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Comparative analysis of Wall Belt Systems, Shear Core Outrigger Systems and Truss Belt Systems on Residential Apartment

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Abstract: The outrigger structural system is one of the horizontal load resisting systems. In this system the belt truss ties all the external columns on the periphery of the structure and the outriggers connect these belt trusses to the central core of the structure thus restraining the exterior columns from rotation. The shear wall was implemented to oppose lateral loads. To complete these characteristic the Outrigger & wall belt system used in the structure. In this project a G+10 Storey structure has analysed using seven different cases named as RA1 to RA7-OTB. 1 to 7 indicates single outrigger system, shear core outrigger system truss belt support system with optimized trusses, at various locations under seismic zone III. The built up area used for various case as 315 sq. m. After performing result analysis, the comparative analysis of all the cases shows that the most efficient case for the above study is Case RA4. Here for efficiency of the project, two types of optimized truss belt support which has performed well and observed as most optimized and correspondingly minimum in all the cases.
Keywords: Truss wall belt support, core wall belt support, outrigger, wall belt, CSI-ETABS, multi-storey

I. INTRODUCTION

Lateral stiffness governs the structural design of tall buildings, and, consequently, structural systems in tall buildings have evolved to produce higher lateral stiffness more efficiently. Among various structural systems developed for tall buildings, perimeter tube type structures with diagonals, such as braced tubes and diagrams, are very efficient in general. This is because they carry lateral loads by their primary structural members' axial actions and the structural depth of the systems is maximized by placing the structural members on the building perimeter. Another very efficient structural system widely used today is the outrigger system. Perimeter mega-columns, connected to shear wall type core structure through outrigger trusses, resist overturning moments very efficiently in outrigger structures. Outriggers are rigid horizontal structures designed to improve strength and building overturning stiffness by connecting the core or spine to distant columns. An Outrigger system functions by tying together two structural systems- typically a perimeter system and a core system to yield the whole structural behaviour that is much better than those of component system. The benefits of an outrigger system lie in the fact that the overturning moments causing building deformations get reduced resulting, on the other hand, greater efficiency is achieved in resisting forces.

People had always fascinated for height and throughout our history, we have constantly sought to metaphorically reach for the stars. From the ancient pyramids to today's modern skyscraper, a civilization's power and wealth has been repeatedly expressed through spectacular and monumental structures. Today, the symbol of economic power and leadership is the skyscraper. There has been a demonstrated competitiveness that exists in mankind to proclaim to have the tallest building in the world. This undying quest for height has laid out incredible opportunities for the building profession. From the early moment frames to today's ultra-efficient mega-braced structures, the structural engineering profession has come a long way. The recent development of structural analysis and design software coupled with advances in the finite element method has allowed the creation of many structural and architecturally innovative forms. The design of skyscrapers is usually governed by the lateral loads imposed on the structure. As buildings have gotten taller and narrower, the structural engineer has been increasingly challenged to meet the imposed drift requirements while minimizing the architectural impact of the structure. In response to this challenge, the profession has proposed a multitude of lateral schemes that are now expressed in tall buildings across the globe. These towers are self-supporting structures and categorized as three-legged and four-legged space trussed structures. The self-supporting towers are normally square or triangular in plan and are supported on ground or on buildings. They act as cantilever trusses and are designed to carry wind and seismic loads. These towers even though demand more steel but cover less base area, due to which they are suitable in many situations.

II. OBJECTIVES OF THE PROJECT

Following heads shows the point of comparison of result parameters between various models during earthquake forces for building and its various cases. They are as follows:-

1) Determination of effective case among general, shear core outrigger and belt wall supported system as well as shear core outrigger and truss supported system.
2) To determine Base shear response when seismic forces are applied in X, Y and Z direction to the structure.
3) To examine column Axial Forces for total seven cases with efficient case to determine minimum axial force.
4) To find member Shear Forces and Bending Moment values with efficient case of all 7 cases.
5) To determine and compare member Torsion values.
6) To show whether truss is better or shear wall at an optimum outrigger height of structure.
7) To analyse the maximum nodal displacement case in X direction with most efficient case that provides more stability.
8) To obtain the maximum nodal displacement values in Z direction with most efficient case among all cases.
9) To compare the story drift case in X direction with most efficient case that provides more stability.
10) To evaluate story drift values in Z direction with most efficient case among all cases.
11) To study and compare the time period and mass participation factor of the structure
12) To demonstrate the efficiency of truss belt or wall belt at optimum height.

III.METHODOLOGY, ANALYSIS AND MODELLING

Table 1: Details of various building model cases

Case	Description
RA1	Residential Apartment on plane ground
RA2	Residential Apartment with shear core
RA3	Residential Apartment with shear core and wall outriggers
RA4	Residential Apartment with Shear core outrigger and wall belt supported system
RA5	Residential Apartment with Shear core outrigger and truss belt supported system
RA6-OTA	Residential Apartment with Shear core outrigger and optimized truss belt supported system A
RA7-OTB	Residential Apartment with Shear core outrigger and optimized truss belt supported system B

Table 2: Data taken for analysis of structure

Constraint	Assumed data for all buildings
Soil type	Medium Soil
Built up area of apartment	315 sq. m
Floors configuration	G + 10 (Residential Apartment)
Depth of foundation	3 m
Floor to floor height	GF-3.66 m, All floors-3.66 m each
Beam sizes	0.60m x 0.35m
Column sizes	0.50m x 0.50m
Slab thickness	130 mm (0.130 m)
Shear wall and Outrigger thickness	230 mm (0.230 m)
Truss belt concrete sections	0.23m x 0.23m
Material properties	M 30 Concrete and Fe 500 grade steel

Table 3: Seismic parameters on the structure

Importance factor I	1.2
Fundamental natural period (Ta) for X direction	1.006 seconds
Fundamental natural period (Ta) for Z direction	0.850 seconds
Response reduction factor R	5
Zone factor	0.16
Zone	III
Soil type	Medium soil
Damping Ratio	5% (0.05)

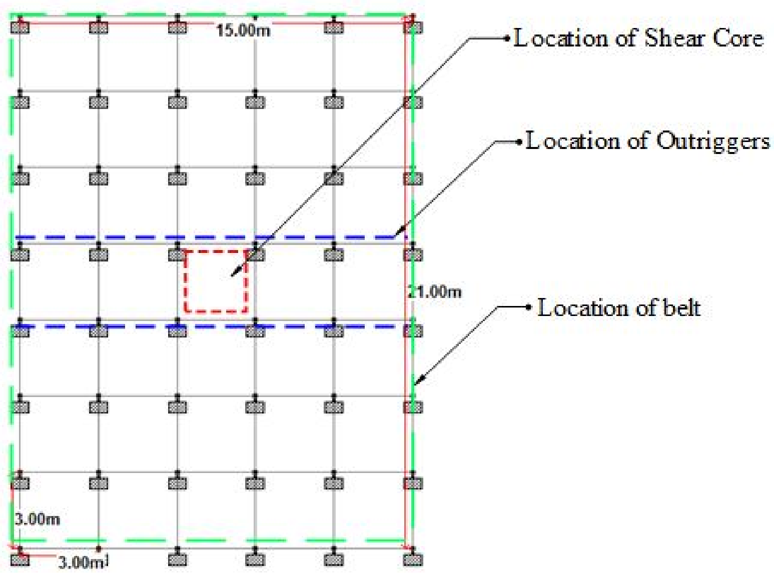

Fig. 1: Typical Floor Plan

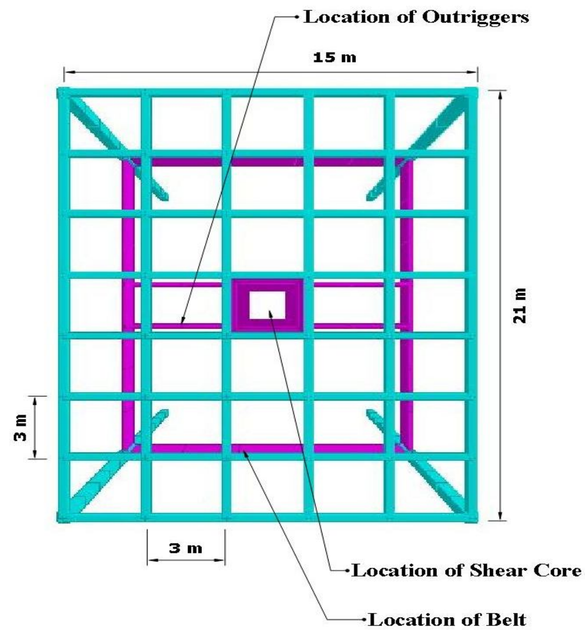

Fig. 2: Actual 3D frame plan after rendering

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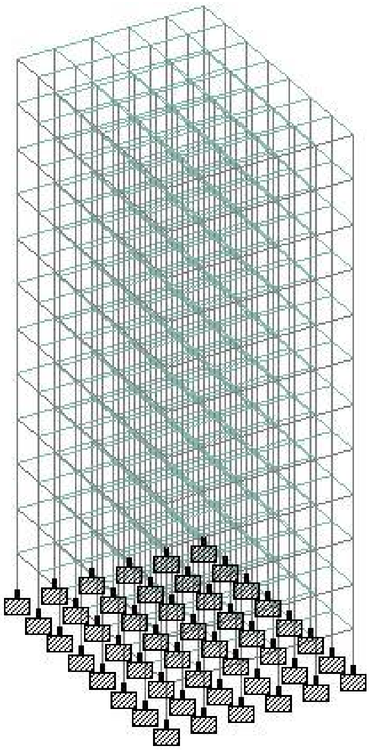

Fig. 3: 3D view of case (RA1) Residential Apartment on plane ground

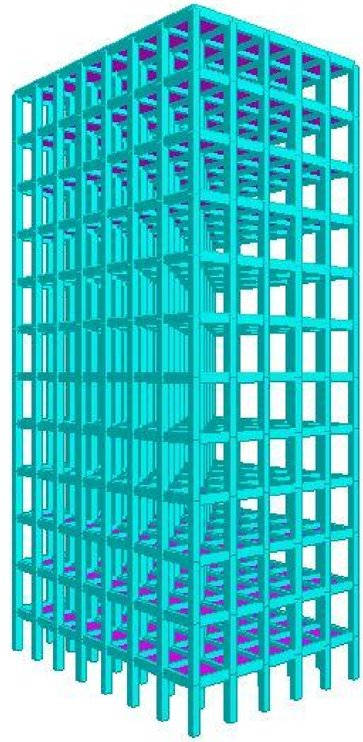

Fig. 4: Actual 3D view of case (RA1) Residential Apartment on plane ground after rendering

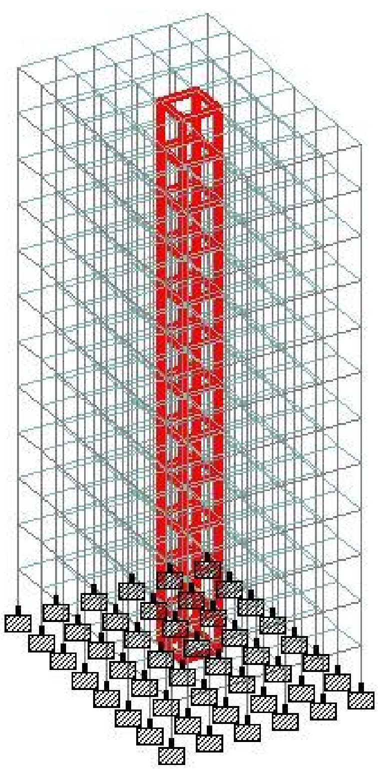

Fig. 5: 3D view of case (RA2) Residential Apartment with shear core

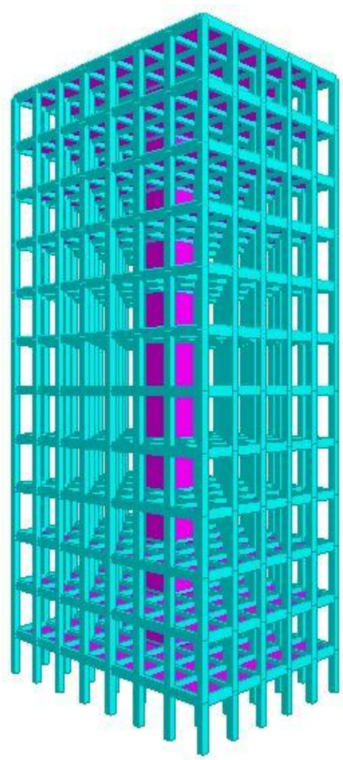

Fig. 6: Actual 3D view of case (RA2) Residential Apartment with shear core after rendering

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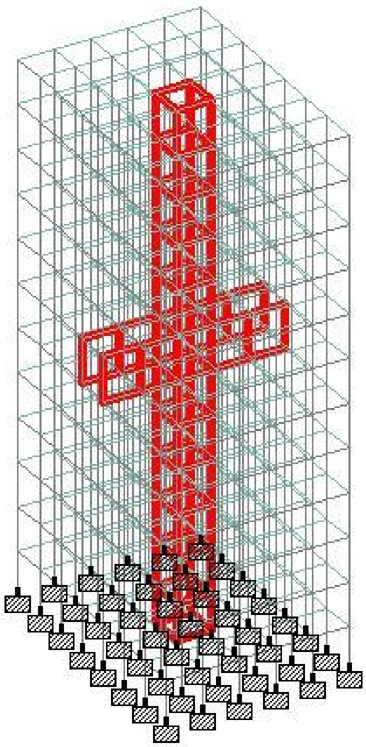

Fig. 7: 3D view of case (RA3) Residential Apartment with shear core and wall outriggers

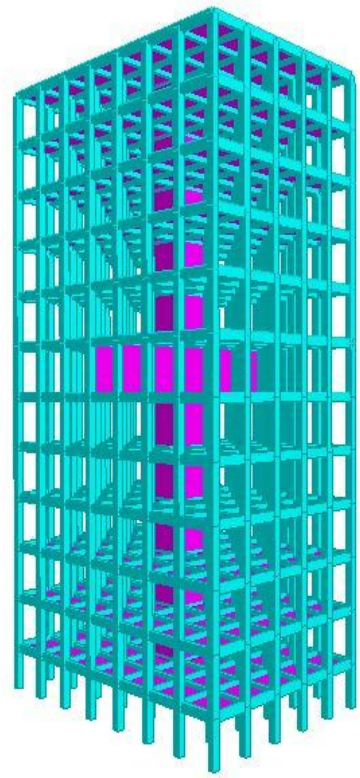

Fig. 8: Actual 3D view of case (RA3) Residential Apartment with shear core and wall outriggers after rendering

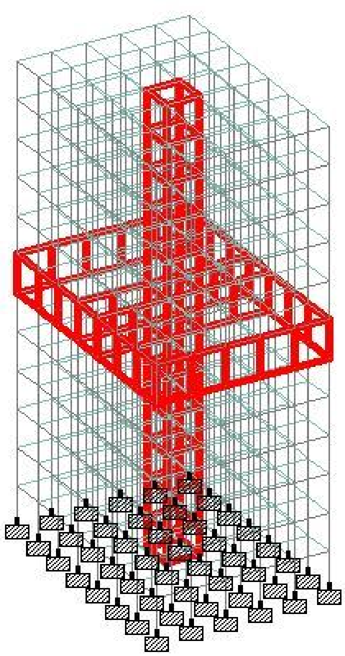

Fig. 9: 3D view of case (RA4) Residential Apartment with Shear core outrigger and wall belt supported system

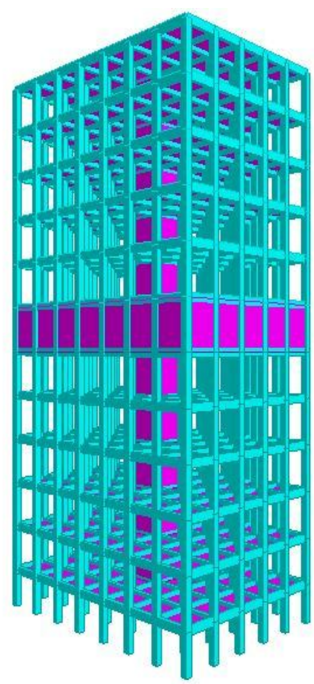

Fig. 10: Actual 3D view of case (RA4) Residential Apartment with Shear core outrigger and wall belt supported system after rendering

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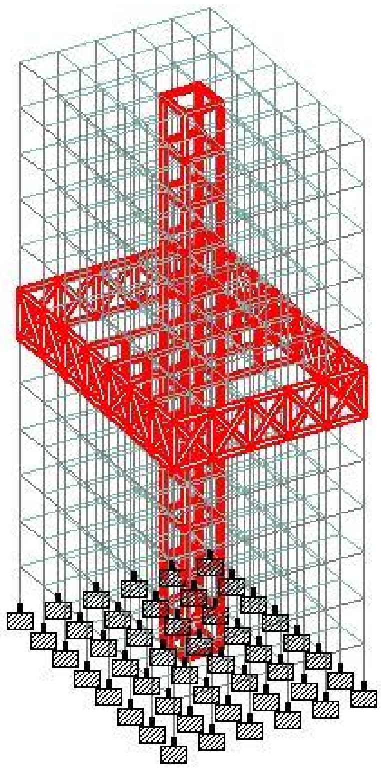

Fig. 11: 3D view of case (RA5) Residential Apartment with Shear core outrigger and truss belt supported system

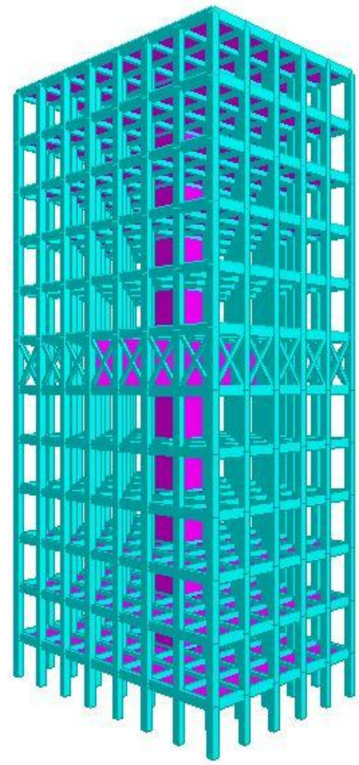

Fig. 12: Actual 3D view of case (RA5) Residential Apartment with Shear core outrigger and truss belt supported system after rendering

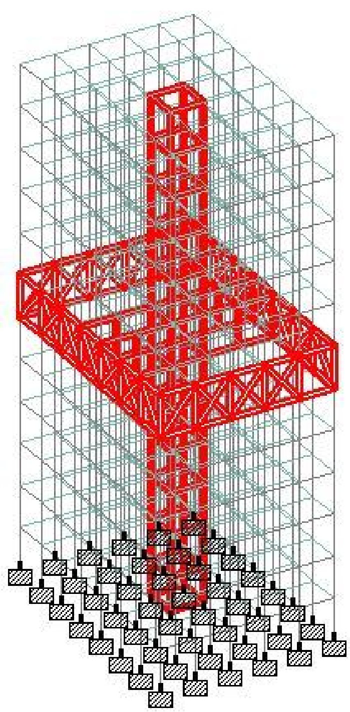

Fig. 13: 3D view of case (RA6-OTA) Residential Apartment with Shear core outrigger and optimized truss belt supported system A

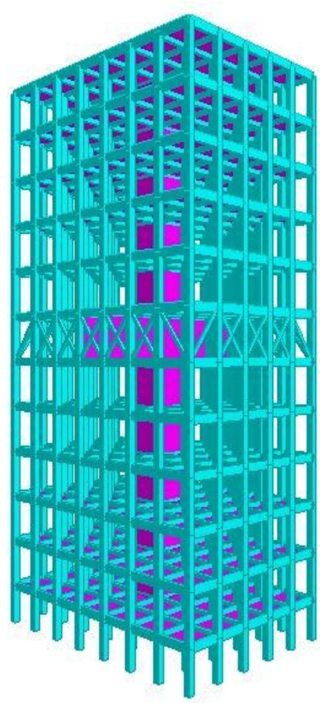

Fig. 14: Actual 3D view of case (RA6-OTA) Residential Apartment with Shear core outrigger and optimized truss belt supported system A after rendering

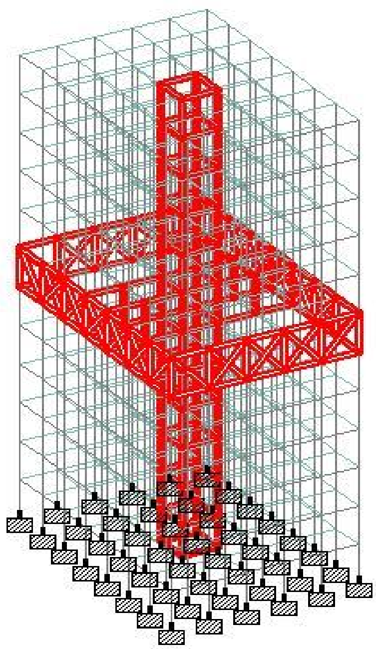

Fig. 15: 3D view of case (RA7-OTB) Residential Apartment with Shear core outrigger and optimized truss belt supported system B

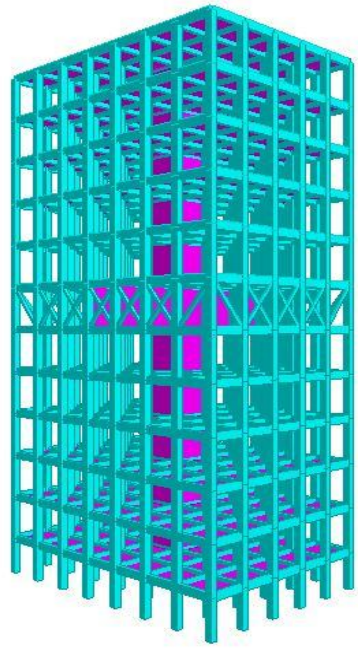

Fig. 16: Actual 3D view of case (RA7-OTB) Residential Apartment with Shear core outrigger and optimized truss belt supported system B

IV. RESULTS ANALYSIS

As per the objectives, Comparative analysis of Wall Belt Systems, Shear Core Outrigger Systems and Truss Belt Systems on Residential Apartment has been done using software approach. In this research or models of high rise structure consist of structure made up of G+10 Storey building in Zone III. For determination of Comparative analysis using software approach, different loads applied to the structures and the results of each case has compared with each other as discussion of the research project. The result parameters obtained by the application of loads and their combinations on various cases as per Indian Standard 1893: 2016 code of practice. Result of each parameter has discussed with its representation in graphical form below:-

Displacement: It is defined as the maximum displacement or distance moved by a point on a vibrating body or wave measured from its equilibrium position. Figure shows the maximum value of displacement in G+10 Storey Building for different cases.

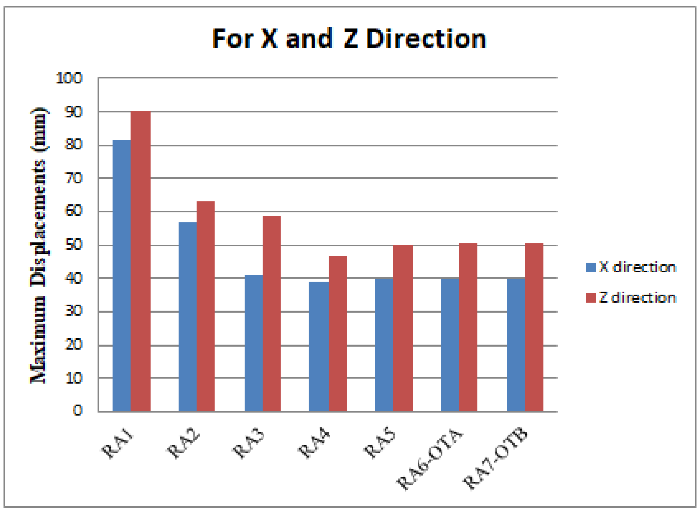

Fig. 17: Graphical Representation of Maximum Displacement in X and Z directions for all cases direction

Story Drift: Story Drift is an estimate of the maximum expected inter-adjacent Storey displacement with respect to each other. Figure below shows the maximum value of drift in G+10 Storey Building for different cases.

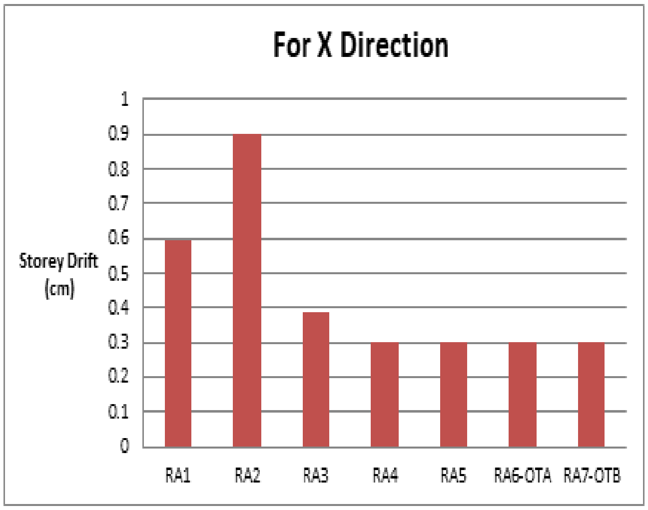

Fig. 18: Graphical Representation of Storey Drift in X direction for all cases

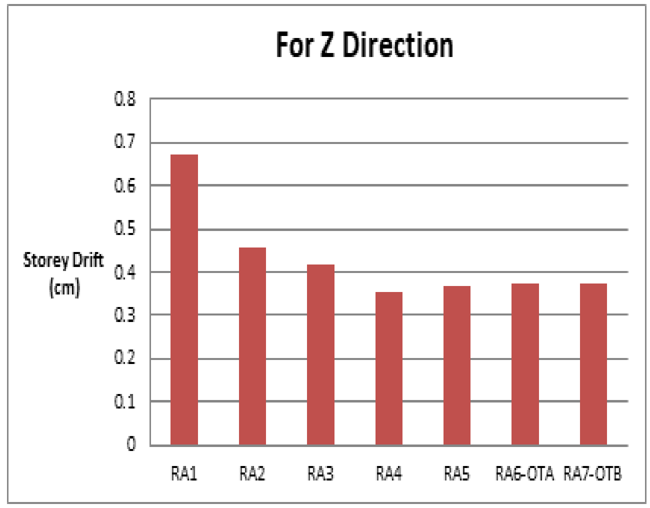

Fig. 19: Graphical Representation of Storey Drift in Z direction for all cases

Base Shear: Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity. Figure shows the maximum value of base shear in G+10 Storey Building for different cases.

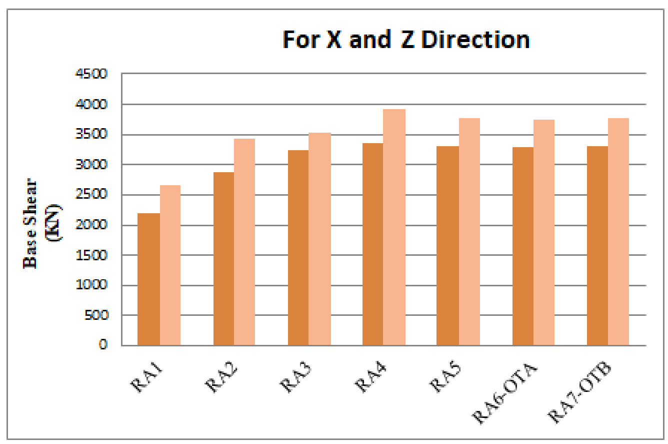

Fig. 20: Graphical Representation of Base Shear in X and Z directions for all cases

Axial Forces: If the load on a column is applied and the forces transfers from through the center of the column axis of its cross section, it is called an Axial Load. Figure shows the maximum value of Axial Forces in G+10 Storey Building for different cases.

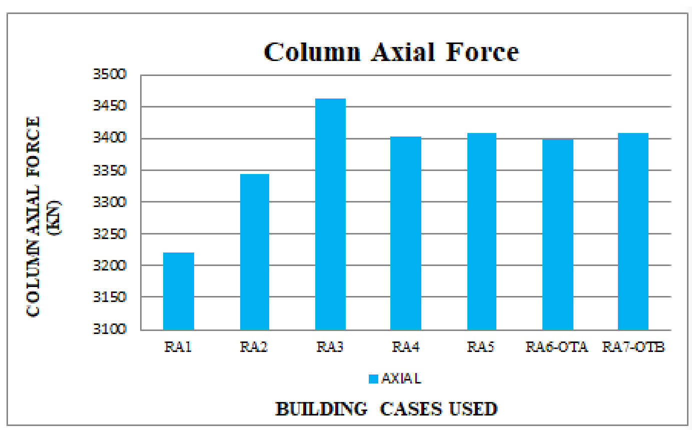

Fig. 21: Graphical Representation of Maximum Axial Forces in Column for all cases

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Shear Forces in Column: Shearing forces are unaligned forces pushing one part of a body in one specific direction, and another part of the body in the opposite direction. Figure shows the maximum value of Shear Forces in column in G+10 Storey Building for different cases.

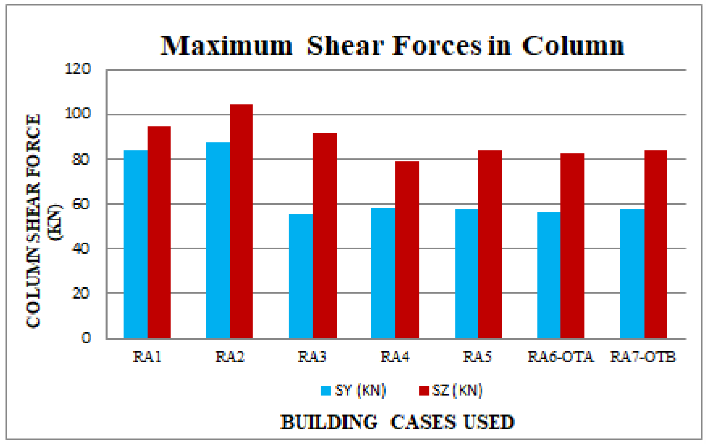

Fig. 22: Graphical Representation of Maximum Shear Force in Column for all cases

Bending Moment in Column: A bending moment is the reaction induced in a structural element; when an external force or moment is applied to the element causing the element bend. Figure shows the maximum value of Bending Moment in column in G+10 Storey Building for different cases.

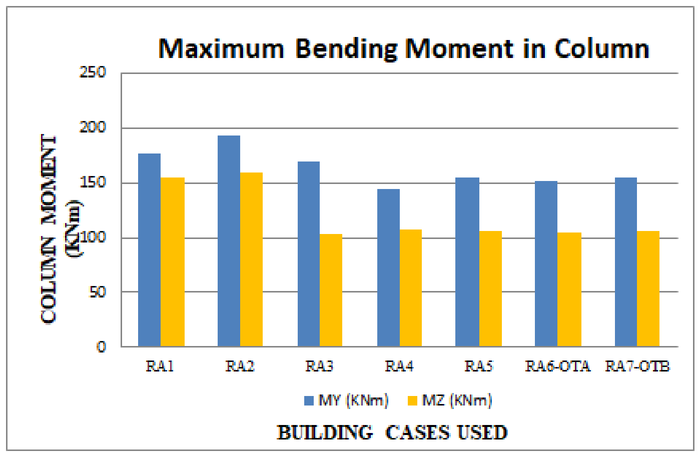

Fig. 23: Graphical Representation of Maximum Bending Moment in Column for all cases

Shear Force in Beam: Shearing forces are unaligned forces pushing one part of a body in one specific direction, and another part of the body in the opposite direction. Figure shows the maximum value of Shear Forces in beams in G+10 Storey Building for different cases.

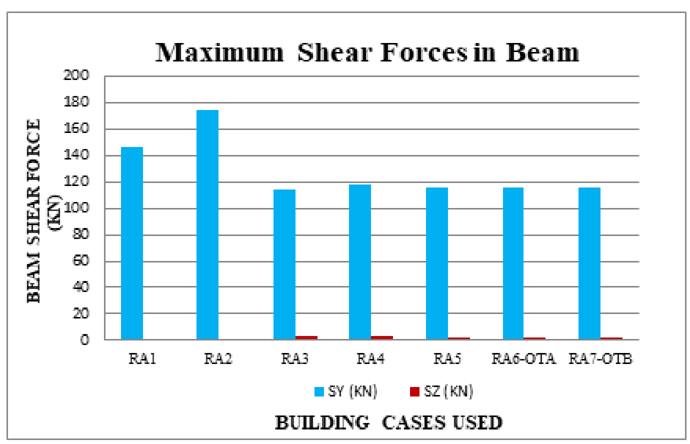

Fig. 24: Graphical Representation of Maximum Shear Force in Beam for all cases

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Bending Moment in Beam: A bending moment is the reaction induced in a structural element; when an external force or moment is applied to the element causing the element bend. Figure shows the maximum value of Bending Moment in beams in G+10 Storey Building for different cases.

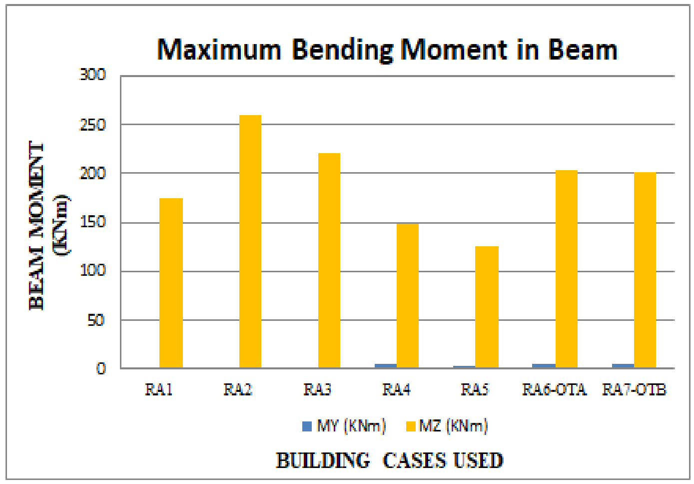

Fig. 25: Graphical Representation of Maximum Bending Moment in Beam for all cases

Torsional Moments in Beam & Column: Torsion, also known as torque, describes a moment that is acting upon an object around the same axis in which the object lies. Figure below shows the maximum value of Torsional Moment in beams and columns in G+10 Storey Building for different cases.

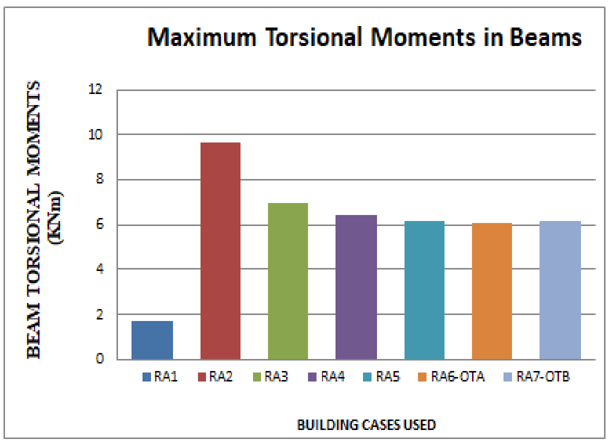

Fig. 26: Graphical Representation of Maximum Torsional Moments in Beam for all cases

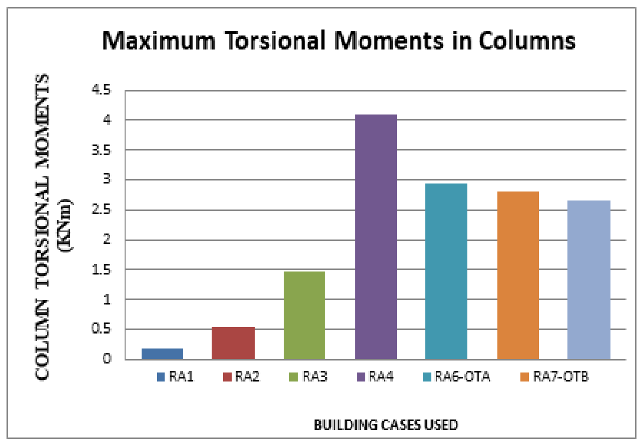

Fig. 27: Graphical Representation of Maximum Torsional Moments in Columns for all cases

Bending Moment in Beam: A bending moment is the reaction induced in a structural element; when an external force or moment is applied to the element causing the element bend. Figure shows the maximum value of Bending Moment in beams in G+10 Storey Building for different cases.

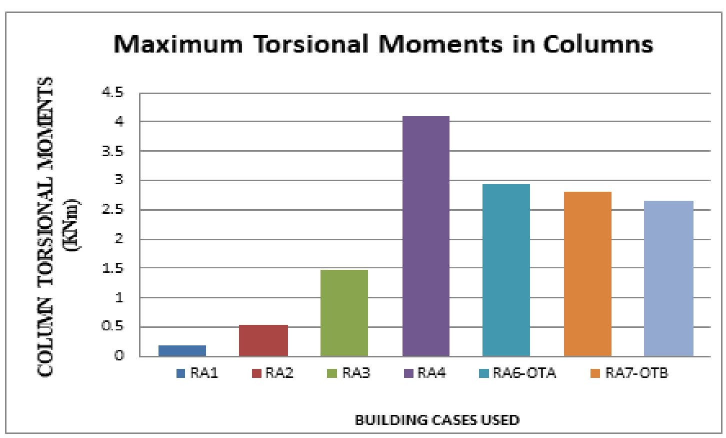

Fig. 28: Graphical Representation of Maximum Bending Moment in Beam for all cases

V. CONCLUSIONS

As we analysis about seven diverse cases of Wall Belt Systems, Shear Core Outrigger Systems and Truss Belt Systems on Residential Apartment in Staad Pro. In term of mentioned cases following conclusion are find out from this comparative analysis.

1) On comparing it has been concluded that the maximum displacement obtained in X and Z direction seems efficient in RA4.
2) Comparing the Story drift for all location in X direction, Case RA5 and RA7-OTB is observed as most efficient. In this case, the values first increases, then downward trend has observed.
3) Comparing the Story drift for all location in Z direction, Case RA4 is observed as most efficient. In this case, downward trend has observed from first to last case.
4) As per comparative results of Base Shear, other than case RA1, Case RA2 value in both X direction and Z directions observed is efficient among all cases. When additional member increases, the Base Shear values also increases.
5) As per comparative results in axial force, the values first increases up to Case RA3, then values became constant. Other than case RA1, case RA2 is very effective than other cases.
6) Comparing the column shear force for all cases, RA3 is the optimum than other cases.
7) As per comparative results in column bending moment, Case RA4 is respectively efficient for Y and Z axis and is very effective than other cases. In this case, the values first increases, then downward trend has observed.
8) Comparing the beam shear force in Y and Z axis Case RA3 is the optimum than other cases. In this case, the values first increases, then downward trend has observed.
9) As per comparative results of bending moment in beam in Y and Z axis, Case RA5 is very effective than other cases.
10) As per comparative results in Torsional Moments in beam, other than RA1, case RA3 to RA7-OTB are very effective than other cases. In this case, the values first increases up to case RA2, then downward trend has observed.
11) On analysing the Torsional Moments in column, other than RA1, case RA2 is very effective than other cases. In this case, the values first increases up to case RA4, then downward trend has observed.

As we analysis about seven diverse cases of Wall Belt Systems, Shear Core Outrigger Systems and Truss Belt Systems on Residential Apartment in Staad Pro. In term of mentioned cases following conclusion are find out from this comparative analysis.

Overall analysis said that the most efficient case for the above study is Case RA4. It is consider as the suitable arrangement for the structure of among all of these. This particular project also represents with the use truss belt support for optimizing the building material as compared the using of shear wall. This also concludes that if we using wall truss belt support with respect to shear wall arrangement structure stability and performance will be better. Here for efficiency of the project, two types of optimized truss belt support which has performed well and observed as most optimized and correspondingly minimum in all the cases.

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