PERFORMANCE AND OPTIMIZATION OF OUTRIGGER WITH BELT TRUSS SYSTEM IN MULTISTORIED BUILDING

Aswathi C[1], Sruthi Das K K[2]

[1]PG Student, Dept. of Civil Engineering, Sree Narayana Guru College of Engineering and Technology , Payyannur Kerala, India- 670307

[2]Assistant Professor, Sree Narayana Guru College of Engineering and Technology, Payyannur Kerala, India- 670307

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Abstract - *The outrigger system is one of the most common and efficient systems that can be used to improve the performance of tall buildings under wind and seismic forces. An Outrigger is a horizontal projection attached to any member and helps in increasing its stability. When the height of the structure increases, the building stiffness becomes more important and introduction of the outrigger beams between shear walls and external columns is often used to provide sufficient lateral stiffness to the structure. The objective of the study is to optimize outrigger and outrigger with belt truss system location and to access the efficiency of each outrigger used in the structure and different types of bracings adopted at optimum position. The analysis is done by considering the models of normal building, symmetric setback building and asymmetric setback building. The analysis is carried out in ETABS 16.0.2*

Key Words: Outriggers, Lateral loads, Displacement, Base Shear, Lateral Stiffness, Belt truss system.

1.INTRODUCTION

The outrigger and belt truss system acts very important role to resist the lateral loads in the structure. In this structure the external columns are tied to the central core wall with stiffened outriggers and belt truss at one or different levels. The outrigger beam and belt truss system is the lateral loads resisting system in which the central core is tied to the external columns with very stiff outriggers beam and belt truss at one or more levels. The belt truss tied the peripheral column of the building while the outriggers engage them with main core or central shear wall. The core may be centrally located with outriggers extending on both sides or it may be located on one side of the building with outriggers extending to the building columns on one side. The outrigger and belt truss system effectively control the excessive drift due to lateral load and minimize the risk of structural and non-structural damage. Outriggers are stiff elements connected to a structure core to outer columns. The outrigger with belt truss system improves the structural stiffness of building against overturning moment by developing a tension-compression couple in perimeter columns when a central core tries to bend, generating restoring moment acting on the core at the outrigger level.

The concept of the conventional outrigger is the outrigger trusses are directly connected to the shear walls or braced frames at the core of the structures. The basic principle is the same as when belt trusses are used as virtual outriggers. Some of the moment in the core is transformed into a horizontal couple and transferred to the truss chords in the floors at the top and the bottom of the diaphragm and it finally converted into vertical forces at the exterior columns. The fundamental idea behind the virtual outrigger system is to use rigid floor diaphragms, which are very stiff and stronger in their own plane, to transfer moment in the form of a horizontal couple moment from the core to trusses and trusses to exterior column. Basement walls and belt trusses are appropriate to use as virtual outriggers. The way in which overturning moment in the core is converted into a vertical couple at the exterior columns in case of conventional outrigger, rotation of the core is resisted by floor diaphragms at the top and bottom of the belt trusses; thus, part of the moment in the core is converted into a horizontal couple in the floors. The horizontal couple, transferred through two floors to the truss chords, is converted by the truss into vertical forces at the exterior columns.

2.SCOPE

The main scopes of this study are follows.

- The building models are compared by changing the soil interaction or types of soil to provide better information about the response of the system.
- The behavior of building for other types of irregular building can be studied. The base isolation or spring technique may be used with outrigger structural system.
- The behaviour of building for other types of braces can be studied

3. OBJECTIVES

The main objectives of this study are follows.

- To find out the optimum location of outrigger in normal building, symmetric setback building and asymmetric setback building.

- Comparison with different type of X bracing, V bracing, two storey V bracings and combination of X –V bracing, X –two storey V bracing adopted at optimum position.
- To investigate the seismic behaviour of best model with time history analysis.

4.MODELLING AND MODEL ANALYSIS

4.1 Modeling

Etabs software is used for modeling and model analysis. Building configuration and loading data of models are described in table 1. In this project the models are normal building, symmetric setback building and asymmetric setback building of 30storey with 7 X 7 bay.

4.2 Building configuration

Table -1: Building configuration

Number of storey	G+29
Floor height	3.3m
Spacing between frame in X direction	5.5m
Spacing between frame in Z direction	5.5m
Grade of concrete	M40
Grade of steel	Fe500
Size of beam	230X450 mm
Size of column	800X800 mm
Thickness of slab	150mm
Thickness of shear wall	300mm
Support	Fixed
Type of building	OMRF
Outrigger size	300x300mm
Belt truss	ISLB600

4.3 Loading consideration

- Live load : 3kN/m^2
- Floor finish : 1kN/m^2
- Seismic loading (IS : 1893 (Part I) -2002)
- Zone factor : 0.36
- Medium soil
- Terrain category – 3

4.4 Models created

Table - 2: Models designation

DESIGNATION	DESCRIPTION
NB	Normal 30 storey building without outrigger
NB+OT @ 10	Normal building with Outrigger at 10^{th}storey
NB+OT @ 20	Normal building with Outrigger at 20^{th}storey
NB+OT @ 30	Normal building with Outrigger at 30^{th}storey
SSB	Symmetric set back building without outrigger
SSB+ OT@10	Symmetric set back building with Outrigger at 10^{th}storey
SSB+ OT@20	Symmetric set back building with Outrigger at 20^{th}storey
SSB+ OT@30	Symmetric set back building with Outrigger at 30^{th}storey
ASB	Asymmetric set back building without outrigger
ASB+OT@10	Asymmetric set back building with Outrigger at 10^{th}storey
ASB+OT@20	Asymmetric set back building with Outrigger at 20^{th}storey
ASB+OT@30	Asymmetric set back building with Outrigger at 30^{th}storey
NB + OT V	Normal building with V bracing Outrigger and X bracing belt truss
NB + BT V	Normal building with X bracing Outrigger and V bracing belt truss
NB + BT OT V	Normal building with V bracing Outrigger and V bracing belt truss
SSB + OT V	Symmetric set back building with V bracing Outrigger and X bracing belt truss
SSB + BT V	Symmetric set back building with X bracing Outrigger and V bracing belt truss
SSB + BT OT V	Symmetric set back building with V bracing Outrigger and V bracing belt truss
ASB + OT V	Asymmetric set back building with V bracing Outrigger and X bracing belt truss
ASB + BT V	Asymmetric set back building with X bracing Outrigger and V bracing belt truss
ASB + BT OT V	Asymmetric set back building with V bracing Outrigger and V bracing belt truss
NB + OT TWO STOREY V	Normal building with two storey V bracing Outrigger and X bracing belt truss
NB + BT TWO STOREY V	Normal building with X bracing Outrigger and two storey V bracing belt truss
NB + BT OT TWO STOREY V	Normal building with two storey V bracing Outrigger and VV bracing belt truss
	Symmetric set back building

SSB +OT TWO STOREY V	with two storey V bracing Outrigger and X bracing belt truss
SSB + BT TWO STOREY V	Symmetric set back building with X bracing Outrigger and two storey V bracing belt truss
SSB + BT OT TWO STOREY V	Symmetric set back building with two storey V bracing Outrigger and VV bracing belt truss
ASB + OT TWO STOREY V	Asymmetric set back building with two storey V bracing Outrigger and X bracing belt truss
ASB + BT TWO STOREY V	Asymmetric set back building with X bracing Outrigger and two storey V bracing belt truss
ASB + BT OT TWO STOREY V	Asymmetric set back building with two storey V bracing Outrigger and VV bracing belt truss

Fig - 1: NB without outrigger

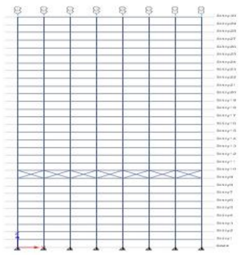

Fig - 2: NB + OT@ 10

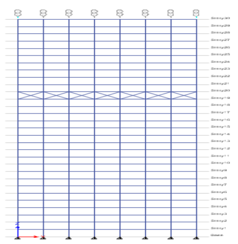

Fig - 3: NB + OT @ 20

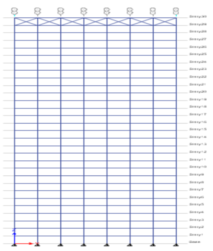

Fig 4: NB + OT@ 30

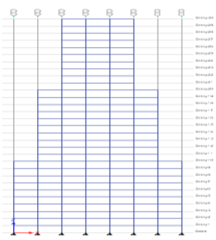

Fig - 5: SSB without OT

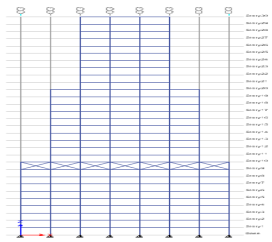

Fig 6: SSB + OT@10

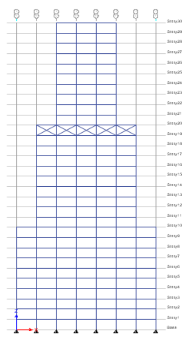

Fig - 7: SSB + OT@20

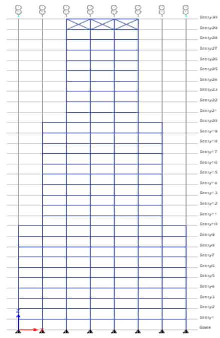

Fig - 8: SSB + OT@30

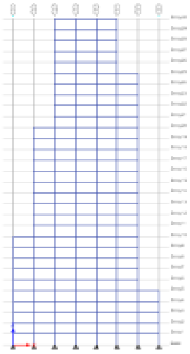

Fig - 9: ASB without OT

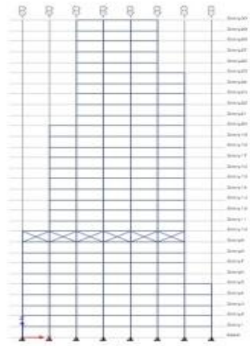

Fig - 10: ASB + OT@10

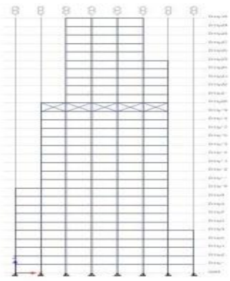

Fig - 11: ASB + OT@20

Fig - 12: ASB + OT@30

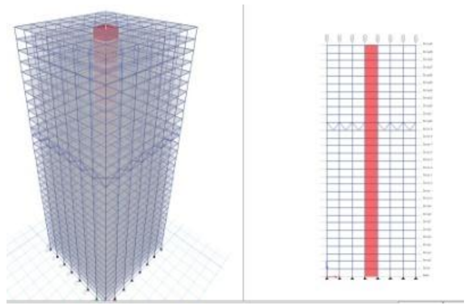

Fig - 13: NB + OT V Bracing

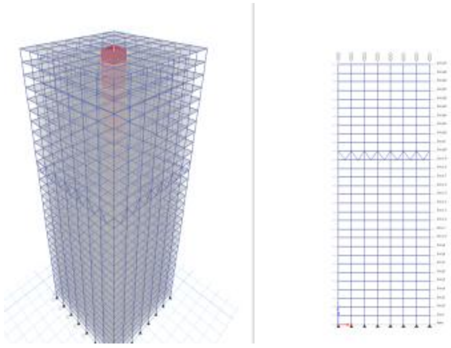

Fig - 14: NB+ BT V Bracing

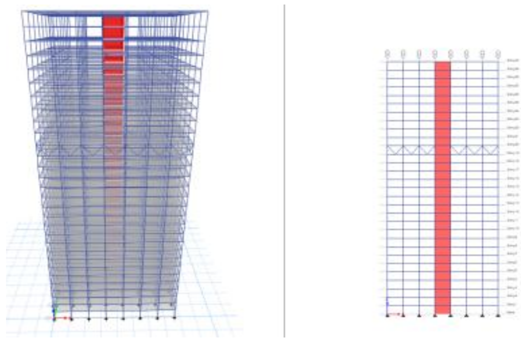

Fig - 15: NB+ OT BT V Bracing

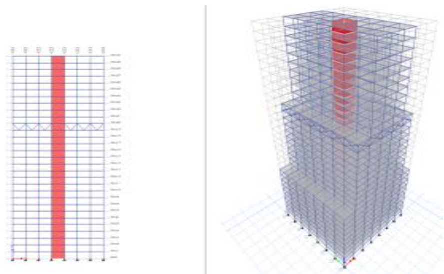

Fig - 16: SSB + OT V Bracing

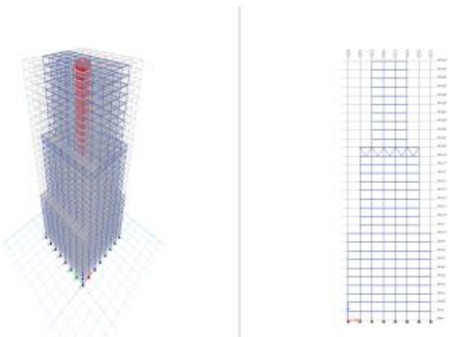

Fig - 17: SSB + BT V Bracing

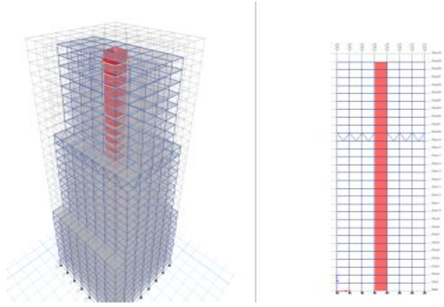

Fig - 18: SSB + OT BT V Bracing

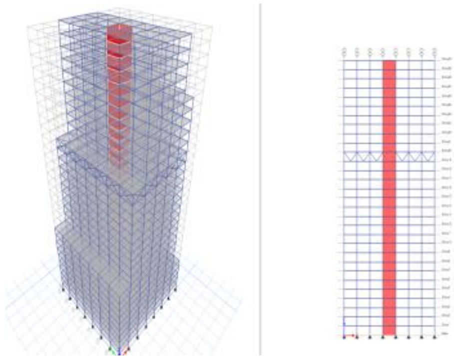

Fig - 19: ASB + OT V Bracing

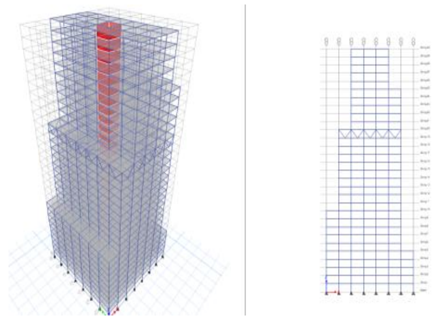

Fig - 20: ASB + BT V Bracing

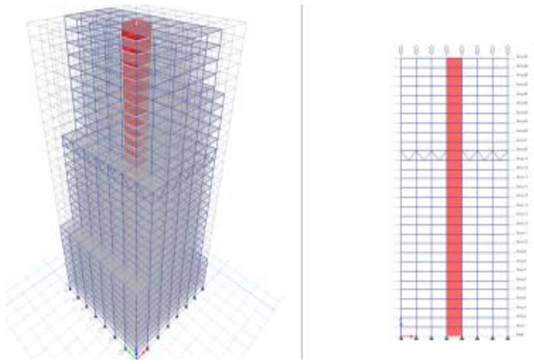

Fig - 21: ASB + OT BT V Bracing

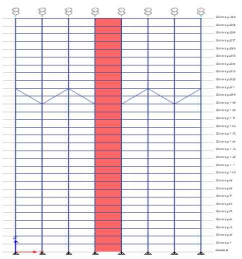

Fig - 22: NB + OT two storey V Bracing

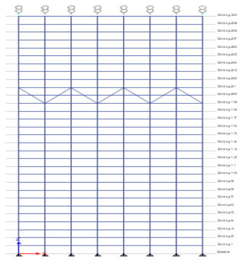

Fig - 23: NB + BT two storey V Bracing

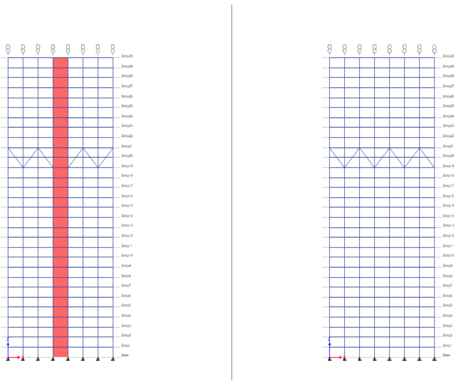

Fig - 24: NB + OT BT two storey V Bracing

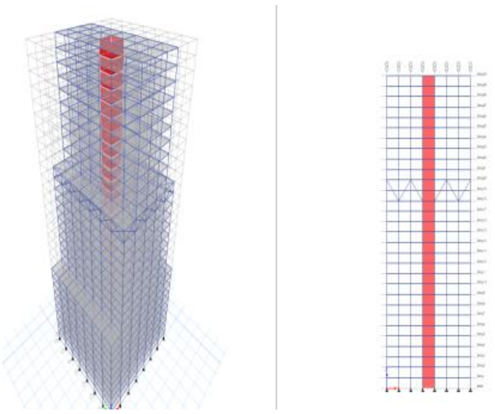

Fig - 25: SSB + OT two storey V Bracing

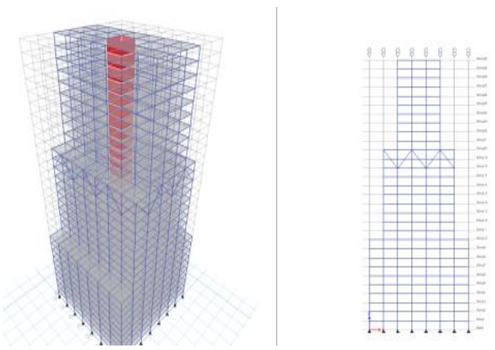

Fig - 26: SSB + BT two storey V Bracing

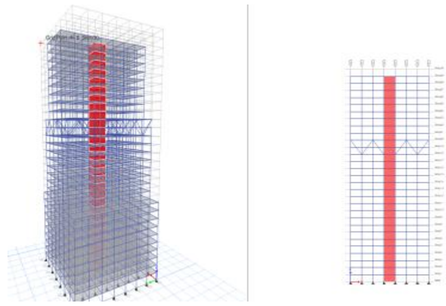

Fig - 27: SSB + OT BT two storey V Bracing

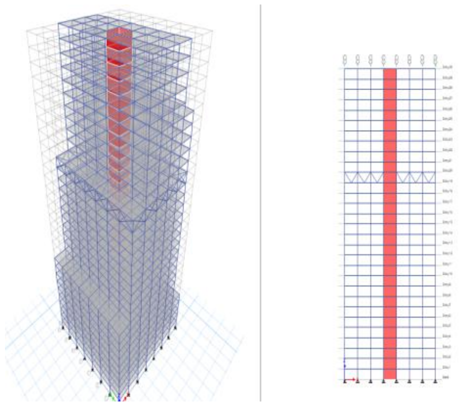

Fig - 28: ASB + OT two storey V Bracing

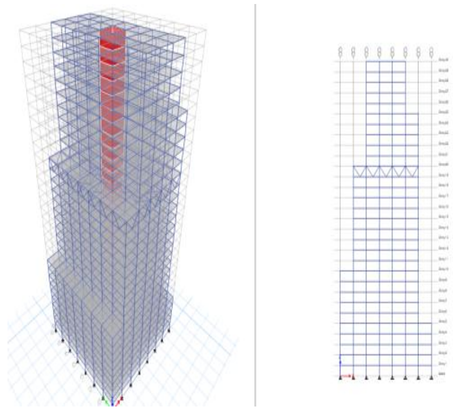

Fig - 29: ASB + BT two storey V Bracing

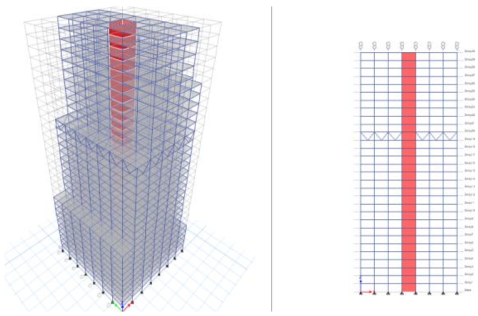

Fig - 30: ASB + OT BT two storey V Bracing

5.RESULT AND DISCUSSION

Table - 3: Normal building analysis result

MODEL	NORMAL BUILDING			
	Max Displacement (mm)		Max Drift(mm)	
	X	Y	X	Y
NB without OT	130	130	0.00187	0.00187
NB + OT @ 10	114	114	0.00175	0.00175
NB + OT @ 20	105	105	0.00157	0.00157
NB + OT @ 30	117.33	117.33	0.00181	0.00181

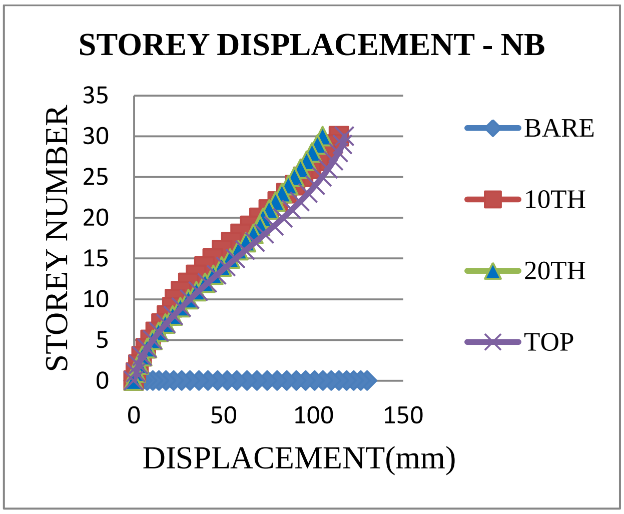

Chart -1: Displacement graph of Normal building

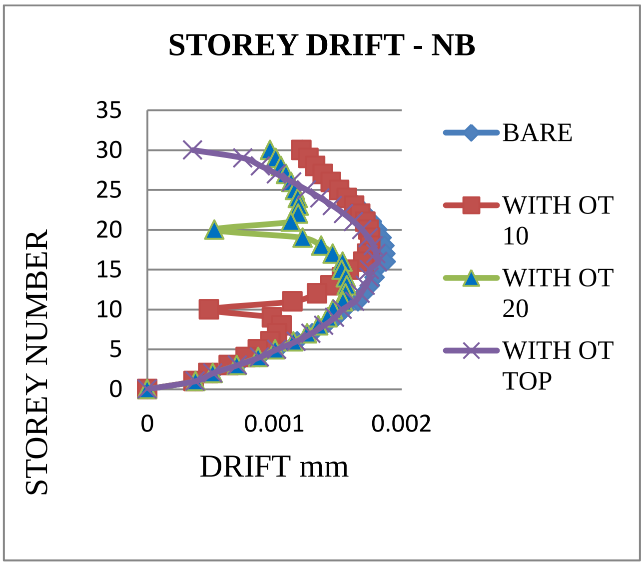

Chart -2: Drift graph of Normal building

Table - 4: Symmetric setback building analysis result

MODEL	SSB			
	Max Displacement(mm)		Max Drift(mm)	
	X	Y	X	Y
SSB without OT	131	129	0.00190	0.00188
SSB + OT @ 10	128	123	0.00199	0.00189
SSB + OT @ 20	113	107	0.00161	0.00157
SSB + OT @ 30	124	114	0.00180	0.00172

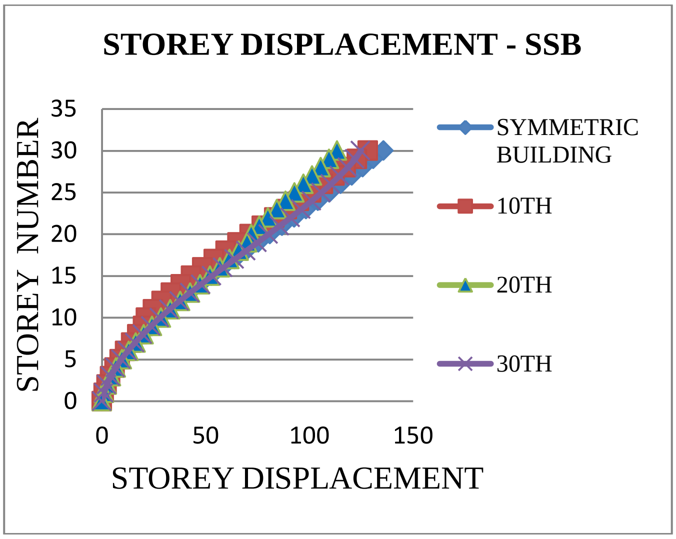

Chart -3: Displacement graph from SSB

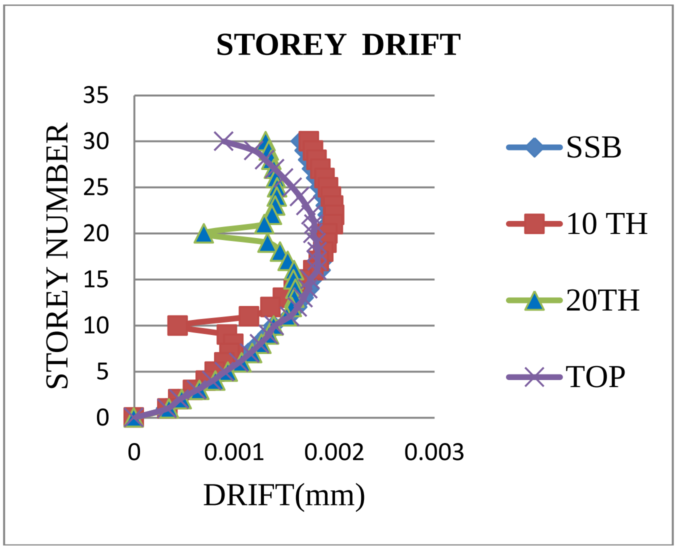

Chart -4: Drift graph from SSB

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Table - 5: Asymmetric setback building analysis result

MODEL	SSB			
	Max Displacement (mm)		Max Drift(mm)	
	X	Y	X	Y
ASB without OT	129	127	0.00183	0.00185
ASB + OT @ 10	122	119	0.00186	0.00186
ASB + OT @ 20	110	106	0.00159	0.00162
ASB + OT @ 30	119	113	0.00178	0.00179

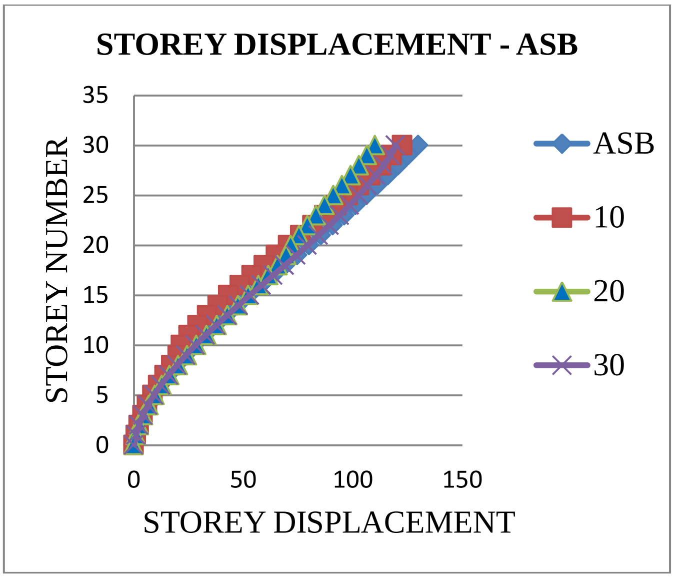

Chart -5: Displacement graph from ASB

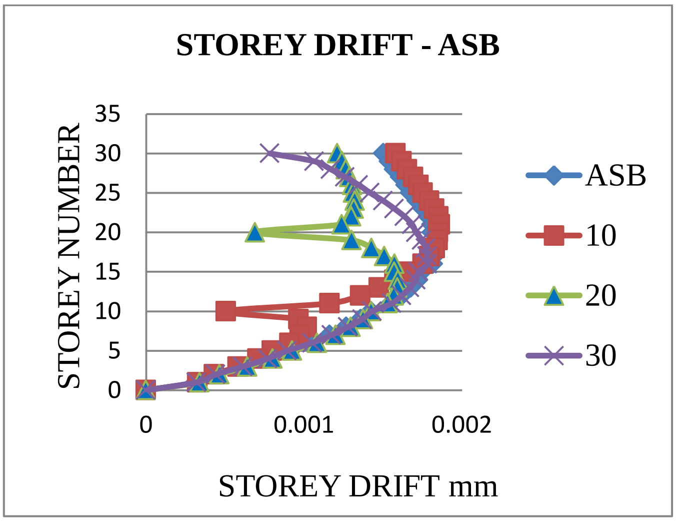

Chart -6: Drift graph from ASB

Table - 6: Analysis result of normal building with X-V bracing

MODEL	X-V BRACING -NB			
	Max displacement(mm)		Max drift(mm)	
	X	Y	X	Y
NB + OT V	105.62	0.00157	0.00157	0.00157
NB + BT V	105.57	0.00159	0.00159	0.00159
NB + OT BT V	104.85	0.00156	0.00156	0.00156

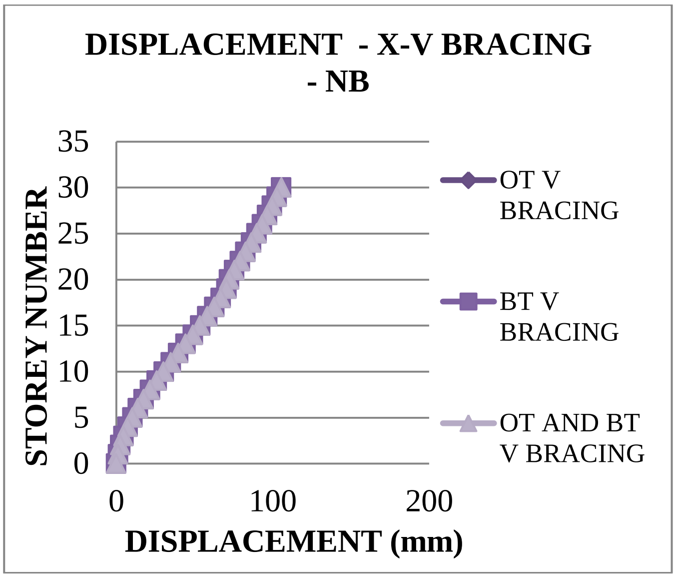

Chart -7: NB with X-V bracing displacement graph

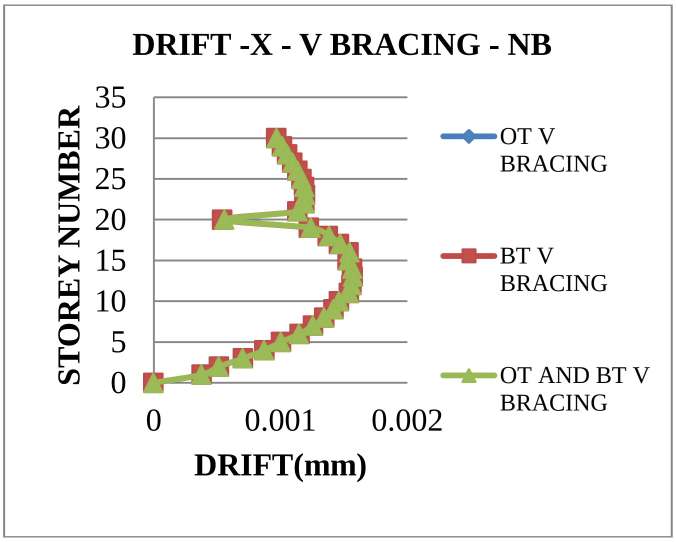

Chart -8: NB with X- V bracing drift graph

Table - 7: Analysis result of symmetric setback building with X-V bracing

MODEL	X-V BRACING –SSB			
	Max displacement(mm)		Max drift(mm)	
	X	Y	X	Y
SSB + OT V	114.5	109	0.00132	0.00132
SSB + BT V	114	108.3	0.00132	0.00132
SSB + OT BT V	108.9	105.25	0.00127	0.00125

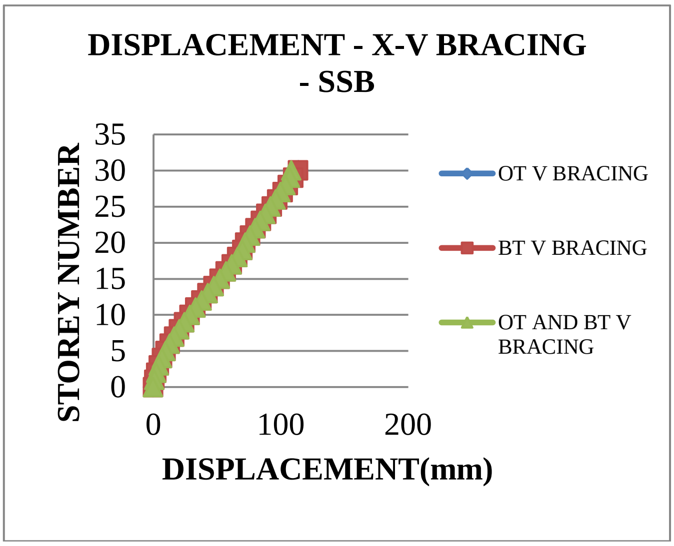

Chart -9: SSB with X-V bracing displacement graph

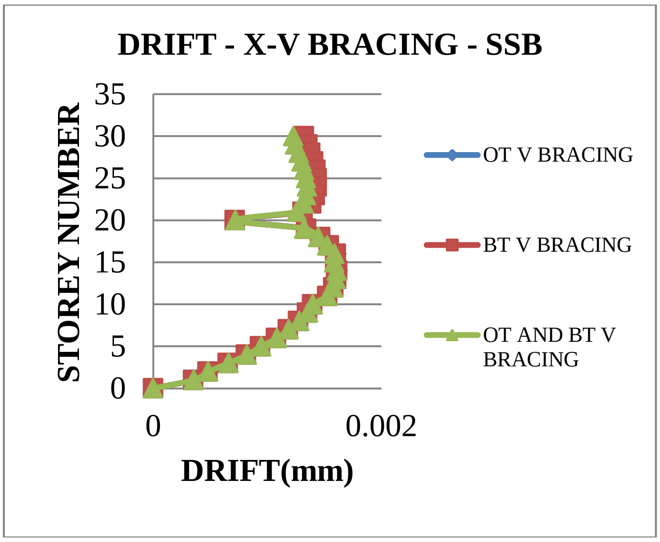

Chart -10: SSB with X-V bracing drift graph

Table - 8: Analysis result of asymmetric setback building with X- V bracing

MODEL	X-V BRACING -ASB			
	Max displacement(mm)		Max drift(mm)	
	X	Y	X	Y
ASB + OT V	110.546	106.48	0.00121	0.00122
ASB + BT V	110.42	106.25	0.00122	0.00123
ASB + OT BT V	107.264	103.45	0.00120	0.00121

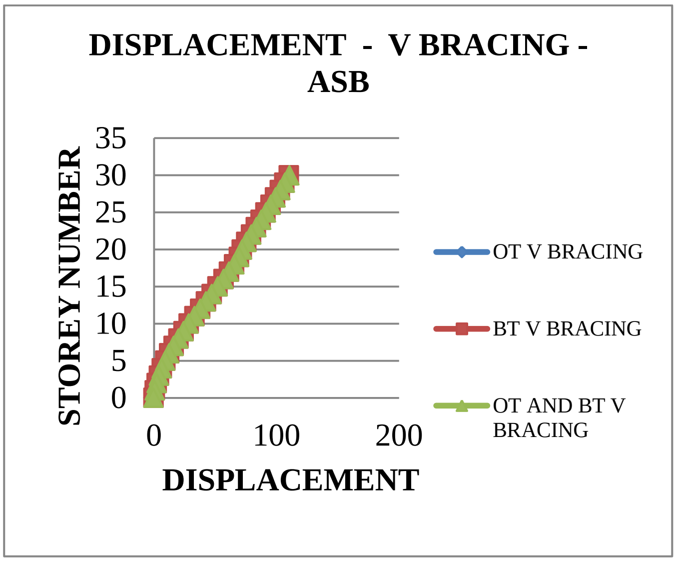

Chart -11: ASB with X-V bracing displacement graph

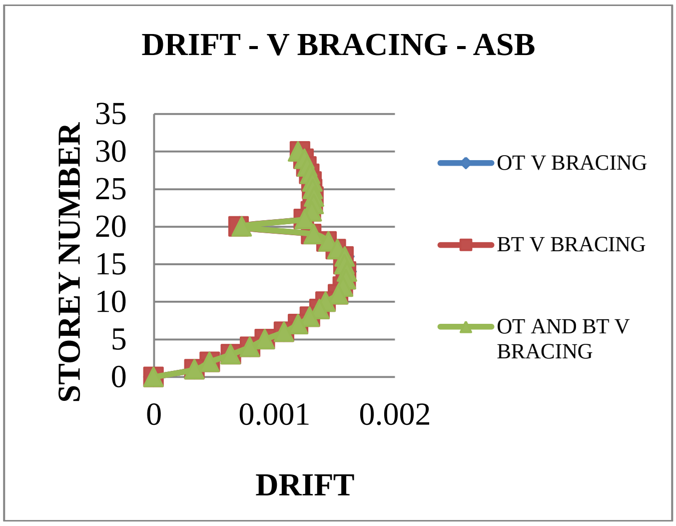

Chart -12: ASB with X-V bracing drift graph

Table - 9: Analysis result of normal building with X-Two storey V bracing

MODEL	TWO STOREY V BRACING -SSB			
	Max displacement (mm)		Max drift(mm)	
	X	Y	X	Y
NB + OT V	103	103	0.00156	0.00156
NB + BT V	103.11	103.11	0.00157	0.00159
NB + OT BT V	102.26	102.62	0.00154	0.00154

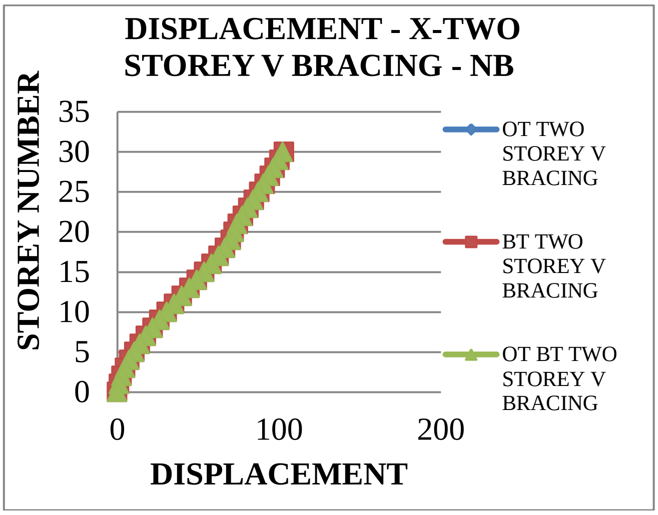

Chart -13: NB with X-Two storey V bracing displacement graph

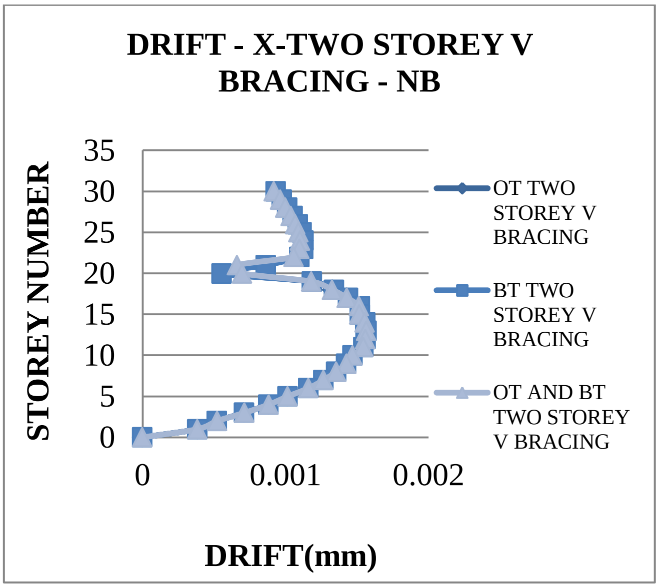

Chart -14: NB with X-Two storey V bracing drift graph

Table - 10: Analysis result of symmetric setback building with X-Two storey V bracing

MODEL	TWO STOREY V BRACING -SSB			
	Max displacement (mm)		Max drift(mm)	
	X	Y	X	Y
SSB + OT V	111.49	105	0.0013	0.00136
SSB + BT V	111.56	105.6	0.00139	0.00132
SSB + OT BT V	105.5	101.25	0.00122	0.00123

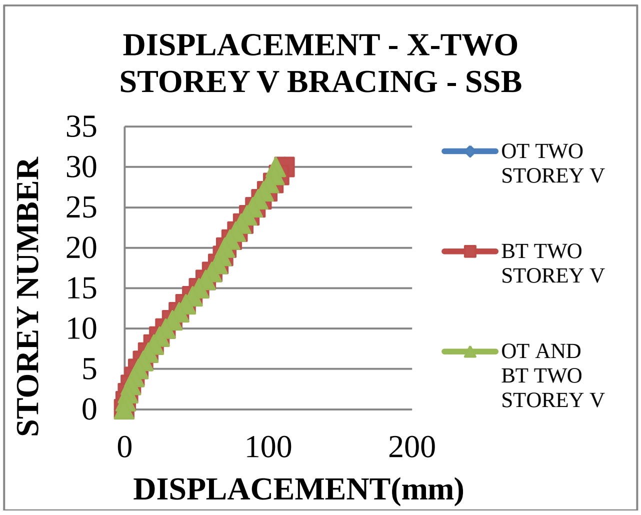

Chart -15: SSB with X-Two storey V bracing displacement graph

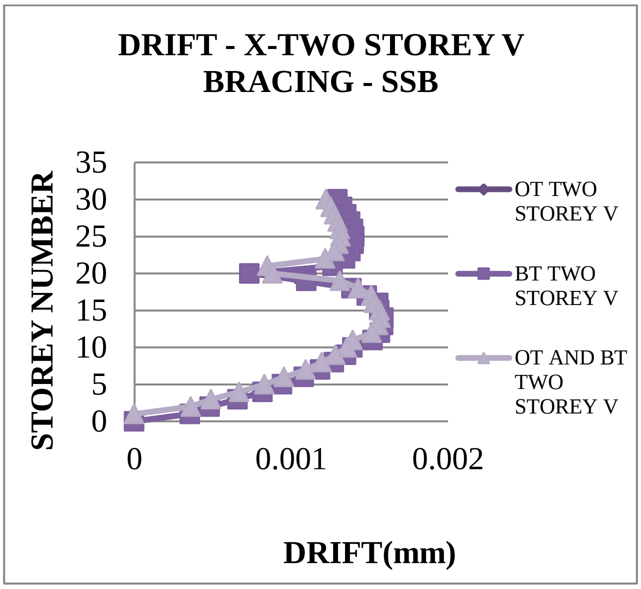

Chart -16: SSB with X-Two storey V bracing drift graph

Table - 11: Analysis result of asymmetric setback building with X-Two storey V bracing

MODEL	X-TWO STOREY V BRACING -ASB			
	Max displacement(mm)		Max drift(mm)	
	X	Y	X	Y
ASB + OT V	108.70	102.8	0.00120	0.00121
ASB + BT V	107.23	101.35	0.00119	0.00120
ASB + OT BT V	107.97	100.4	0.00118	0.00119

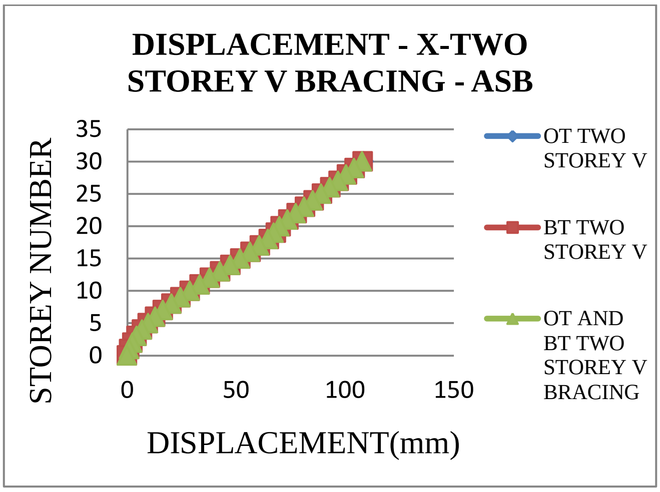

Chart -17: ASB with X-Two storey V bracing displacement graph

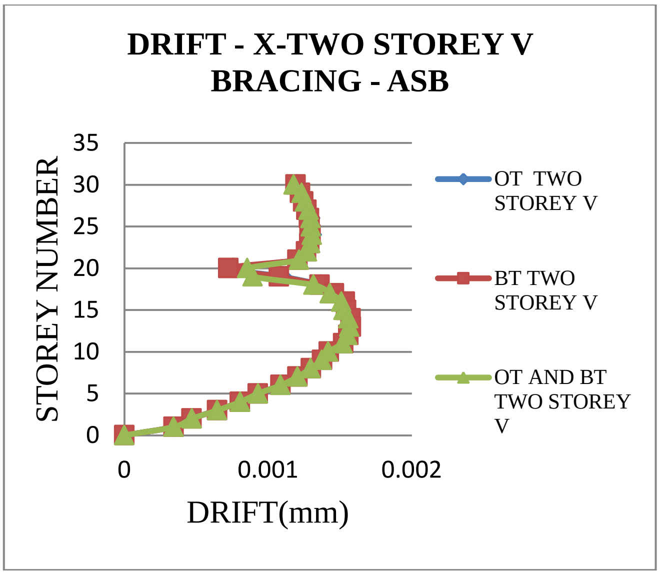

Chart -18: ASB with X-Two storey V bracing drift graph

Table - 12: Time history analysis for normal building with and without OT

Parameters	Without OT	Two storey V bracing	% variation
Displacement(mm)	200.822	181.56	10%
Drift(mm)	0.005	0.004	20%

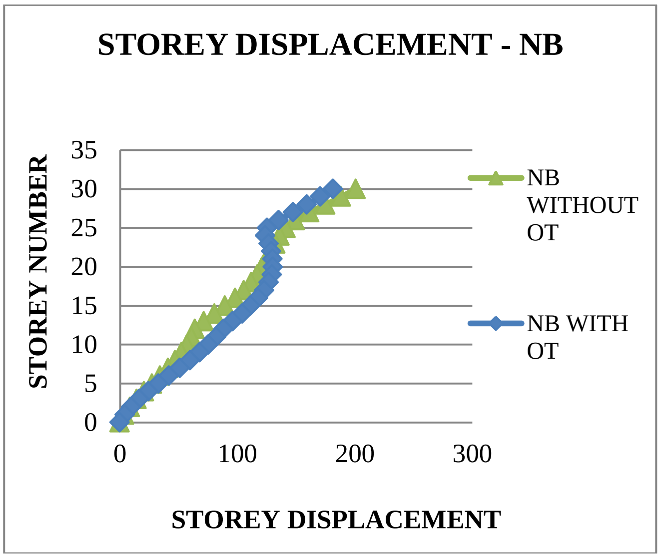

Chart -19: Time history analysis displacement graph of NB with and without OT

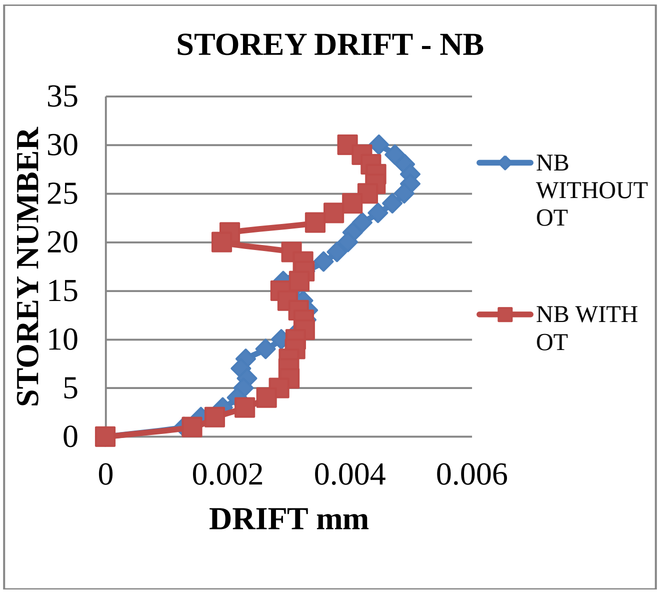

Chart -20: Time history analysis drift graph of NB with and without OT

Table - 13: Time history analysis for symmetric setback building with and without OT

Parameters	Without OT	Two storey V bracing	% variation
Displacement (mm)	258.54	240	7.10%
Drift(mm)	0.0067	0.0056	21.7%

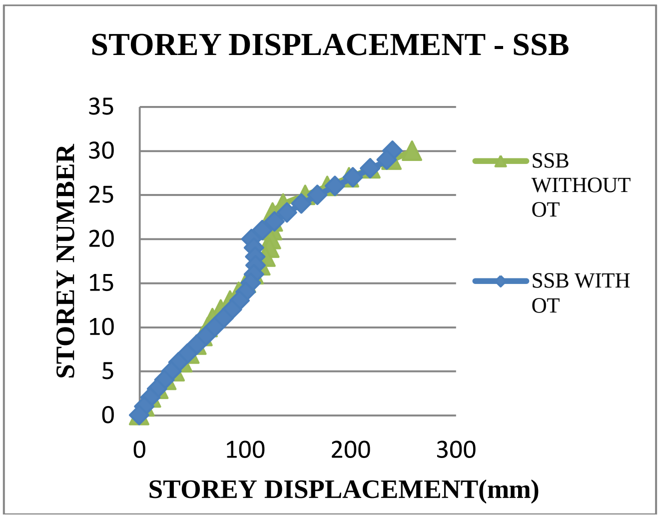

Chart -21: Time history analysis displacement graph of SSB with and without OT

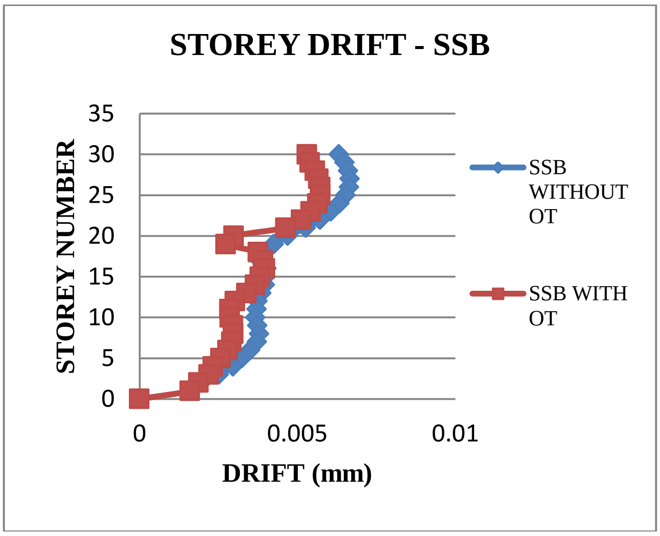

Chart -22: Time history analysis drift graph of SSB with and without OT

Table - 14: Time history analysis for asymmetric setback building with and without OT

Parameters	Without OT	Two storey V bracing	% variation
Displacement (mm)	246.303	227.79	7.5%
Drift (mm)	0.0068	0.0058	15%

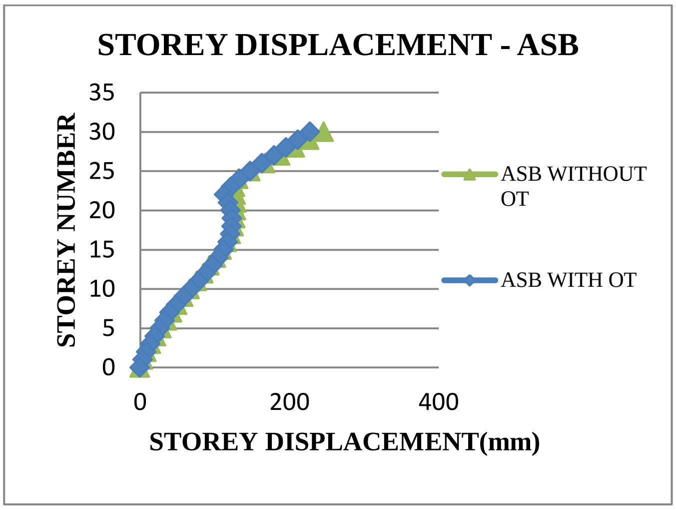

Chart -23: Time history analysis displacement graph of ASB with and without OT

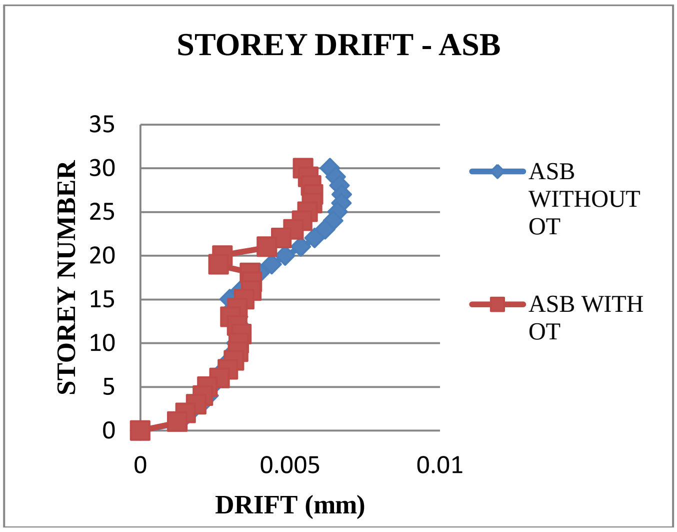

Chart -24: Time history analysis displacement graph of ASB with and without OT

6.CONCLUSIONS

- The behavior of outrigger with belt truss system is studied in multistoried building. It is studied that the outrigger with belt truss system is effective in controlling drift, displacement, of the building and makes the structural form efficient under seismic loading.
- In normal building with outrigger when outrigger is placed at 10thstorey, 20thstorey and 30thstorey there is a decrease of 12%, 19% and 10% in storey displacement respectively as compared to normal building without outrigger.
- In normal building with outrigger when outrigger is placed at 10thstorey, and 20thstorey and 30thstorey there is a decrease of 6.4%, 16% and 3.2% in storey drift respectively as compared to normal building without outrigger.
- In symmetric setback building with outrigger when outrigger is placed at 10thstorey, 20thstorey and 30thstorey there is a decrease of 2%, 13% and 5.3% in storey displacement respectively as compared to normal building without outrigger.
- In symmetric setback building with outrigger when outrigger is placed at 10thstorey and 20thstorey there is a decrease of 3.7%, 16% and 8.5% in storey drift respectively as compared to normal building without outrigger.
- In asymmetric setback building with outrigger when outrigger is placed at 10thstorey and 20thstorey there is a decrease of 5% , 14% and 7.7% in storey displacement respectively as compared to normal building without outrigger.
- In asymmetric setback building with outrigger when outrigger is placed at 10thstorey and 20thstorey there is a decrease of 1.6%, 13% and 2.7% in storey drift respectively as compared to normal building without outrigger. Placing outrigger at 20thstorey is the optimum position.
- In further modeling X bracing, V bracing, two storey V bracings and combination of X –V bracing, X –two storey V bracing are adopted at optimum position.
- In normal building with X bracing, V bracing and X-V bracing at optimum position, storey displacement and storey drift reduces when X bracing is used as both outrigger and belt truss. Similarly storey displacement and storey drift reduces when V bracing is used as both outrigger and belt truss.
- In normal building with X bracing, two storey V bracing and X-two storey V bracing at optimum position, storey displacement and storey drift reduces when X bracing is used as both outrigger and belt truss. Similarly storey displacement and storey drift reduces when two storey V bracing is used as both outrigger and belt truss.
- In normal building, by comparing reduction in storey displacement and storey drift providing two storey V bracing as both outrigger and belt truss results minimum storey displacement and storey drift
- In symmetric setback building with X bracing, V bracing and X-V bracing at optimum position, storey displacement and storey drift reduces when X bracing is used as both outrigger and belt truss. Similarly storey displacement and storey drift reduces when V bracing is used as both outrigger and belt truss.
- In symmetric setback building with X bracing, two storey V bracing and X-two storey V bracing at optimum position, storey displacement and storey drift reduces when X bracing is used as both outrigger and belt truss. Similarly storey displacement and storey drift reduces when two storey V bracing is used as both outrigger and belt truss.
- In symmetric setback building, by comparing reduction in storey displacement and storey drift providing two storey V bracing as both outrigger and belt truss results minimum storey displacement and storey drift.
- In asymmetric setback building with X bracing, V bracing and X-V bracing at optimum position, storey displacement and storey drift reduces when X bracing is used as both outrigger and belt truss. Similarly storey displacement and storey drift reduces when V bracing is used as both outrigger and belt truss.
- In asymmetric setback building with X bracing, two storey V bracing and X-two storey V bracing at optimum position, storey displacement and storey drift reduces when X bracing is used as both outrigger and belt truss. Similarly storey displacement and storey drift reduces when two storey V bracing is used as both outrigger and belt truss.
- In asymmetric setback building, by comparing reduction in storey displacement and storey drift providing two storey V bracing as both outrigger and belt truss results minimum storey displacement and storey drift.
- Time history analysis of normal building with two storey V bracing results 10% reduction in storey displacement and 20 % reduction in storey drift as compared to normal building without outrigger.
- Time history analysis for symmetric setback building with two storey V bracing results 7.10% reduction in storey displacement and 21.7 % reduction in storey drift as compared to symmetric setback building without outrigger.
- Time history analysis for asymmetric setback building with two storey V bracing results 7.5% reduction in storey displacement and 15.0 % reduction in storey drift as compared to asymmetric setback building without outrigger.
- Hence outrigger with belt truss improves the performance of the building by resisting the seismic forces.
- Location and type of outrigger plays a very important role in the design of tall buildings.

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