DYNAMIC ANALYSIS USING OUTRIGGER AND BELT TRUSS SYSTEM

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Abstract : The outrigger and belt truss system are one of the lateral loads resisting system in which the external columns are tied to the central core wall with very stiff outriggers and belt truss at one or more levels. The belt truss tied the peripheral column of building while the outriggers engage them with main or central shear wall. The aim of this method is to reduce obstructed space compared to the conventional method. The floor space is usually free of columns and is between the core and the external columns, thus increasing the functional efficiency of the building. Exterior columns restrained the core wall from free rotation through outrigger arms. Outrigger and belt trusses connect planar vertical trusses and exterior frame columns. Outrigger system can lead to very efficient use of structural materials by mobilizing the axial strength and stiffness of exterior columns. In this paper we are going to study the effect of Outrigger and belt truss system for dynamic (Response Spectrum) analysis under different seismic zones using software package viz., CSIETABS over the effect of shear wall in case of multi-rise structure. In order to determine optimum location, deflection and response by using shear wall and outrigger belt truss system to avoid effect of overturning movement.

***IndexTerms* - Outriggers, Belt-truss, shear wall, Response spectrum, CSIETABS.**

I. INTRODUCTION

The outrigger and belt truss system is one of the lateral loads resisting system in which the external columns are tied to the central core wall with very stiff outriggers and belt truss at one or more levels. The belt truss tied the peripheral column of building while the outriggers engage them with main or central shear wall. The aim of this method is to reduce obstructed space compared to the conventional method. The floor space is usually free of columns and is between the core and the external columns, thus increasing the functional efficiency of the building. Exterior columns restrained the core wall from free rotation through outrigger arms. Outrigger and belt trusses connect planar vertical trusses and exterior frame columns. Outrigger system can lead to very efficient use of structural materials by mobilizing the axial strength and stiffness of exterior columns.

II. OUTRIGGER SYSTEM:

The explanation of building outriggers behavior is simple because out riggers act as stiff arms engaging outer columns, when a central core tries to tilt, its rotation are the outrigger level induces a tension-compression couple in the outer column acting opposition to the movement the result is a type of restoring moment acting on the core at that level. Analysis and design of complete core and outrigger system is not that simple, distribution of forces between the core and the outrigger system depends on the relative stiffness of each element. It is certain that bringing parameter structural elements together with the core as one lateral load system will reduce core overturning moment, but not core horizontal shear forces. Although 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. Innovative structural schemes are continuously being sought in the field. Structural Design of High-Rise Structures with the intention of limiting the Drift due to Lateral Loads to acceptable limits without paying a high premium in steel tonnage. The savings in steel tonnage and cost can be dramatic if certain techniques are employed to utilize the full capacities of the structural elements. Various wind bracing techniques have been developed in this regard; one such is an Outrigger System, in which the axial stiffness of the peripheral columns is invoked for increasing the resistance to overturning moments. Belt such as trusses or wall encircling the building, add further complexity. Belt can improve lateral system efficiency. A core and outrigger system are frequently selected for a lateral load resisting system of tall or slender buildings where overturning moment is large compared to shear, and where overall building flexural deformation are major contributes to lateral deflection such as story drift. In such case, outriggers reduce building drift and core wind moments. Because of the increased stiffness they provide, outrigger system are very efficient and cost-effective solutions to reduce building accelerations, which improves occupant comfort during high winds.

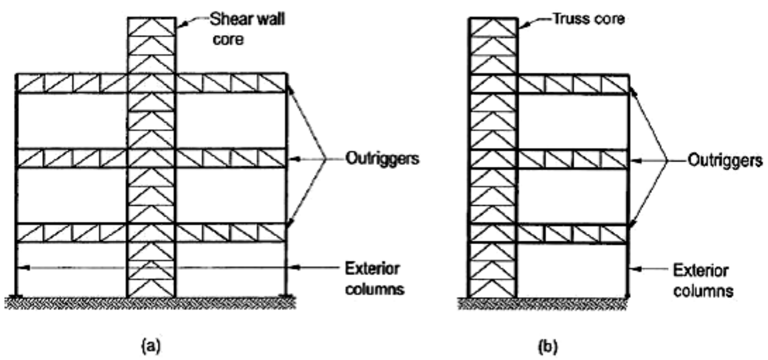

Figure 1(a). Outrigger system with a central core **(b)** Outrigger system with offset core

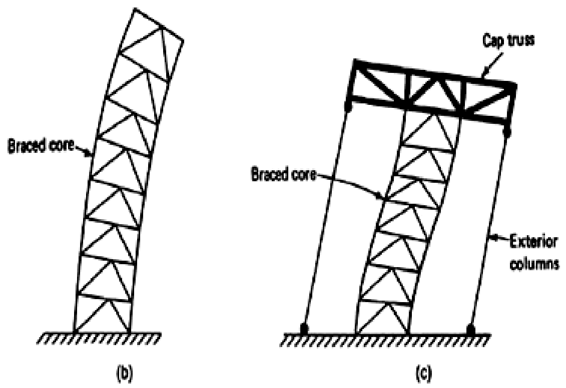

Figure 1(b) Cantilever bending of core **(c)** tie-down action of cap truss.

When Horizontal loading acts on the building, the column restrained outriggers resist the rotation of the core, causing the lateral deflections and moments in the core to be smaller than if the free-standing core alone resisted the loading. The result is to increase the effective depth of the structure when it flexes as a vertical cantilever, by inducing tension in the windward columns and Compression in the leeward columns. In addition to those columns located at the ends of the outriggers, it is usual to also mobilize other peripheral columns to assist in restraining the outriggers. This is achieved by including a deep Spandrel Girder, or a Belt Truss, around the structure at the levels of the outriggers.

III. MATERIAL AND METHODS

3.1. Response Spectrum Method (Dynamic Analysis)

3.1.1 General Codal Provisions:

- Dynamic analysis should be performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to various lateral load resisting elements, for the following buildings:
- Regular buildings- Those are greater than 40 m in height in zone IV, V and those are greater than 90 m height in zones II, III, and
- Irregular buildings-All framed buildings higher than 12 m in zone IV and V, and those are greater than 40 m in height in zone II and III.
- Dynamic analysis may be performed either by time history method or by the response spectrum method. However, in either method, the design base shear *Vb* shall be compared with a base shear calculated using a fundamental period *Ta*. When Vb is less than all the response quantities shall be multiplied by V_b /VB.
- The values of damping for a building may be taken as 2 and 5 percent of the critical, for the purpose of dynamic analysis of steel and reinforced concrete buildings, respectively.

3.2 Modes to be considered

The number of modes to be considered in the analysis should be such that the sum of the total modal masses of all modes considered is at least 90% of the total seismic mass and the missing mass correction beyond 33%. If modes with natural frequency beyond 33 Hz are to be considered, modal combination shall be carried out only for modes up to 33 Hz.

3.3 Computation of Dynamic Quantities:

Buildings with regular, or nominally irregular plan configuration may be modeled as a system of masses lumped at the floor levels with each mass having one degree of freedom, that of lateral displacement in the direction of consideration. In such a case, the following expressions shall hold in computations of various quantities.

3.4 Modal Masses: -

$$M_k = \frac{\left[\sum_{i=1}^{n} W_i \phi_{ik}\right]^2}{g \sum_{i=1}^{n} W_i (\phi_{ik})^2}$$

Where,
g = acceleration due to gravity
mode shape coefficient of floor, i in mode, k, and = ikφ
Wi = seismic weight of floor, i

3.5 Modal Participation Factor: The factor is given by,

$$P_k = \frac{\sum_{i=1}^{n} W_i \varphi_{ik}}{\sum_{i=1}^{n} W_i (\varphi_{ik})^2}$$

a) Design lateral force at each floor in each Mode: The peak lateral force at floor i in k^{th} mode is given by

$$Q_{ik} = A_k \phi_{ik} p_k W_i$$

Where, Ak = Design horizontal acceleration spectrum values using the natural period of vibration

b) Storey shear force in each mode: The storey peak shear force at ith storey in mode k is given by

$$V_{ik} = \sum_{j=i+1}^{n} Q_{ik}$$

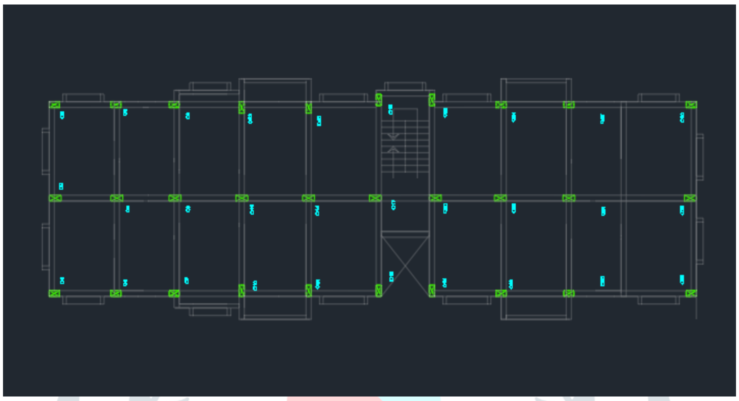

Figure 2. Plan of Multi-Rise Building (G+24)

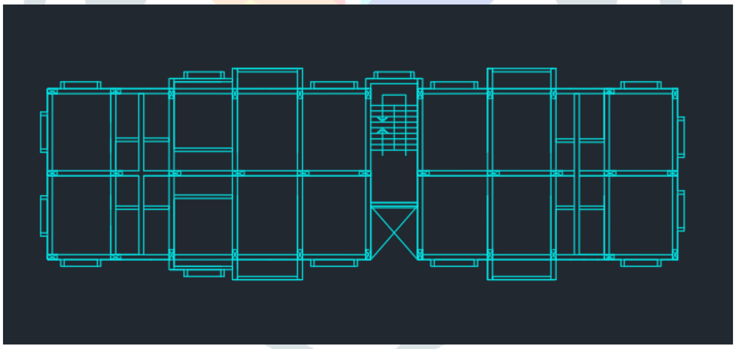

Figure 3. Column layout

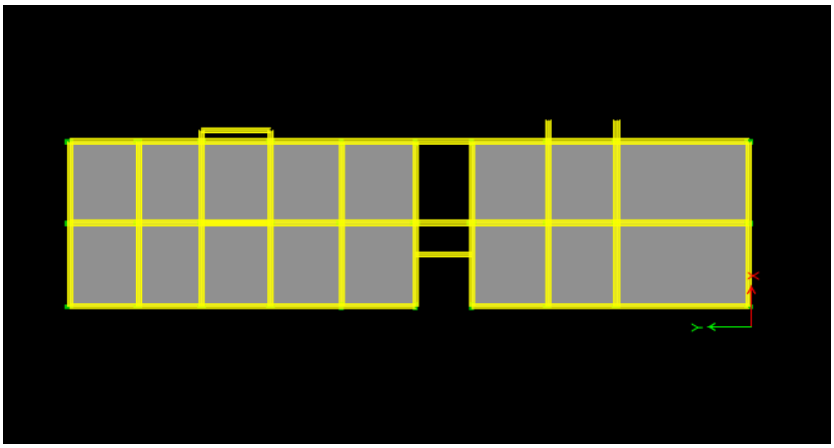

Figure 4. Plan of Multi-Rise Building (Extruded View) in ETABS

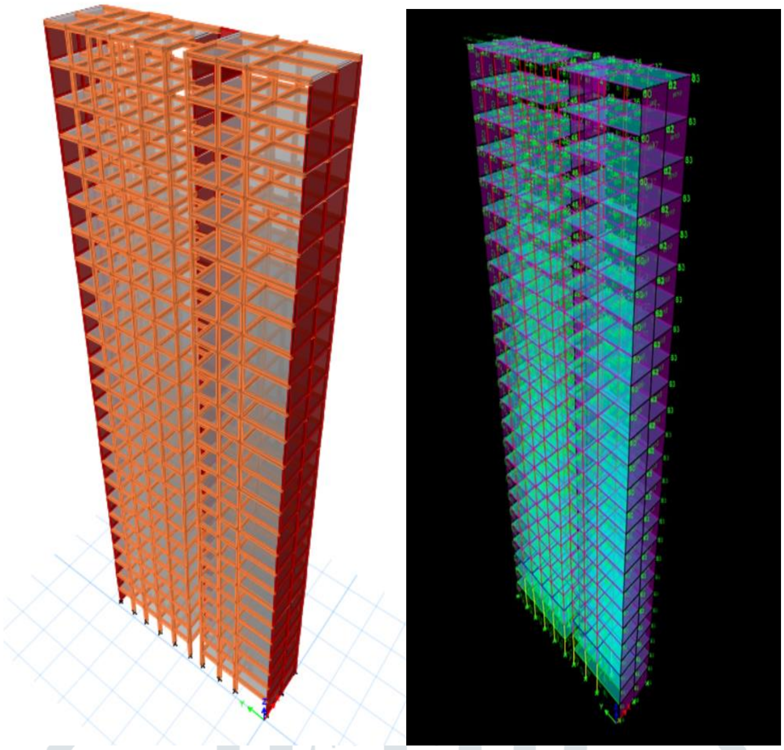

Figure 5. Model in ETABS (With Shear Wall)

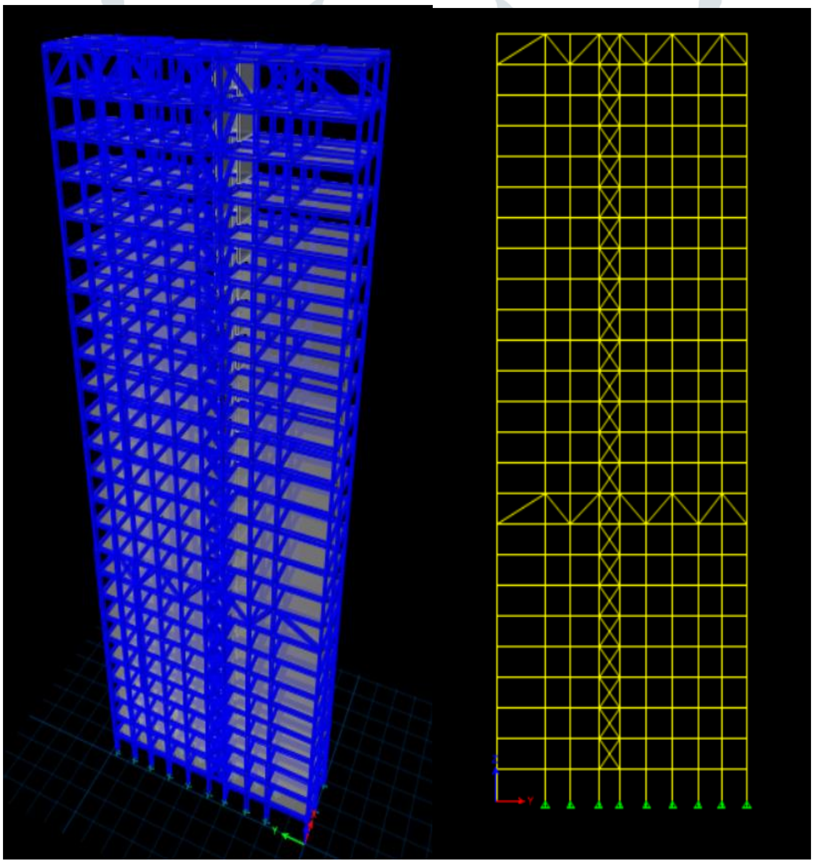

Figure 7. Model in ETABS (With Outrigger and Belt Truss

3.6 Methodology:

- Techniques for using belt trusses and basements as "virtual" outriggers in tall buildings have been proposed. Belt trusses used as virtual outriggers offer many of the benefits of the outrigger concept, while avoiding most of the problems associated with conventional outriggers. In many applications, the reduced effectiveness or efficiency of the virtual outrigger system (compared to conventional direct outriggers) will be more than compensated for by the following benefits offered by the proposed concept:
- There are no trusses in the space between the core and the building exterior.
- There are fewer constraints on the location of exterior columns. The need to locate large exterior columns where they can be directly engaged by outrigger trusses extending from the core is eliminated.
- All exterior columns (not just certain designated outrigger columns) participate in resisting overturning moment.

- The difficult connection of the outrigger trusses to the core is eliminated.
- Complications caused by differential shortening of the core and the outrigger columns are avoided.

3.6.1 Input Design Details:

Table 1. Section Properties

Sr. No.	Type of Element	Size of Element	Remark
1	Slab	150 mm	
2	Beam	230 mm X 380 mm 230 mm X 450 mm 230 mm X 530 mm	Secondary/Tertiary Beams From story 13 to story 24 From story 1 to story 12
3	Column	230 mm x 450 mm 230 mm x 530 mm 230 mm x 630 mm	From story 17 to story 24 From story 9 to story 16 From story 1 to story 8
4	Outriggers	230 mm x 530 mm	1. Conventional Outriggers 2. Belt Truss as Virtual Outrigger

Table 2. Loading Details

Sr. No.	Type of Loading	Intensity of Loading	Remark
1	**Dead Load** Self-Weight of member Member Load (Super Dead Load) Floor Finish Load Water Proofing Load	(γ) X V Calculate by Formula [(H-D) x tw x (γ)] 1 KN/m2 1 KN/m2	V = Volume of Section H = Height of Masonry Wall D = Overall Depth of Beam tw = Thickness of Masonry wall Exterior (230 mm) Interior (115 mm) γ = Density of Masonry
2	**Live Load**	3 KN/m2	
3	**Wind Load**	Vb = 39 m/s	Location = Nashik Vb = Basic Wind Speed As per IS 875:2015
4	**Seismic Load** Seismic Zone Response Reduction Factor (R) Importance Factor (I)	Zone II to zone V 5 1	Location = Nashik

IV. RESULTS AND ANALYSIS

Table no 3. Base Reactions

Sr. No.	With Outriggers and Belt truss				With Shear Wall			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
1	136.05	217.6	326.52	136.05	146.02	233.64	350.46	525.68
2	136.05	217.68	326.52	135.05	146.02	233.64	350.46	525.68
3	81.86	128.15	194.45	81.86	169.39	271.02	406.54	609.80
4	81.84	128.21	194.45	81.84	169.39	271.02	406.54	609.80
5	109.18	216.93	325.39	111.89	106.33	106.33	106.35	106.3
6	135.3	216.82	326.0	108.99	201.00	201.00	201.00	201

Table no 4. Displacement Results

Story. No.	With Shear Wall				With Outriggers and Belt truss			
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 1**	**Model 2**	**Model 3**	**Model 4**
24	1.594	2.551	3.826	1.594	0.148	0.237	0.355	0.148
23	6.06	2.57	3.855	1.606	0.131	0.209	0.314	0.131
22	1. 1664	2.663	3.994	1.664	0.148	0.237	0.355	0.148
21	1.764	2.822	4.234	1.764	0.158	0.253	0.379	0.158
20	1.857	2.971	4.456	1.857	0.181	0.289	0.434	0.181
19	1.942	3.107	4.66	1.942	0.199	0.318	0.478	0.199
18	2.017	3.227	4.841	2.017	0.214	0.342	0.513	0.214
17	2.082	3.331	4.996	2.082	0.226	0.361	0.541	0.226
16	2.135	3.415	5.123	2.135	0.245	0.392	0.587	0.245
15	2.175	3.479	5.219	2.175	0.265	0.423	0.635	0.265
14	2.201	3.522	5.283	2.201	0.281	0.45	0.675	0.281
13	2.214	3.542	5.314	2.214	0.296	0.474	0.711	0.296
12	2.212	3.54	5.309	2.212	0.309	0.495	0.742	0.309
11	2.196	3.513	5.27	2.196	0.322	0.515	0.772	0.322
10	2.163	3.462	5.192	2.163	0.334	0.535	0.802	0.334
9	2.115	3.384	5.076	2.115	0.347	0.556	0.834	0.347
8	2.049	3.278	4.917	2.049	0.362	0.58	0.87	0.362
7	2.004	3.206	4.81	2.004	0.38	0.608	0.912	0.38
6	1.966	3.145	4.718	1.966	0.401	0.641	0.962	0.401
5	1.921	3.074	4.611	1.921	0.425	0.681	1.021	0.425
4	1.866	2.985	4.477	1.866	0.452	0.724	1.086	0.452
3	1.717	2.746	4.12	1.717	0.452	0.723	1.084	0.452
2	1.34	2.144	3.216	1.34	0.389	0.623	0.935	0.389
1	1.174	1.879	2.819	1.174	0.376	0.601	0.901	0.376

V. CONCLUSIONS

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 which predominantly tends to reduce the impact of lateral force effect on multi rise structure.

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