When there is attempt of bend in central core, the outrigger with belt truss structure develops a tension-compression pair in perimeter columns, which generates a restoring type of moment acts at outrigger level on the core. Such that improvement in structural rigidity of the building against overturning force. There is direct attachment of outrigger trusses to the bracing type frames or shear walls at the central part of the assembly in the typical outrigger concept. As belt trusses are employed as virtual outriggers, idea of basic principle will remain same. Some core moment is converted to a couple which is horizontal. That moment is transferred to chords of the at bottom and top diaphragm in the floors and ultimately at the outer columns in form of vertical forces. Use of stiff base elements which are particularly inflexible and robust in their own level, to shift moment by means of horizontal couple moment from primary core to outer truss and from the truss members to outlying column. Belt trusses and basement walls works well as virtual outrigger. The rotation of the core is restrained by floor diaphragms at the upper and lowest of the belt trusses in case of conventional outriggers. Therefore, core moment converted into horizontal couple is in the floors.

2. SCOPE

The main scopes of this study are follows.

1. Maximum of research is done on the outrigger structure performance under application of wind loads. Study of Seismic resistance by outrigger structures is underestimated.
2. Multi-outrigger concept is used in this since it is efficient in High rise building.

3. OBJECTIVES

1. To investigate the optimal location of outrigger in 30 and 60 story normal building.
2. Comparison of different models with and without facility of core wall in building.
3. Comparison of different models by provision of outrigger and with facility of outrigger with belt truss structure in building.
4. To investigate the seismic behavior of best model with Response Spectrum analysis.

4. BUILDING MODELING AND ANALYSIS

4.1 Modelling

Etabs software is used for modeling and model analysis. Building configuration and loading data of models are described in Table 1 and Table2. In this project the models are normal building of 30story and 60 story with 7 X 7 bay.

4.2 Loading consideration

Live load - 3kN/m^2
Floor finish - 1kN/m^2
Seismic loading - IS : 1893 (Part I) -2002
Zone factor – 0.24
Soil Type – Medium soil

4.3 Building model Data

Table 1 – Building Consideration for NB30

Sr. No.	Particulars	Model Data
1.	Size of plan	38.5m x 38.5 m
2.	No. of Stories	30 story
4.	Size of Column	900 mm x 900 mm
5.	Size of Beam	400 mm X 600mm
6.	Size of Beam	ISHB 450 -2
7.	Size of Slab	150 mm (Grade - M-40)
8.	Core (Shear Wall)	300 mm (Grade - M-40)

Table 2 – Building Consideration for NB60

Sr. No.	Particulars	Model Data
1.	Size of plan	38.5m x 38.5 m
2.	No. of Stories	60 story
4.	Size of Column	C1 1200mm x 1200mm C2 1100mm x 1100mm C3 800mm x 800mm
5.	Size of Beam	400 mm X 600 mm
6.	Size of belt truss member (X Bracing)	ISHB 450 -2
7.	Size of Outrigger	400 mm X 400 mm
8.	Size of Slab	150 mm (Grade - M-40)
9.	Core (Shear Wall)	300 mm (Grade - M-40)

4.4 Models Created

Comparison between different structures is studied on the basis of base shear, time period, maximum storey drift and maximum storey displacement. So to interpret optimum location of outrigger along belt truss structure different models are created as mentioned in Table3. X typed braced outriggers and outrigger along belt truss are used in these models as shown in Fig - 1 and Fig – 2 respectively.

Table 3 – Model Description

30 STORY MODELS	
BARE FRAME	Normal building of 30 story without outrigger and core
NB 30	Normal building of 30 story without outrigger
NO10	Normal building of 30 story with outrigger @ 10
NO20	Normal building of 30 story with outrigger @ 20
NO30	Normal building of 30 story with outrigger @ 30
NOWC10	Normal building of 30 story with outrigger @ 10 without core
NOWC20	Normal building of 30 story with outrigger @ 20 without core
NOWC30	Normal building of 30 story with outrigger @ 30 without core
NOB10	Normal building of 30 story with outrigger @ 10 along belt truss
NOB20	Normal building of 30 story with outrigger @ 20 along belt truss
NOB30	Normal building of 30 story with outrigger @ 30 along belt truss
NOBWC10	Normal building of 30 story with outrigger @ 10 along belt truss without core
NOBWC20	Normal building of 30 story with outrigger @ 20 along belt truss without core
NOBWC30	Normal building of 30 story with outrigger @ 30 along belt truss without core
60 STORY MODELS	
NB 60	Normal building of 60 story without outrigger
NO20	Normal building of 60 story with outrigger @20
NO40	Normal building of 60 story with outrigger @40
NO60	Normal building of 60 story with outrigger @60
NO30	Normal building of 60 story with outrigger @30
NO20+60	Normal building of 60 story with outrigger @ 20 + 60
NO40+60	Normal building of 60 story with outrigger @ 40 + 60

NO30+60	Normal building of 60 story with outrigger @ 30 + 60
NOB20	Normal building of 60 story with outrigger @20 along belt truss
NOB40	Normal building of 60 story with outrigger @40 along belt truss
NOB60	Normal building of 60 story with outrigger @60 along belt truss
NOB30	Normal building of 60 story with outrigger @30 along belt truss
NOB20+60	Normal building of 60 story with outrigger @20+60 along belt truss
NOB40+60	Normal building of 60 story with outrigger @40+60 along belt truss
NOB30+60	Normal building of 60 story with outrigger @30+60 along belt truss

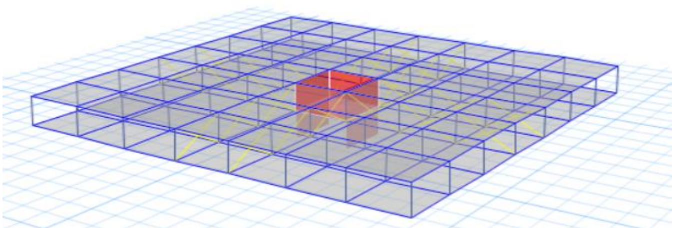

Fig-1: X type braced outrigger

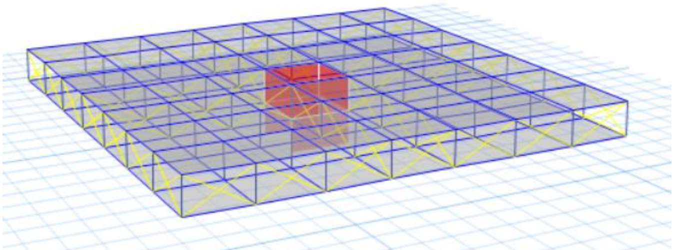

Fig-2: X type braced outrigger along belt truss

5. RESULTS AND DISCUSSION

Response spectrum analysis for various models with and without core provision was carried out for 30 story models, and with and without belt truss was carried out for 60 story models.

- Base Shear

The maximum predictable lateral force due to earthquake activity on the base of structure is evaluated using base shear. It is determined by the earthquake zone, type of soil, and time period. The base shear value of building models without core provision is lower than that of models with core provision, as shown in Fig-3 for 30 story and Fig-5 for 60 story.

- Fundamental period of Vibration

Modal analysis is performed on all building models to determine the fundamental time period of the structure. With a change in the position of the outrigger and outrigger belt truss structure, the time period changes. Models with core provision have a shorter time period than models without core provision, as shown in Fig-4 for 30 story and Fig-6 for 60 story.

Table 4 - 30 story base shear and time period results

MODEL	Base shear (KN)		Time Period (Sec)	
	RSPX	RSPY	RSPX	RSPY
BARE FRAME	9088.1895	9088.1895	3.033	3.033
NB	9238.4866	9238.4866	2.637	2.637
NO10	9259.5633	9259.5633	2.466	2.466
NO20	9259.4	9259.4	2.543	2.543
NO30	9232.1076	9232.1076	2.628	2.628
NOB10	9263.3689	9263.3689	2.428	2.428
NOB20	9277.3791	9277.3791	2.515	2.515
NOB30	9237.2952	9237.2952	2.628	2.628
NOWC10	9099.2366	9099.2366	2.877	2.877
NOWC20	9099.2774	9099.2774	2.966	2.966
NOWC30	9111.2281	9111.2281	3.039	3.039
NOBWC10	9104.4033	9104.4033	2.857	2.857
NOBWC20	9215.6246	9215.6246	2.961	2.961
NOBWC30	9115.1597	9115.1597	3.04	3.04

MODEL	Base shear (KN)		Time period (Sec)	
	RSPX	RSPY	RSPX	RSPY
NO20	20609.953	20609.95	5	5
NO40	20609.953	20609.95	5.083	5.083
NO0	20609.953	20609.95	5.136	5.136
NO30	20609.953	20609.95	5.039	5.039
NO20+60	20629.651	20629.65	5.005	5.005
NO40+60	20629.652	20629.65	5.088	5.088
NO30+60	20629.651	20629.65	5.044	5.044
NOB20	20615.168	20615.17	4.974	4.974
NOB40	20609.953	20609.95	5.083	5.083
NOB60	20615.168	20615.17	5.137	5.137
NOB30	20609.953	20609.95	5.039	5.039
NOB20+60	20640.084	20640.08	4.98	4.98
NOB40+60	20629.652	20629.65	5.088	5.088
NOB30+60	20639.081	20639.08	5.027	5.027

Table 5 - 60 story base shear and time period results

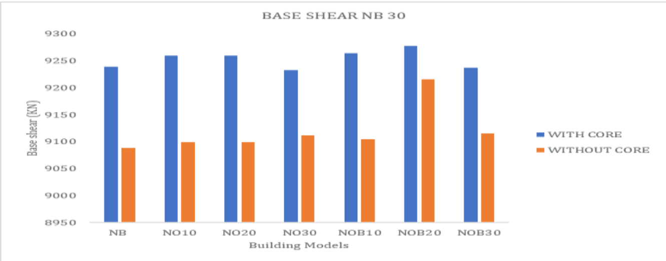

Fig -3 : Base Shear comparison of NB 30 models

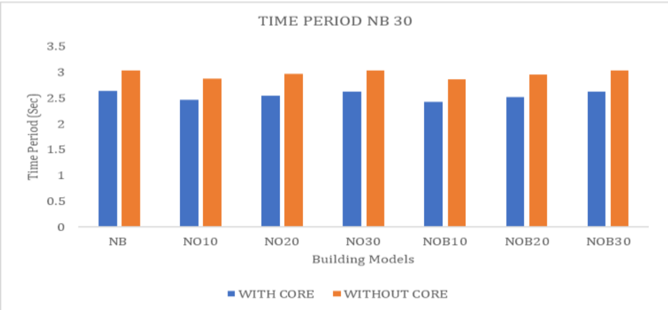

Fig - 4 : Time period comparison of NB 30 models

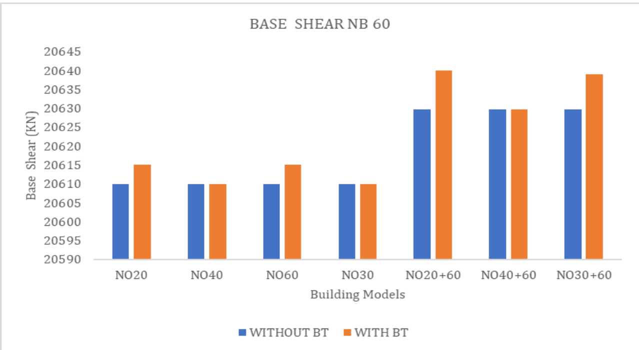

Fig - 5 : Base shear comparison of NB 60 models

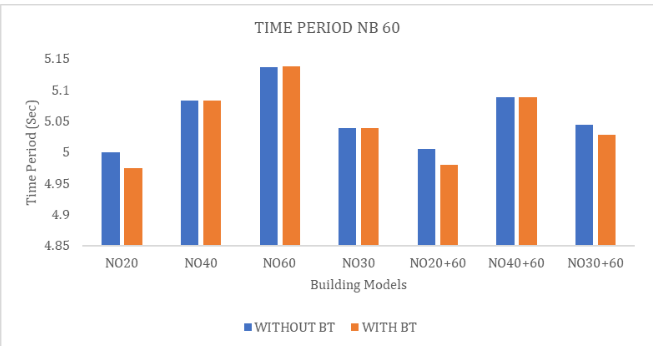

Fig - 6 : Time period comparison of NB 60 models

- Maximum story Drift

Maximum story drift is evaluated after response spectrum analysis of building structure. It is the displacement ratio of two consecutive floors to the height of that floor. Fig–7 shows maximum story drift for 30 story models and Fig-9 for 60 story models. Maximum story drift is limited by providing outriggers at various locations along the belt truss structure.

- Top story Displacement

Response Spectrum Analysis is carried out on all models to evaluate maximum story displacement of structure which is lateral displacement of story relative to base. Fig-8 shows maximum story displacement for 30 story models and Fig-10 for 60 story models. Top story displacement is controlled with the use of outriggers and belt trusses at various levels.

Table 6 - 30 story maximum story displacement and maximum story drift results

MODEL	Maximum story displacement (mm)		Maximum story drift	
	RSPX	RSPY	RSP X	RSP Y
BARE FRAME	55.868	55.868	0.000848	0.000848
NB	43.409	43.409	0.000597	0.000597
NO10	38.918	38.918	0.000524	0.000524
NO20	39.683	39.683	0.000585	0.000585
NO30	42.164	42.164	0.000595	0.000595
NOB10	38.291	38.291	0.000519	0.000519
NOB20	38.658	38.658	0.000584	0.000584
NOB30	42.012	42.012	0.000595	0.000595
NOWC10	51.317	51.317	0.000844	0.000844
NOWC20	52.199	52.199	0.000843	0.000843
NOWC30	55.404	55.404	0.000846	0.000846
NOBWC10	50.698	50.698	0.000844	0.000844
NOBWC20	51.383	51.383	0.000855	0.000855
NOBWC30	55.344	55.344	0.000845	0.000845

Table 7 - 60 story maximum story displacement and maximum story drift results

MODEL	Maximum story displacement (mm)		Max story drift	
	RSPX	RSPY	RSPX	RSPY
NO20	171.86	171.86	0.001099	0.001099
NO40	173.536	173.536	0.001168	0.001168
NO60	178.952	178.952	0.001176	0.001176
NO30	172.814	172.814	0.001153	0.001153
NO20+60	171.449	171.449	0.0011	0.0011
NO40+60	173.176	173.176	0.001169	0.001169
NO30+60	172.389	172.389	0.001154	0.001154
NOB20	170.668	170.668	0.001093	0.001093
NOB40	173.536	173.536	0.001168	0.001168
NOB60	178.975	178.975	0.001177	0.001177
NOB30	172.814	172.814	0.001153	0.001153
NOB20+60	170.411	170.411	0.001097	0.001097
NOB40+60	173.176	173.176	0.001169	0.001169
NOB30+60	172.16	172.16	0.001149	0.001149
NB 60	179.283	179.283	0.001174	0.001174

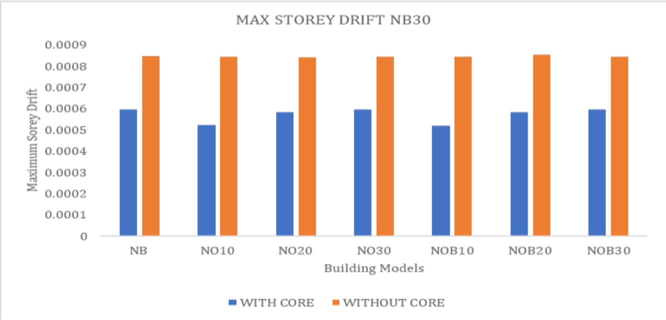

Fig -7 : Max story drift comparison of NB 30 models

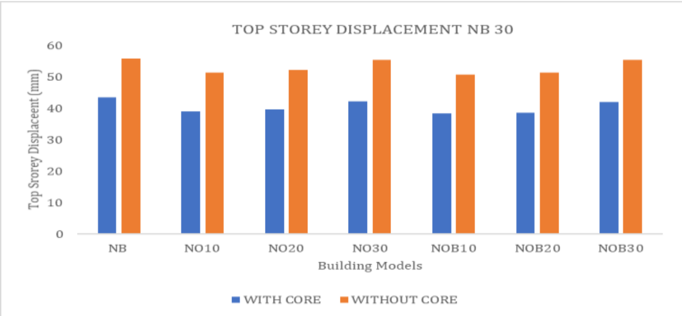

Fig -8 : Top story displacement comparison of NB 30 models

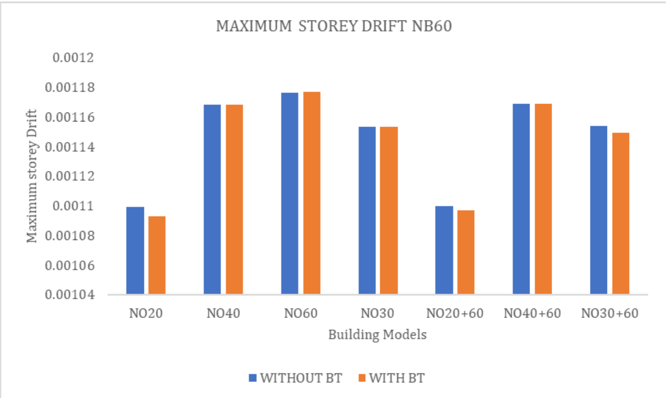

Fig -9 : Max story drift comparison of NB 60 models

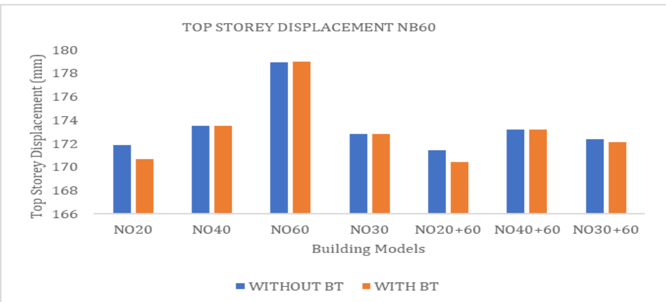

Fig -10 : Top story displacement comparison of NB 60 models

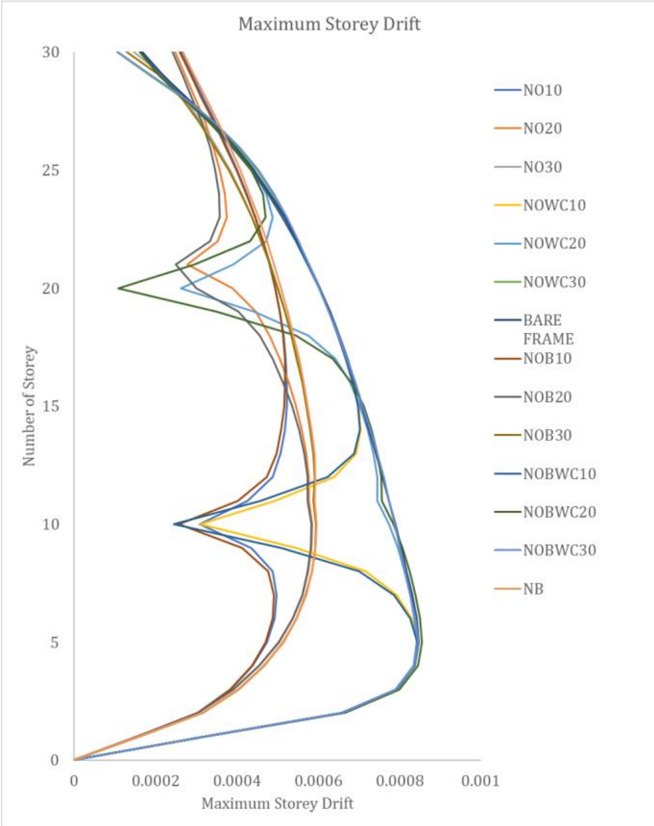

Chart 1 : Maximum Story drift of NB30 models

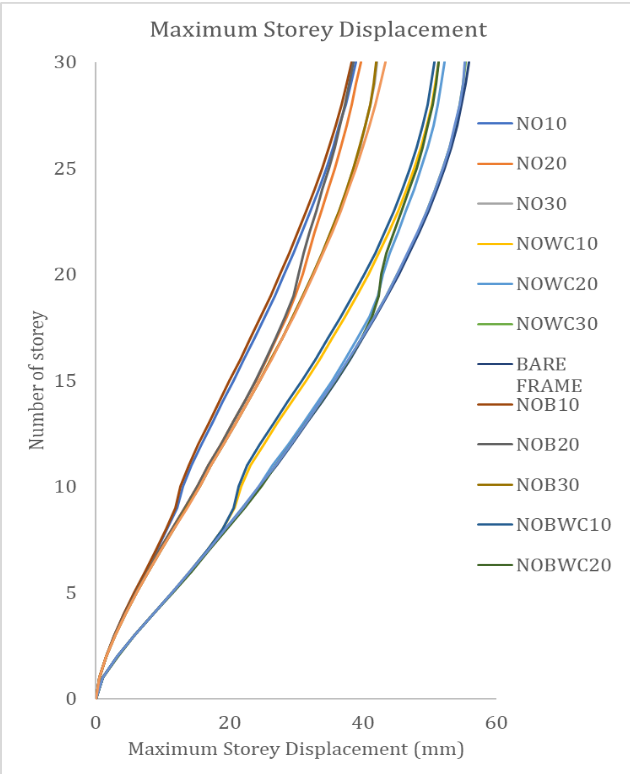

Chart 2 : Maximum Story displacement of NB30 models

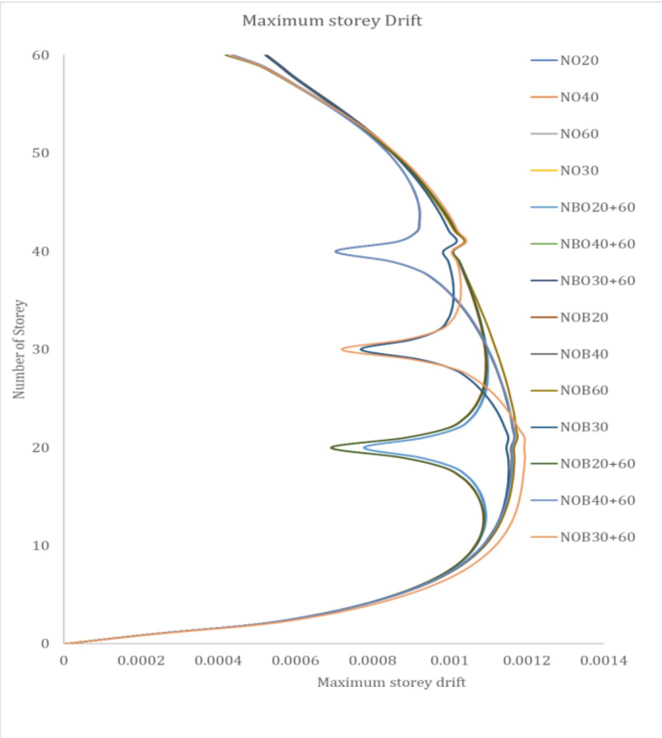

Chart 3 : Maximum Story drift of NB60 models

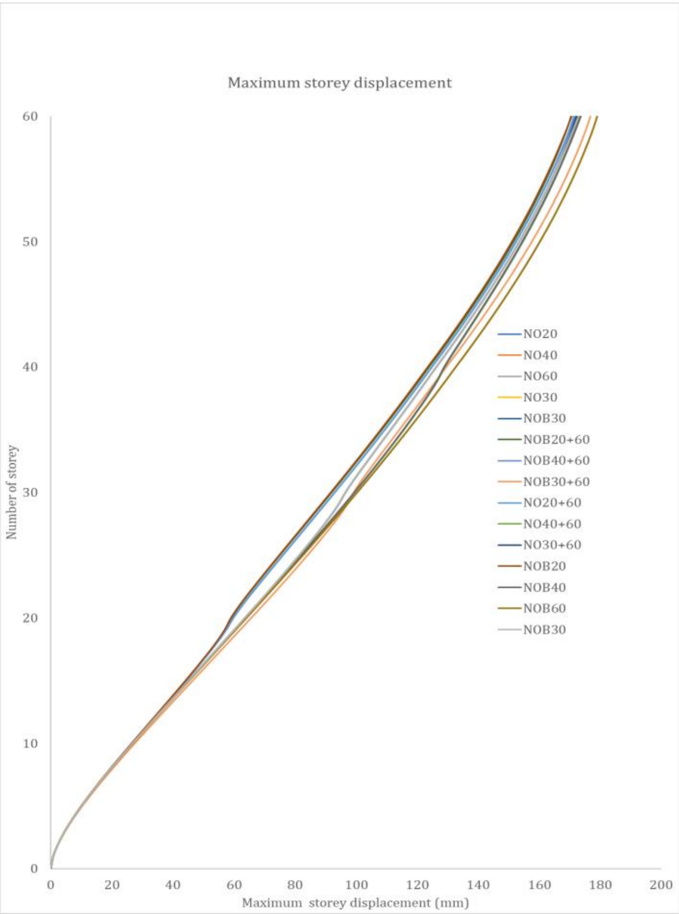

Chart 4 : Maximum Story displacement of NB60 models

6. CONCLUSIONS

1. The practice of outrigger along belt truss structure in high rise construction increases stiffness and build structure effective to sustain loads which acts laterally.
2. Outriggers provided with core wall are beneficial as compare to without core wall with considering maximum story displacement along with time period.
3. Outriggers with belt truss is more effective for high rise building considering maximum story displacement and drift.
4. For NB 30 subjected to earthquake load, about 11.79 % reduction in lateral displacement can be achieved and 13.06 % drift is restricted with provision of truss outrigger at H/3 level.
5. For 60 story building provision of two outriggers are efficient as compare to one outrigger structure.
6. For NB 60 subjected to earthquake load, about 4.94% reduction in lateral displacement can be achieved with outrigger truss at top and H/3 level.
7. For NB 60 it is observed that 6.54 % drift is restricted with making provision of outrigger at top and H/3 location.

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REFERENCES

1. Alhaddad, Wael, et al. "A comprehensive introduction to outrigger and belt-truss system in skyscrapers." Structures. Vol. 27. Elsevier, 2020.
2. Aswathi C, Sruthi Das K K ,"Performance and optimization of outrigger with belt Truss system in multistoried building" International Research Journal of Engineering and Technology (IRJET) Volume: 07 Issue: 07 | July 2020
3. C. Bhargav Krishna, V. Rangarao, Comparative "Study of Usage of Outrigger and Belt Truss System for High-Rise Concrete Buildings", International Journal of Recent Technology and Engineering (IJRTE), 6C2 , 2019
4. Dangi, Archit, and Sagar Jamle, "Determination of Seismic parameters of RCC Building Using Shear Core Outrigger, Wall Belt and Truss Belt Systems." International Journal of Advanced Engineering Research and Science 5.9 ,2018

5. Preeti. M. NagargojeShilpa. Kewate, "Analysis of Outrigger Structural System for Tall Building Subjected to Lateral Loads" International Journal of Science Technology & Engineering Volume 3 Issue 12 June 2017
6. Amaresh S. Patil, "Lateral stability analysis of high rise building with the effect of outrigger and belt truss system." International Research Journal of Engineering and Technology (IRJET) 3.1 , 2016
7. Sitapara, Karan Dipak, and N. G. Gore. "Review on Feasibility of High Rise Outrigger Structural System in Seismically Active Regions." International Research Journal of Engineering and Technology (IRJET) 3.05 ,2016
8. Chandak N. R. "Response Spectrum Analysis of Reinforced Concrete Buildings." Journal of the Institution of Engineers (India): Series A 93.2 (2012): 121-128 – Springer 2012
9. Haghollahi, Abbas, Mohsen Besharat Ferdous, and Mehdi Kasiri , "Optimization of outrigger locations in steel tall buildings subjected to earthquake loads." The 15th World Conference on Earthquake Engineering, LISBOA. 2012.
10. Zou X. K. and Chan C. M., "Optimal seismic performance-based design of reinforced concrete buildings using nonlinear pushover analysis." Engineering structures 27.8 (2005): 1289-1302 , 2005