Evaluation of Seismic Performance For High Rise Building With Outrigger And Belt Truss System

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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 position optimization of outrigger as well as outrigger along belt truss structure. Outrigger and belt truss are provided at different location such as H/3, 2H/3, Top position from base. Multi outrigger system is used for 60 story building. Also, compared and find out optimal shape of outrigger and belt truss from X, V, Inv V bracing. Response spectrum analysis is done for Normal Building (NB) and Symmetric Setback Building (SSB) of 30 and 60 story by taking outriggers and belt truss structure into account. The ETABS software is utilized for response spectrum analysis. Parameters considered to get optimum location and optimal shape of braced outriggers and belt truss are maximum story drift, top storey displacement, base shear, time period. With optimum location of outriggers there was 7% to 8% reduction in maximum story drift and top story displacement. It is found out that X type bracing in outrigger are effective.*

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

I. INTRODUCTION

Complex projects have practically established a need for the current world's people, which has led to a rise in their demand. Because cities have a limited quantity of available land, taller structures are preferable. Due to the narrow structure of skyscrapers, there is a large danger of deflection, which also has spurred scientists and engineers to devise imaginative strategies to counteract these consequences. Consequently, as a neighborhood's height grows, the residual stresses become of crucial importance. Consequently, the formwork that resists weight of the structure has become less important than the mechanism that resists sideways stresses.

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.

1.1 OUTRIGGERSYSTEM

This same crossbar and belts in the suspension construction play a crucial role in resisting the monument's developing lateral force. Using protected step for achieving and belt bridges at one or maybe more layers, this construction connects exterior elements to the underpinning structure. 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. This same band bridge was linked to the room's outlying poles, whereas this large local solid barrier was joined to the periphery opinion pieces through support beams. The core may be situated in the middle of the structure, with displacements running to the tower foundations across both wings. Both band truss construction and cantilever manage lateral huge pile excessively drift and decrease fundamental and non-structural deterioration with efficiency. Caster wheels are stiff elements that link a material's interior to its external beams. When there is attempt of bend in central core, the outrigger with belt truss structure develops a tension-compression pair in perimeter columns, which nuilding 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 turn 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. hypothetical bulwark, belt girder and bulkheads perform effectively. In typical support beams, the revolution of the foundation is restricted by basement condoms at the top and bottom of the belted rafters. Accordingly, the floor is the location of the fundamental present transformed to perpendicular pair. (Sitapara, 2016).

Engineering layout of windmills is often determined by base shear that act on the structure. As complexes have become higher and shorter, the design team has had greater difficulty to fulfil drift criteria while limiting the material's aesthetic effect (Nanduri et al., 2013). As a reaction to this difficulty, the professions has offered a plethora of lateral designs which are currently evident in skyscrapers throughout the world.

1.2 EARTHQUAKE RESISTANTDESIGN

An earthquake-resistant structure is one that performs better than its standard counterpart during an earthquake. Design philosophy and methodologies have evolved over time to deal with the complexity of the design in order to make buildings more earthquake resistant. Earthquake Resistant Design focuses on methodologies and design principles such as braced frames, tubular frames, damper and base isolation. A significant earthquake with a given likelihood will occur in that precise area, according to the construction standards. In the infrequent case of an earthquake, the building's construction is intended to operate optimally. The loss of life should be reduced in rare earthquakes by avoiding building collapse, although the loss of utility should be reduced in more regular earthquakes.

OBJECTIVE

1. Formulation of problem statement, development of methodology, and possible validation with high quality research article.
2. To design outrigger structural system and belt truss system as lateral load resisting system.
3. Optimization of positions of outrigger structural system in buildings.
4. To evaluate the effectiveness of change in shape of outrigger belt truss system in building.
5. Nonlinear analysis of core walls with braced outrigger and truss belt system.

II. LITERATURE REVIEW

1. (Smith and Salim, 1983)

Through their research, they examined and produced many formulae for the optimal drift protection of outrigger-braced increased structures. The mathematics for an asymmetric system that has the core member articles are identical in bending stiffness and length are investigated. Therefore, approximation analysis is designed to determine energies and bending stresses in non-uniform buildings.

2. (Po Seng Kian, 2001)

reviewed that Outrigger and belt Truss systems for skyscrapers subjected to lateral loads. In ETABS software, a two-dimensional and three-dimensional model is analyzed for eight different situations that provide outrigger Truss system at various locations throughout the building. With the appropriate amount of outrigger positions, the lateral displacement can be decrease.

3.(Hoenderkamp, 2004)

proposed a graphical method for analyzing outrigger Truss braced designs in their review. It implements the process for determining the effective outrigger location and determining the lateral deflection and bending moment of a high-rise structure quickly.

4.(Herath *et al.*, 2009)

arranged outrigger beams in high rise buildings has a major impact on the lateral structural behavior under earthquake load. For both wind and seismic loading, the effective location for a skyscraper is between 0.44 to .48 times the height of the building from the base level.The research examined at a 50-story skyscraper and used multiple peak ground acceleration and velocity ratios and records. Response spectrum analysis is used to look at the response parameters to lateral displacement and inter-storey drift

5.(Haghollahi, Ferdous and Kasiri, 2012)

proposed an optimality criterion approach for tackling the explicit performance-based seismic design of outrigger optimization problem for RC buildings. And studied design consideration required in outrigger systems which includes a recommendation suggest differential column shortening and construction sequence impacts as there are not standardized procedure is available due to variety of challenges causes while construction. For that CTBUH has formed some guidelines.

III. METHODOLOGY

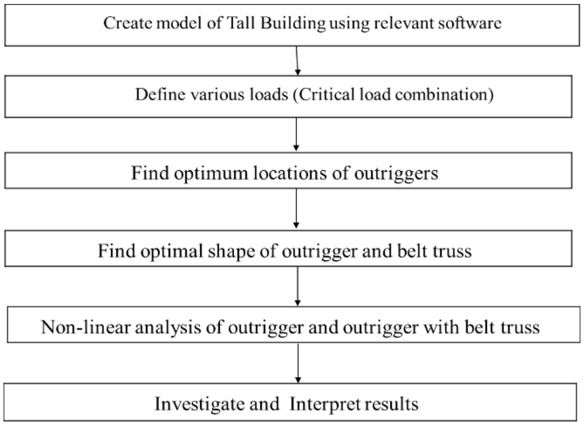


Fig. Flowchart

3.1SEISMIC EVALUATION METHOD

Vibratory Evaluation of multiple floors is necessary to determine the geological reactions of the project in order to comprehend the real performance of the structure; this may be accomplished through either dynamics or simple equivalent lateral analyses. The above Based on finite element approach may be used to regular structures of restricted height. The ground response approach may be used to conduct some linear calculations, hence dynamic analysis appraisal, i.e. time ’s historical study, is the only way to identify the current performance of a structure undergoing earthquakes stimulation (Fajfar, 2018).

Determining tsunami, the structure's forces is one of the most difficult tasks in construction applications. It has been discovered that, with the exception of comprehensive non - linear finite element interpretation, the methodologies have confined useful applications and are not appropriate for all types of buildings, despite the extensive data analysis undertaken in this area to develop simplification approaches that predict future performance (Fajfar, 2018).

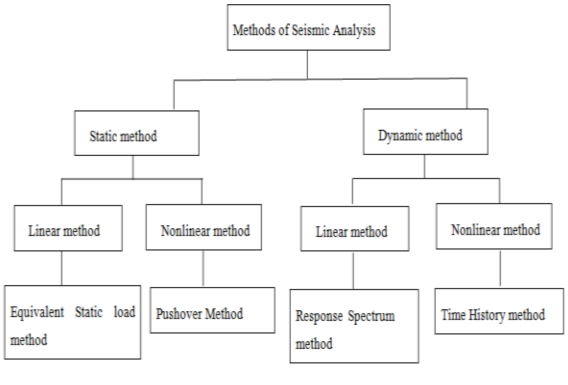


Fig. Methods of Seismic Analysis

3.2 Linear Static Analysis

In order to estimate demand for structures whose reactions are dominated by first mode and considered to be elastic, this approach is also known as the Static Equivalent method. The demands are estimated using this method, which calculates lateral loads based on the structural basic period and applies them to the design center of mass at each floor level. In linearly elastic structure, magnitude of these pseudo lateral loads was set with the objective of resulting in design displacement predicted during the design earthquake.

3.3Non-Linear Static Analysis

This describes the act of forcing a construct that accounted for large deformation until it yields a total loser curve, which is then employed to estimate the objective position during which the responsiveness amount is recoverable from a deformation mode.

- Pushover Analysis

Progressive collapse analysis is the technique of approximatively evaluation during which a material is exposed to uniformly escalating lateral pressures with an unchangeable length distribution until a predetermined distortion is attained. Ultimate bearing capacity is a sequence of consecutive elastic studies that are stacked to approximation a pressure curve of the whole superstructure (Sermin Oguz 2005). First, a two- or two half model containing symmetric or specifically identified capacity flow charts of all directional pressure factors is invented. High system are therefore applied, followed by a previously defined dynamic loads template scattered along the structure's tallness. The displacements are then enhanced until another member nations fail (Sermin Oguz 2005). The convergent validity is customised to accept responsibility for the diminished hardness of managed to produce delegates, but instead forces acting are enhanced until additional components yield. This procedure continues until a power deflection at the structure's uppermost portion reaches a specific amount of compression or the configuration would become volatile, at which point the pushing back is obtained by plotting with the foundation shear to obtain the world wide reliability index (Sermin Oguz 2005).

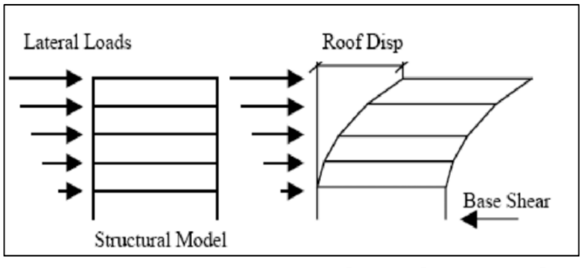


Fig. Static Approximations in the Pushover Analysis

The pushover analysis of the structure represents a static nonlinear analysis under constant vertical loads and gradually increasing lateral loads and Equivalent Static lateral loads approximately represent seismic generated forces(Dinar, 2013). Analysis is carried out till to failure of the structures so this analysis identifies weakness in the structure so that appropriate retrofitting could be provided in governing element such that demand and capacity are the two components of the performance-based analysis and design where demand is a representation of the seismic ground motion and capacity is a representation of the structure ability to resist seismic demand.

IV. RESULTANDDISCUSSION

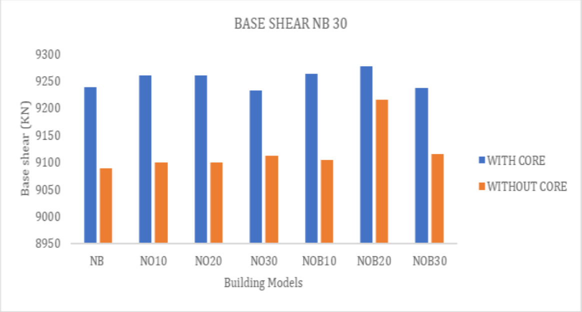
4.1 NB 30 Results

Table.1 Base shear and time period of NB30

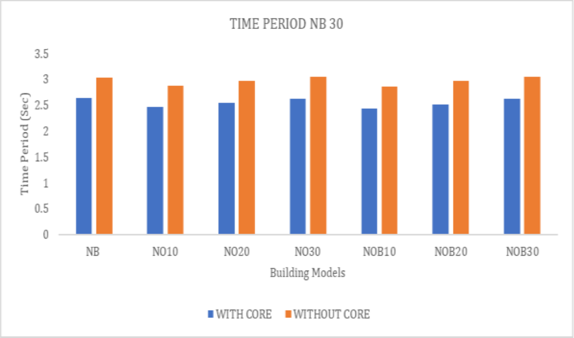
MODEL	Base shear		Time Period	
	RSP X	RSPY	RSPX	RSPY
BARE FRAME	9087.1895	9087.1895	3.033	3.033
NB	9237.4866	9237.4866	2.637	2.637
NO10	9258.5633	9258.5633	2.466	2.466
NO20	9258.4	9258.4	2.543	2.543
NO30	9232.1076	9232.1076	2.628	2.628
NOB10	9263.3689	9263.3689	2.428	2.428
NOB20	9276.3791	9276.3791	2.515	2.515
NOB30	9236.2952	9236.2952	2.628	2.628
NOWC10	9098.2366	9098.2366	2.877	2.877
NOWC20	9098.2774	9098.2774	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

Table.2 Top story displacement and Maximum Story Drift of NB 30

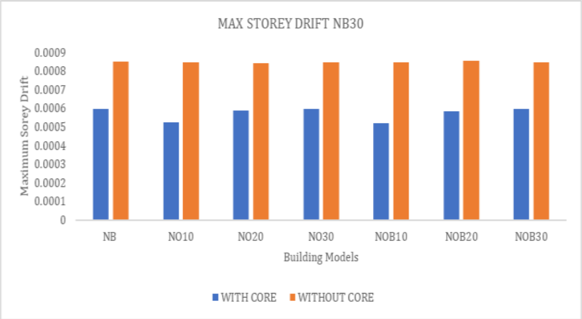
MODEL	Top story displacement		Maximum story drift	
	RSP X	RSPY	RSPX	RSPY
BARE FRAME	55.868	55.868	0.000848	0.000848
NB	43.409	43.409	0.000597	0.000597
NO10	37.918	37.918	0.000524	0.000524
NO20	38.683	38.683	0.000585	0.000585
NO30	42.164	42.164	0.000595	0.000595
NOB10	37.291	37.291	0.000519	0.000519
NOB20	37.658	37.658	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



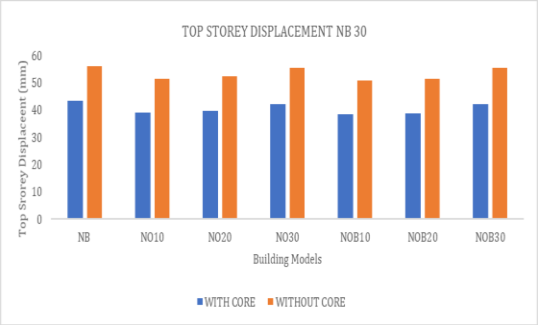
Graph.1 Base shear of NB 30 with core and without core models



Graph.2 Time Period of NB 30 with core and without core models



Graph.3 Maximum story drift of NB 30 with core and without core models



Graph.4 Top Story Displacement of NB 30 with core and without core models

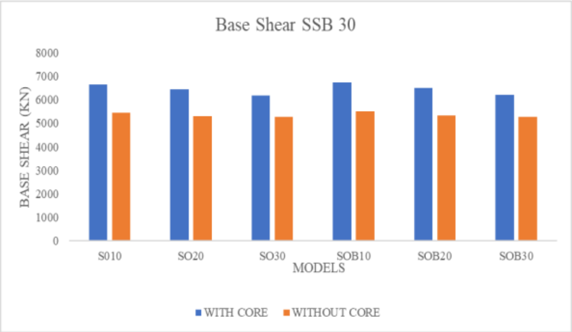
4.2 SSB 30 Results

Table.3 Base shear and time period of SSB 30

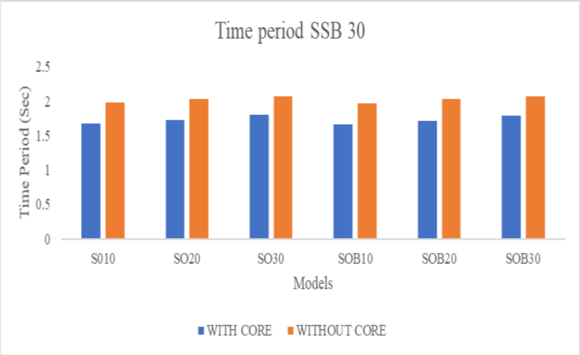
MODEL	Base shear (KN)		Time period (Sec)	
	RSP X	RSP Y	RSP X	RSP Y
SSB	6136.123	6136.123	1.812	1.812
S010	6645.7606	6645.7606	1.679	1.679
SO20	6445.5053	6445.5053	1.729	1.729
SO30	6191.4734	6191.4734	1.798	1.798
SOB10	6735.3659	6735.3659	1.658	1.658
SOB20	6502.2655	6502.2655	1.715	1.715
SOB30	6203.3112	6203.3112	1.795	1.795
SOWC10	5455.532	5455.532	1.981	1.981
SOWC20	5306.8628	5306.8628	2.033	2.033
SOWC30	5283.8885	5283.8885	2.068	2.068
SOBWC10	5513.7595	5513.7595	1.967	1.967
SOBWC20	5320.4444	5320.4444	2.03	2.03
SOBWC30	5286.1247	5286.1247	2.07	2.07

Table.4 Top story displacement and Maximum Story Drift of SSB 30

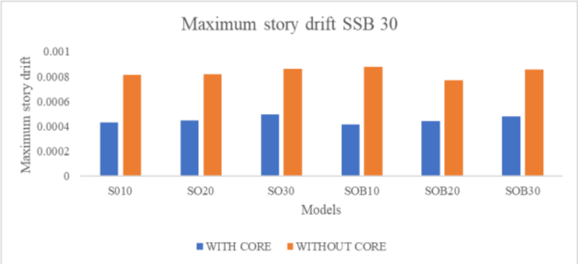
MODEL	Top story displacement (mm)		Max story drift	
	RSP X	RSP Y	RSP X	RSP Y
SSB	31.821	31.821	0.000493	0.000493
S010	30.83	30.83	0.00043	0.00043
SO20	30.708	30.708	0.000449	0.000449
SO30	30.045	30.045	0.000496	0.000496
SOB10	30.809	30.809	0.000416	0.000416
SOB20	30.392	30.392	0.000441	0.000441
SOB30	28.406	28.406	0.00048	0.00048
SOWC10	40.843	40.843	0.000812	0.000812
SOWC20	37.832	37.832	0.000816	0.000816
SOWC30	37.265	37.265	0.000861	0.000861
SOBWC10	37.415	37.415	0.00088	0.00088
SOBWC20	37.298	37.298	0.000771	0.000771
SOBWC30	36.45	36.45	0.000857	0.000857



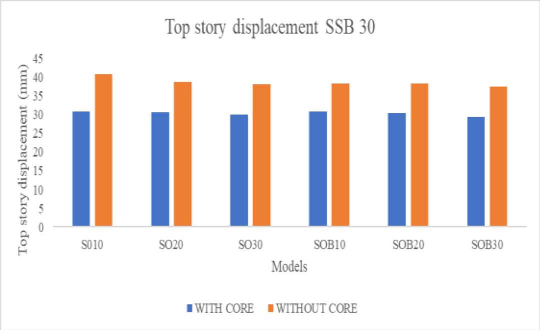
Graph.5 Base shear of SSB 30 with core and without core models



Graph.6Time Period of SSB 30 with core and without core models



Graph.7 Maximum story drift of NB 30 with core and without core models



Graph.8 Top Story Displacement of NB 30 with core and without core models

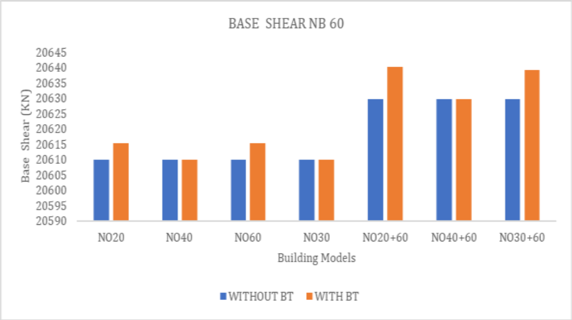
4.3 NB 60 Results

Table.5 Base shear and time period of NB 60

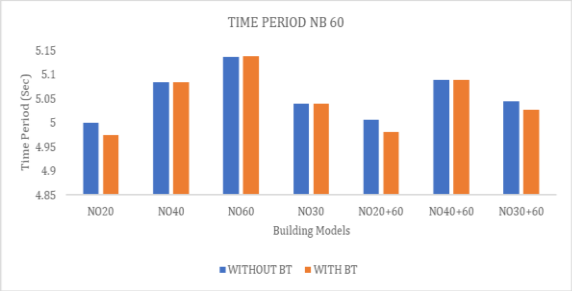
MODEL	Base shear (KN)		Time period (Sec)	
	RSP X	RSP Y	RSP X	RSP Y
NO20	20608.953	20608.95	5	5
NO40	20608.953	20608.95	5.083	5.083
NO0	20608.953	20608.95	5.136	5.136
NO30	20608.953	20608.95	5.039	5.039
NO20+60	20628.651	20628.65	5.005	5.005
NO40+60	20628.652	20628.65	5.088	5.088
NO30+60	20628.651	20628.65	5.044	5.044
NOB20	20615.168	20615.17	4.974	4.974
NOB40	20608.953	20608.95	5.083	5.083
NOB60	20615.168	20615.17	5.137	5.137
NOB30	20608.953	20608.95	5.039	5.039
NOB20+60	20640.084	20640.08	4.98	4.98
NOB40+60	20628.652	20628.65	5.088	5.088
NOB30+60	20638.081	20638.08	5.027	5.027

Table.6 Top story displacement and Maximum Story Drift of NB 60

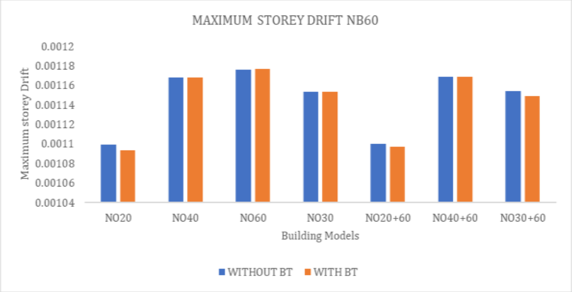
MODEL	Maximum story displacement (mm)		Max story drift	
	RSP X	RSP Y	RSP X	RSP Y
NO20	171.86	171.86	0.001099	0.001099
NO40	173.536	173.536	0.001168	0.001168
NO60	177.952	177.952	0.001176	0.001176
NO30	172.814	172.814	0.001153	0.001153
NO20+60	171.449	171.449	0.0011	0.0011
NO40+60	173.176	173.176	0.001169	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	177.975	177.975	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	178.283	178.283	0.001174	0.001174



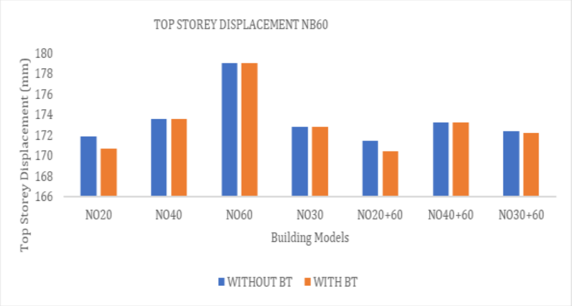
Graph.9 Base shear of NB 60 with core and without Belt truss models



Graph.10 Time Period of NB 60 with core and without Belt truss models



Graph.11 Maximum story drift of NB 60 with core and without Belt truss models



Graph.12 Top Story Displacement of NB 60 with core and without Belt truss models

SSB 60 Results

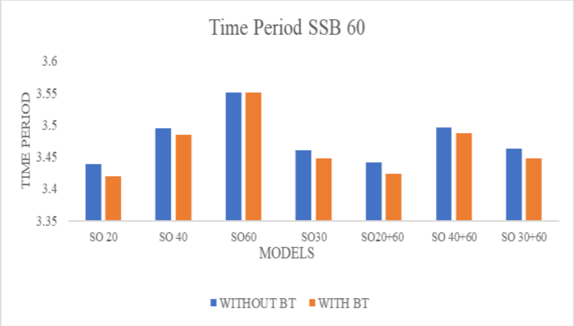
Table.7 Base shear and time period of SSB 60

MODEL	Base shear (KN)		Time period (Sec)	
	RSP X	RSP Y	RSP X	RSP Y
SSB	12507.1149	12507.1149	3.547	3.547
SO 20	12526.814	12526.814	3.438	3.438
SO 40	12521.2457	12521.2457	3.494	3.494
SO60	12514.681	12514.681	3.55	3.55
SO30	12521.2442	12521.2442	3.46	3.46
SO20+60	12534.3791	12534.3791	3.441	3.441
SO 40+60	12526.8108	12526.8108	3.496	3.496
SO 30+60	12526.8108	12526.8108	3.463	3.463
SOB 20	12533.0242	12533.0242	3.419	3.419
SOB 40	12526.0871	12526.0871	3.484	3.484
SOB 60	12516.9122	12516.9122	3.551	3.551
SOB 30	12528.3698	12528.3698	3.447	3.447
SOB 20+60	12541.8272	12541.8272	3.423	3.423
SOB 40+60	12533.7729	12533.7729	3.487	3.487
SOB 30+60	12533.776	12533.776	3.448	3.448

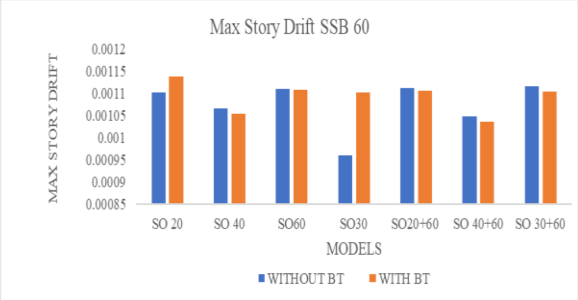
Table.8 Top story displacement and Maximum Story Drift of SSB 60

MODEL	Top story displacement (mm)		Max story drift	
	RSP X	RSP Y	RSP X	RSP Y
SSB	127.383	127.383	0.001123	0.001123
SO 20	127.283	127.283	0.001102	0.001102
SO 40	123.413	123.413	0.001066	0.001066
SO60	126.212	126.212	0.001109	0.001109
SO30	127.492	127.492	0.000961	0.000961
SO20+60	127.69	127.69	0.001112	0.001112
SO 40+60	120.684	120.684	0.001047	0.001047
SO 30+60	125.866	125.866	0.001115	0.001115
SOB 20	126.745	126.745	0.001138	0.001138
SOB 40	120.416	120.416	0.001053	0.001053
SOB 60	126.065	126.065	0.001107	0.001107
SOB 30	122.696	122.696	0.001101	0.001101
SOB 20+60	123.013	123.013	0.001106	0.001106
SOB 40+60	120.15	120.15	0.001036	0.001036
SOB 30+60	124.299	124.299	0.001104	0.001104

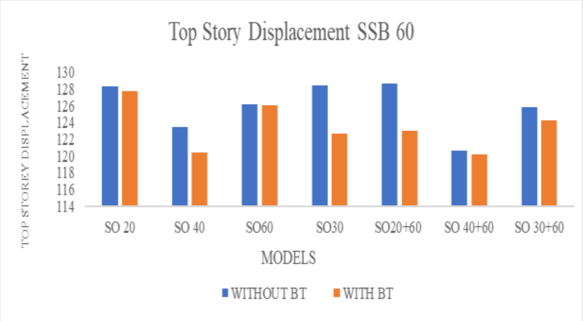
Graph.13 Base shear of SSB 60 with core and without Belt truss models



Graph.14 Time Period of SSB 60 with core and without Belt truss models



Graph.15 Maximum story drift of SSB 60 with core and without Belt truss models



Graph.16 Top Story Displacement of SSB 60 with core and without Belt truss models

V. CONCLUSION

- The employment of outrigger and shoulder strap truss systems in skyscrapers promotes strength and stability and applied load efficiency.
- Outriggers provided with core wall are beneficial as compare to without core wall with considering top story displacement and time period.
- Outriggers with belt truss is more effective for high rise building considering top story displacement and maximum story drift.
- 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.
- For 60 story building provision of two outriggers are efficient as compare to one outrigger system.
- 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.
- For NB 60 it is observed that 6.53% drift is controlled by providing outrigger at top and H/3 location.
- Base shear shows minimum response value other than general structure at H/3 location for NB.
- 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).
- For SSB 60 it is observed that 7.39 % drift is controlled by providing outrigger at top and 2H/3 location.
- 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).

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