A PERFORMANCE BASED STUDY ON STATIC AND DYNAMIC BEHAVIOUR OF OUTRIGGER STRUCTURAL SYSTEM FOR TALL BUILDINGS

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Abstract - ***Abstract The study focused on performance of multi-outrigger structural system. Static and dynamic behaviour of 40 storey building for various models were examined using ETABS software for concrete outrigger with central shear wall and without outrigger and outrigger bracing with belt truss in replacement with concrete outrigger. Time history analysis for ground motion data of Bhuj earthquake was carried out. The analysis include Lateral displacement, storey drift and base shear for static and dynamic loading and also time period variation of different buildings. From the results obtained the effective performance of building with outriggers at 20th and 26th storeys was found to be more effective.***

Key Words: *Outrigger, belt truss, Seismic Analysis, time history analysis.*

1. INTRODUCTION

The development in tall buildings has evolved rapidly in recent years. Population from rural areas are migrating in large numbers to metro cities in search of jobs and day today facilities metro cities. Due to this, metro cities are getting densely populated day by day in recent years. As population is getting denser the availability of land is diminishing and cost is also increasing. Hence to overcome these problems multi-storey buildings is most prominent and efficient solution. In developing country like India and increased number of population, the multi-storey building is a suitable option. Many numbers of multi-storey buildings have come up in India.

Conventionally tall buildings are built for the function of commercial office buildings, hotels, and shopping malls, suburban. Development in tall buildings involves various compound aspects for example money matters, requirements, technology, construction regularities and so on. The challenges are more for the designer as the height of the building and building plan becomes complex. Adequate and economical tall buildings cannot be designed without taking into account the detailed forbearing of denoting factors that affect for the selection of structural system for tall buildings. Self-weight of the building, live load acting, and earthquake loads and along with wind forces are significant factors and play major role in the design. There will be adequate increase in stress, strain, deflection, lateral displacement and deformation of the building, which hence ultimately increases the cost of construction due to the size and structure of the elements used for the construction.

1.1 Outrigger structural system

Outriggers are firm horizontal structures designed to mend building overturning stiffness and strength by connecting the building core shear wall to the distant column. Outrigger system for tall buildings has been used for narrow and tall buildings to provide resistance to lateral loads. As the outrigger is connected between core and the exterior column, this reduces the over turning moment and efficiently reduces resulting lateral displacement at top floors. When the multi-storeyed structure are subjected to lateral loads, the exterior column and the outrigger battle the rotation of the central core and thus considerably reduce the lateral deflection and base moments, which would have arisen in free core building. Fig. 1 shows outrigger with core wall

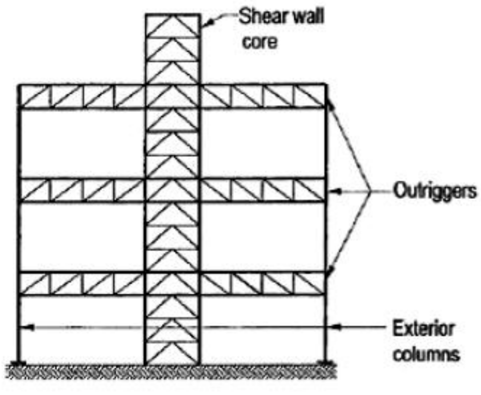

Fig -1: Outrigger with core wall.

Outrigger belt truss is modified form of braced frame and framed structural system with central shear wall. The outrigger belt truss is defined as structural arrangement consisting of central core connected to the exterior columns by relative stiff horizontal members as explained above, referred to as outrigger. The central core may be of steel braced frame or reinforced concrete shear wall, the outrigger may be concrete or steel brace. The outrigger beam or girder is minimum of floor height. The belt truss is provided at outer perimeter of building.

2. MODELLING AND ANALYSIS

For the present study a three dimensional 40 storey building with 3 bays along x direction and 3 bays in y direction with core shear wall of 7m x 8m is considered, the plan of the building is as shown in figure 2. Typical storey height is 3.5m; the size of beam is 0.45m x 0.75m, and that of column as 0.75m x0.75m. Core shear wall thickness is 0.375m which is modelled as shell thin and slab thickness considered as 0.2m, modelled as membrane. For outrigger beam the depth is taken to be height of one storey, the size of outrigger is 0.5m x 3.5m. For belt truss and outrigger bracing ISLB200 structural steel is considered. The shape of outrigger bracing and belt truss is X shaped.

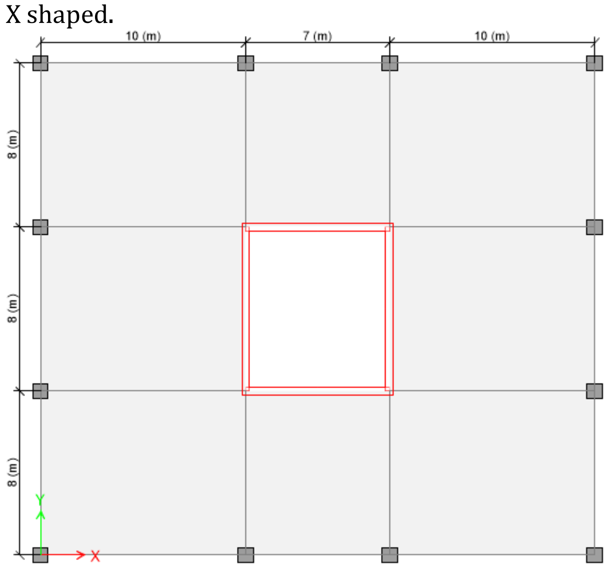

Fig -2: Plan of the building.

Two outriggers are positioned with varying the position of outriggers. Firstly one outrigger is fixed at 40th storey i.e. H_2=H, H being height of building and simultaneously varying H_1, again fixing at H_1=H/2.H_1 and H_2 are as shown in fig 3.

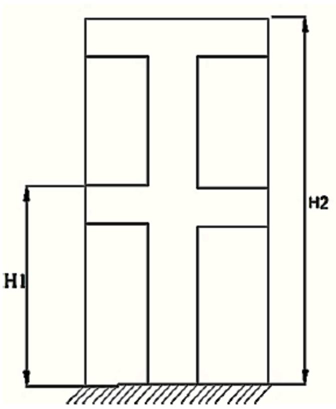

Fig -3: Relative height of outrigger.

Following models are modelled and studied:

1. Core shear wall without outrigger.

For concrete outrigger

2. Keeping H_2=H constant that is one outrigger at 40th storey is fixed and H_1 is varied, 4 different models are modelled;
   - Location of outrigger at storey 6 and 40 H_2/H_1=6.67.
   - Location of outrigger at storey 10 and 40 H_2/H_1=4.
   - Location of outrigger at storey 16 and 40 H_2/H_1=2.5.
   - Location of outrigger at storey 20 and 40 H_2/H_1=2.
3. Keeping H_1=H/2 constant that is one outrigger at 20th storey is fixed and H_2 is varied, 4 different models are modelled;
   - Location of outrigger at storey 20 and 20 H_2/H_1=1.
   - Location of outrigger at storey 26 and 20 H_2/H_1=1.3.
   - Location of outrigger at storey 30 and 20 H_2/H_1=1.5.
   - Location of outrigger at storey 36 and 20 H_2/H_1=1.8.

Similarly modelling for outrigger bracing with belt truss was carried, total of 17 models are been studied.

2.1 LOAD CONSIDERATION AND ANALYSIS

For static behaviour purpose, the dead load of building is considered and live load as 4 KN/m^2, lateral seismic load was considered confirming IS 1893(Part 1)-2002. The following parameters are been taken zone III (Z=016), soil type is medium (Type II), Importance factor (I=1.5), Response reduction factor (R=5) and the time period (T) is program calculated. Analysis is done for different arrangement of outrigger and belt truss and braced outrigger. Equivalent lateral wind load confirming IS 875(Part 3)-1987 the location selected is Hyderabad, the following parameters are obtained, the Terrain category is taken as 4, Structure class B, Basic wind speed V_b =44 m/s, Maximum wind pressure 0.08, Force coefficient 1.2, Risk coefficient(k1 factor) 1 and Topography(k3 factor) 1, for time history analysis the earthquake data of Bhuj earthquake are taken, the magnitude of earthquake was 7.6, duration of earthquake was 42 seconds and peak ground acceleration was around 0.38g..

3. RESULTS AND DISCUSSION

The following results of the 40 storey building are studied, the parameters studied include lateral displacement, storey drift and base shear, due to earthquake and wind loads. Time history analysis results include displacement and base shear for different arrangement of building.

SL. NO.	OUTRIGGER LOCATION H_2/H_1	MAXIMUM LATERAL DISPLACEMENT mm	PERCENTAGE REDUCTION %
1	WITHOUT OUTRIGGER	126.5	-
2	6.67	122.2	3.39
3	4	116.9	7.59
4	2.5	113.6	10.19
5	2	113	10.67

Table-1: Lateral displacement of the building for Earthquake load in x direction for concrete outrigger building for $H_2 = H$

SL. NO.	OUTRIGGER LOCATION H_2/H_1	MAXIMUM LATERAL DISPLACEMENT mm	PERCENTAGE REDUCTION %
1	WITHOUT OUTRIGGER	126.5	-
2	1	113.4	10.36
3	1.3	107.5	15.02
4	1.5	107.7	14.86
5	1.8	109.8	13.20

Table-2: Lateral displacement of the building for Earthquake load in x direction for concrete outrigger building for $H_1 = H/2$

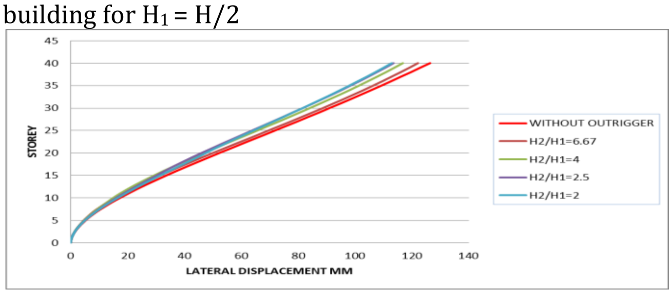

Chart-1: Lateral displacement of the building for Earthquake load in x direction for concrete outrigger building for $H_2 = H$.

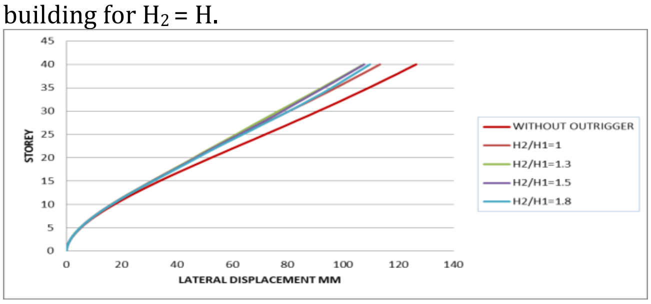

Chart-2: Lateral displacement of the building for Earthquake load in x direction for concrete outrigger building for $H_1 = H/2$

It can observed from above values and figure, the reduction in maximum lateral displacement for building with concrete outrigger beam and without outrigger is effectively reduced for H_2/H_1=1.3 that is outriggers at 20th storey and 26th storey, maximum lateral displacement for building without outrigger is 126.5mm as compared to 107.5mm for outriggers positioned for H_2/H_1=1.3 the percentage reduction was observed to be 15.02%.

SL. NO.	OUTRIGGER LOCATION H_2/H_1	MAXIMUM LATERAL DISPLACEMENT mm	PERCENTAGE REDUCTION %
1	WITHOUT OUTRIGGER	229.5	-
2	6.67	211.6	7.79
3	4	205.0	10.67
4	2.5	200.3	12.72
5	2	200.4	12.67

Table-3: Lateral displacement of the building for wind load in x direction for concrete outrigger for $H_2 = H$

SL. NO.	OUTRIGGER LOCATION H_2/H_1	MAXIMUM LATERAL DISPLACEMENT mm	PERCENTAGE REDUCTION %
1	WITHOUT OUTRIGGER	229.5	-
2	1	203.1	11.50
3	1.3	193.3	15.77
4	1.5	194.0	15.46
5	1.8	196.4	14.42

Table-4: Lateral displacement of the building for wind load in x direction for concrete outrigger for $H_1 = H/2$

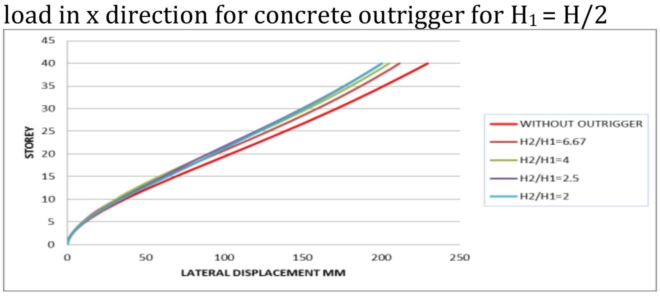

Chart -3: Lateral displacement of the building for wind load in x direction for concrete outrigger for $H_2 = H$.

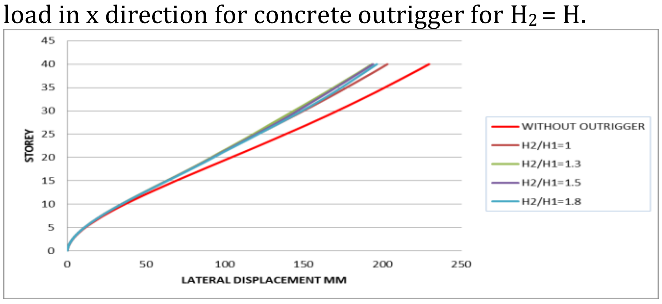

Chart-4: Lateral displacement of the building for wind load in x direction for concrete outrigger for $H_1 = H/2$

It can be observed from above values and charts that the reduction in maximum lateral displacement due to wind load in x direction for outriggers positioned at H_2/H_1=1.3 the percentage reduction was observed to be 15.77%

Sl. No.	OUTRIGGER LOCATION H_2/H_1	MAX. STOREY DRIFT	STOREY	% REDUCED
1	WITHOUT OUTRIGGER	0.00112	24	-
2	6.67	0.00110	24	2.48
3	4	0.00109	24	3.19
4	2.5	0.00107	24	4.69
5	2	0.00106	24	6.02

Table- 5: Maximum storey drift for outrigger bracing and belt truss and without outrigger for $H_2 = H$

SL. NO.	OUTRIGGER LOCATION H_2/H_1	MAX. STOREY DRIFT	STOREY	% REDUCED
1	WITHOUT OUTRIGGER	0.00112	24	-
2	1	0.00107	27	4.69
3	1.3	0.00102	24	9.21
4	1.5	0.00104	24	7.71
5	1.8	0.00105	24	6.47

Table- 6: Maximum storey drift for outrigger bracing and belt truss and without outrigger for $H_1 = H/2$.

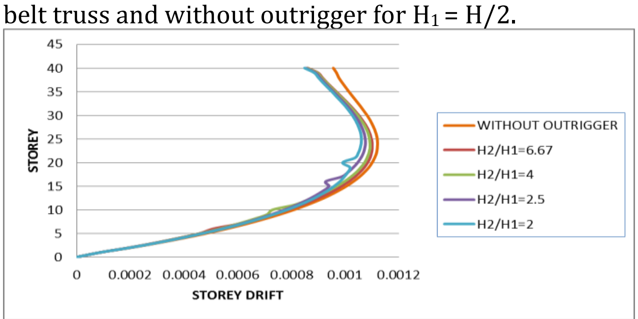

Chart- 5: Maximum storey drift for outrigger bracing and belt truss and without outrigger for $H_2 = H$

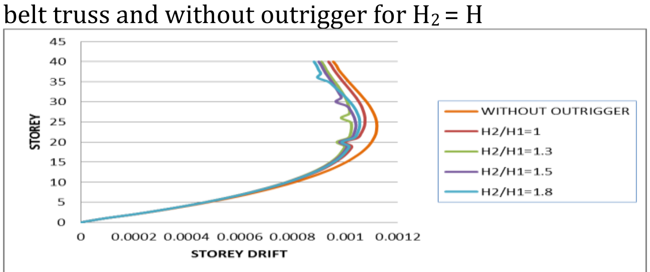

Chart- 6: Maximum storey drift for outrigger bracing and belt truss and without outrigger for $H_1 = H/2$.

The results for outrigger bracing and belt truss and without outrigger the reduction in maximum storey drift is 9.21% for position of outrigger at H_2/H_1=1.

SL. NO.	NUMBER OF OUTRIGGER	WEIGHT OF BUILDING IN KN	BASE SHEAR IN KN
1	WITHOUT OUTRIGGER	258898.2	2112.608
2	TWO CONCRETE OUTRIGGERS	263769.7	2152.361
3	ONE CONCRETE OUTRIGGER	263247.4	2148.099
4	TWO BRACED OUTRIGGERS	259042.7	2113.788
5	ONE BRACED OUTRIGGER	258970.4	2113.198

Table 7: Base shear values for building without outrigger and different numbers of outriggers.

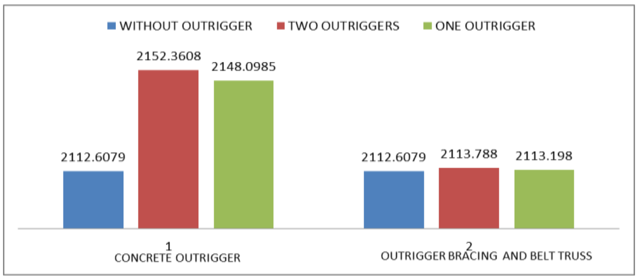

Chart- 7: Variation of base shear values for two outriggers, one outrigger and without outrigger.

SL. NO.	LOCATION H_2/H_1	MAX. DISP.	TIME IN SEC	%AGE VARIATION
1	WITHOUT	0.0147	58	-
2	6.67	0.0146	58	0.72
3	4	0.0146	58	1.062
4	2.5	0.0145	58	1.46
5	2	0.0144	58	2.53

Table 8: Displacement due to time history analysis for H_2=H.

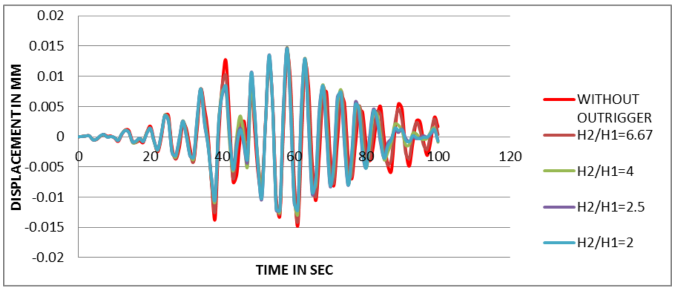

Chart- 8: Variation of Displacement for H_2=H.

SL. NO.	LOCATION H_2/H_1	MAX. DISP.	TIME IN SEC	%AGE VARIATION
1	WITHOUT	0.01478	58	-
2	1	0.01443	58	2.41
3	1.3	0.01438	58	2.75
4	1.5	0.01442	58	2.48
5	1.8	0.01441	58	2.55

Table 9: Displacement due to time history analysis for H_2=H/2.

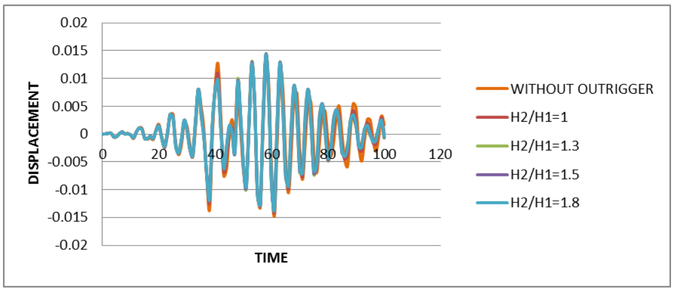

Chart- 8: Variation of Displacement for H_2=H/2.

4. CONCLUSIONS

- The outrigger structural system for tall building substantially increases stiffness and stability against lateral loads acting such as earthquake and wind loads. When the criterion considered for lateral displacement there is considerable reduction of about 15% in lateral displacement, when outriggers are provided at 20th and 26th stories.
- The lateral displacement for buildings with outrigger bracing with belt truss due to earthquake and wind loads in both the directions is reduced. Outrigger bracing with belt truss gives significant reduction of 6.4% in displacement when they are placed at 20th and 26th stories. There was around 35% reduction in percentage for reduction in maximum storey drift when compared with concrete outrigger and outrigger bracing with belt truss for same arrangements in positioning.
- For displacement due to the dynamic time history analysis, it was seen that building having outriggers at 20th and at 26th storeys will have good resistance to the displacement. There is reduction in displacement of about 3% when compared with building without outrigger. Outrigger bracing with belt truss is more suitable as weight of building gets reduced, economy in construction can be achieved and aesthetic of the building is accomplished.

ACKNOWLEDGEMENT

I would like to thank my guide, head of department, principal, friends, family and all others who have helped me in the completion of this thesis.

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