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A Study On Static And Dynamic Behaviour Of Outrigger Structural System For Different Structural Configuration

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ABSTRACT

In comparison to low-rise structures due to the enormous number of different structural systems and components present, high-rise structures are more complicated than short buildings because they are more vulnerable to lateral and gravitational stresses as well as earthquake and wind loads. In comparison to strength standards, the stability and stiffness criteria will thus be of much more relevance and govern the final design. Therefore, outrigger and belt-truss system are one of the most common lateral forces resisting system (LFRS). Here in this study performance-based analysis is carried out by adopting ETABS software for a B+G+24 storey tall structure. And the aim and moto of the study is to compare the structural behaviour of bare frame structure (BFS), outrigger structure(OS) and outrigger with belt-truss structure(OBS) under liner static (LSA) and linear dynamic (LDA) such as response spectrum and time history analysis. From the work carried out, we can conclude that by adopting OS and OBS the structural safety is increased against lateral loads such as earthquake. The overall structural response is improved by increasing its mass and stiffness. Among OS and OBS when compared to BFS. OBS has performed well under both static and dynamic earthquake loading and thereby enabling the outrigger system to be used more effectively and enabling the system be integrated into design rules and standards.

Keywords – Outrigger structures, storey displacement, storey drift, storey shear, base shear, time period.

I. INTRODUCTION

As essential structures in modern cities and metropolises, because of their essential purpose. High-rise structures have to be considered more complicated comparing with low-rise ones because of large variety of structural components they contain & numerous aspects whose impacts have a greater impact on high-rise structures than on low-rise ones. The interplay between gravity and lateral forces in skyscrapers requires some serious structural gymnastics. It's fascinating how engineers need to balance stability, rigidity, and strength to ensure these towering structures stand tall against everything from the forces of nature to the test of time.

High-rise structures are an acceptable solution to this issue due to shortage of land in cities and the rising rates of urbanisation over the past several decades . The competition to build the highest and most recognisable structure in a world, area, nation, or city, where certainlarge structures are seen as tourist attractions in addition to the pride they provide to the city and country, such as the Eiffel Tower, Burj Khalifa, etc. As a result, complexly designed tall buildings, such those that are twisted, slanted, tapered, and aerodynamically structured, are frequently employed in today's high-rise structures.

II. LITERATURE REVIEW

Amoussou et al. (2021)

The author introduces a performance-based design process for tall structures, emphasizing optimization and simplification techniques in the early design stage.ETABS and Peforma-3D software have been utilised for nonlinear analysis for evaluating efficacy of outrigger and ladder systems during seismic events.The study examines global and component responses for outrigger and ladder systems under three performance levels: immediate occupancy (IO), life safety (LS), & CP. The nonlinear time history analysis shows that, compared to the outrigger system, the ladder system reduces the overall structure response by 27.2% for lateral displacement and 30.4% for base shear.The ladder system is observed in enhancing the distribution of plastic damage in parts of exterior structural system while decreasing it in parts of the interior structural system. Offers optimization tall structure designs for enhanced seismic performance.

Kavyashree, Patil, and Rao (2021

In the study by Kavyashree, Patil, and Rao (2021), the focus is on evaluating the efficiency of an outrigger structure resembling the St. Francis Shangri-La Place skyscraper. Structure is exposed to seismic excitations from the El-Centro earthquake, and a numerical simulation is carried out for Kobe earthquake. The assessment includes the incorporation of magnetorheological (MR) and viscous dampers to understand their impact.

The structural analysis is conducted using Bernoulli's Euler beam theory to represent the core as a beam element, & FEM is employed. The entire system, comprising the structure, dampers, and controller interface, with MATLAB and Simulink through the state-space methodology.

Seismic response of damped outrigger structure is compared for two distinct earthquakes to assess its performance with and without dampers. The key finding suggests that, when considering controlled settings incorporating viscous and MR dampers, the uncontrolled structural response exhibits a larger peak value with displacement and acceleration.

Outcomes portray as semi-active controller could be utilised for enhancing structural performance of damped outriggers. This implies that incorporating such controllers can contribute to mitigating the adverse effects of seismic forces on the structure, showcasing potential improvements in its overall response and behavior during earthquakes.

Alhaddad et al. (2020)

Into this study, the author gave comprehensive data with outrigger systems, covering various aspects such as their parts, configurations, types, and factors influencing performance. The structural behavior of outrigger systems with varied loads is explored, along with a discussion on the advantages, disadvantages, and key design deliberations related with these systems.

The study introduces the outrigger and belt truss system, providing practical definitions and highlighting the numerous configurations of this system. Different varieties of outrigger systems are defined based on numerous aspects, like configurations, structural materials, and the desired reaction with varied loading circumstances.

These detailed definitions serve as valuable resources for designers, aiding them in making informed decisions. The study contributes to deeper concept of behavior of outrigger systems, elucidating the aspects which effect their performance. Additionally, advantages & drawbacks of outrigger systems are thoroughly discussed, offering intuitions in probable solutions for addressing concerns pertaining with these structural elements.

Salman et al. (2020)

Author conducted a comprehensive study of a high-rise structure, examining various structural systems such as moment-resisting frames, building frames, and outrigger-braced frames under lateral loads. Static analysis revealed that the outrigger-braced system provides optimal control for high-rise structures. Dynamic analysis, considering vibration responses, was also performed.

The findings indicated that the outrigger system significantly reduces the structure's top displacement and drift response, achieving an ideal reduction of 33% for one outrigger and 60% for two. Moreover, outriggers demonstrated a 40% capacity to reduce acceleration, surpassing the 35% capacity of pendulum tuned mass dampers. The study concludes that an outrigger-braced frame is a valuable addition to a sway frame, enhancing the overall performance of the structure, especially in controlling lateral movements and vibrations.

Gupta and Podder (2020)

In this study, the objective was to identify the optimal location for the outrigger-belt system in high-rise RCC

(Reinforced Concrete) buildings by investigating their behavior under seismic conditions. The researchers employed pushover analysis to capture the seismic response of structures with outrigger-belt systems placed at different heights—specifically, at 10, 15, 20, 25, and 30 stories.

The findings highlight that factors such as the building's height, loading direction, and lateral load patterns significantly influence the ideal placement of the outrigger-belt system. The study also demonstrates how the placement of this system can impact various aspects of a building's performance, including roof displacement, storey shear, fundamental period of vibration, base shear, and performance point.

The conclusion drawn from the study is that, for high-rise RCC structures, the optimal location for the outrigger-belt system falls between 30% and 50% of the building's height. Outcomes offers direction for structural engineers and designers, offering a range within which the outrigger-belt system could be most effectively placed to enhance the seismic performance of high-rise buildings.

OBJECTIVES

1) For studying behaviour of outriggers structural system for the 25-storey building under seismic loading condition in the seismic zone V Using FEA software tool.
2) To compare the structural response of bare frame structure (BFS), outrigger structure (OS) and outrigger with belted-truss system (OBS) for linear static and linear dynamic analysis
3) To compare constraints as maximum story displacement, storey shear, base shear and time period.

III. METHODOLOGY

The goal of the current endeavour is to research structural responses of bare frame structure (BFS), outrigger structure (OS) and OBS. Located into seismiczone- V. Three mathematical models of B+G+24 floors of RC structure are developed in E- tabs (FEA software). The loads are assigned as per IS-875(part 1&2) and IS-1893-2016. Static analysis and dynamic study have been performed utilising RSM & Time history method, for evaluating seismic structural responses of following models & their responses are noted & compared.

Software used for modelling and analysis

E-TABS is reason why PC projects havegrown in demand, particularly for analysing and setting building frameworks. In structural analysis & designing of construction networks, this was first program of its kind to provide really groundbreaking features. Because of its intuitive interface & comprehensive feature set, E-TABS has become industry standard for structural evaluation & design E-TABS is low-cost package for multi-story building analysis. Entire system set maybe made graphically. It has advanced algorithms and cutting-edge visuals and is contained in a very user-friendly environment.

Method of analysis

Seismic Analysis Techniques

Diversification in seismic analysis process is possible depending on behavior of structure & type of outwardly induced load. Both linear & nonlinear analyses are available. Static analysis, that's analogous to linear analysis but has limitations due to height of structure, pertains to just symmetrical structures. Here are 2 approaches to liner dynamics analysis: elastic time history approach & RSM. There have been advancements in linear static analysis. This approach is far more successful in producing real-world force absorption consequences of higher modes in elastic range.

Both static and dynamic nonlinear analysis are considered to be types of nonlinear analysis. This simple technique provides useful information upon building's load distribution, shape memory, plasticity, & strength. Since certain members are prone to cross maximum phase in earthquake, analyzer may use this information to prioritize their design & detail. Nonlinear dynamic analysis is exclusive analytical method which could reliably predict how a building will respond in earthquake. This method incorporates elasto-plastic distortion of building component through direct computation.

IV. MODELLING

As discussed in the introduction and methodology the E-TAB model is developed to the scaleto run the static and dynamic analysis.

Model Description

The below Tables shows the material properties, section properties and design parameters usedin this project.

Table 1:Model description and Design parameters

NUMBER OF STORIES	B+G+24 floors
PLAN SIZE	24 m x 19.7m
FLOOR TO FLOOR HEIGHT	3.2m
HEIGHT OF OUTRIGGER STORY	2 m
NUMBER OF BAYS BOTH IN X AND Y –DIRECTION	5 Bays at podium 3 Bays at typical floor levels
SEISMIC ZONE (Z)	IV
RESPONSE REDUCTION (R)	5 (SMRF)
HEIGHT OF BUILDING	76.7m
SOIL TYPE	Medium
STATIC ANALYSIS	Equivalent Static Analysis
DYNAMIC ANALYSIS	Response Spectrum Method Time History Analysis

Table 2:Material properties provided

KIND OF STRUCTURE ELEMENT	CONCRETE GRADE	STEEL GRADE
BEAM	M25	HYSD500
COLUMN	M40	HYSD500
SLAB	M20	HYSD500
SHEAR WALL	M30	HYSD500
OUTRIGGERS	M40	HYSD500
BELTTRUSS	M40	HYSD500

Table 3: Section properties of structural members

KIND OF STRUCTURE ELEMENT	SECTION (SIZE in mm)
BEAM	300x450
COLUMN	600x600 750x750
SLAB	200 mm
SHEAR WALL	300 mm
OUTRIGGERS	600x600
BELTTRUSS	300x750

Table 4: Cover provided for structural elements

KIND OF STRUCTURE ELEMENT	COVER in 'mm'
BEAM	25
COLUMN	40
SLAB	20
SHEAR WALL	30
OUTRIGGERS	25
BELTTRUSS	25

Table 5:Loading details

TYPES OF LOADS	LOAD APPLIED
TYPICAL LIVE LOAD	3-KN/m^2
ROOF LOAD	1.5-KN/m^2
FLOOR FINISH	1.5-KN/m^2

Table 6: Seismic properties

PARTICULARS	PARAMETER
SIESMIC ZONE	**V**
RESPONSE REDUCTION FACTOR	5(SMRF)
SOIL TYPE	Medium
IMPORTANCE FACTOR	1

DAMPING RATIO	5%

Modelling in ETABS Software

We make sure to follow the blueprint by selecting appropriate grid units & positioning. Run lines and reference points to create a center line diagram of proposed structure. Alternatively, you may model Centre line by drawing it in AutoCAD and save file as a dxf, as are mass sources, beams, columns, & slabs, along with support conditions & loads. Static analytical approach is used to analyze model for earthquake loads, and then model is developed accordingly. Then, time history analysis is used to examine effects of blast load on model, & necessary data is retrieved.

V. RESULT & DISCUSSION

Outcomes attained for bare frame, outrigger frame and outrigger with belt truss for a B+G+24 storied structure using E-tabs software under both linear static and dynamic (response spectrum and time history) analysis for earthquake loading. Following are some of primary factors taken into account while assessing structural reactions of buildings under earthquake loading:

- Storey displacement
- Storey drift
- Base shear
- Storey shear
- Time period

5.1 Storey displacement

Term "storey displacement" refers to movement of single floor above ground level. As a result of lateral loads operating upon structure, building moves to and fro, making occupants uncomfortable. Building's overall height, height of each floor, & lateral stresses acting upon building are primary factors in storey displacement.

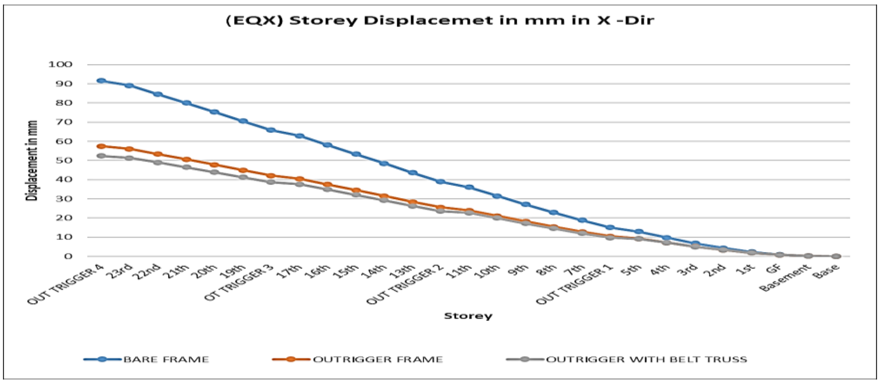

Figure 1: Story displacement for static analysis in X-Dir

Figure 1 shows the comparison of displacement vs storeys for all three models. We can observe that the storey displacement is increasing as the storey height increases and the maximum storey displacement of 91.647 mm for BFS, 57.48 mm for OS and 52.397 mm for OBS frames are seen into top storey level that is at the 24th floor. Where the displacement is reduced by34.167 mm and 39.250 mm for outrigger frame (OS) and outrigger with belt truss (OBS) respectively when compared to bare frame (BFS) under linear static analysis in X – direction. This might be because of increase in the stiffness in OBS and OS structure when compare to BFS.

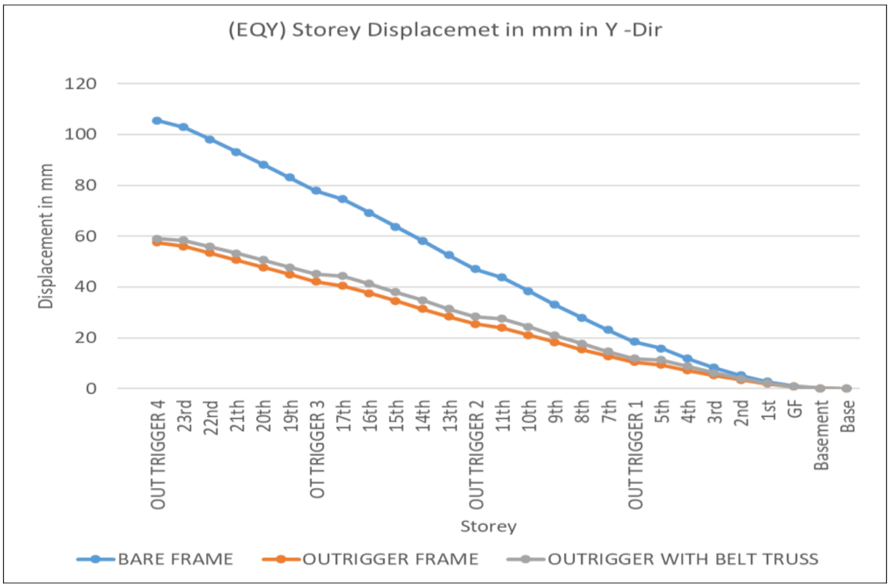

Figure 2: Story displacement for static analysis in Y-Dir

Figure 2 shows the comparison of displacement vs storeys for all three models. We can observe that the storey displacement is increasing as the storey height increases & maximal storey displacement of 105.638 mm for BFS, 57.48 mm for OS and 59.102mm for OBS frames are observed at top storey level that is at the 24th floor. Where the displacement is reduced by 48.158 mm and 46.536 mm for outrigger frame and outrigger with belt truss respectively when compared to bare frame (BFS) under linear static analysis in Y – direction. This may be due to increase in the stiffness in OBS and OS structure when compare to BFS structure.

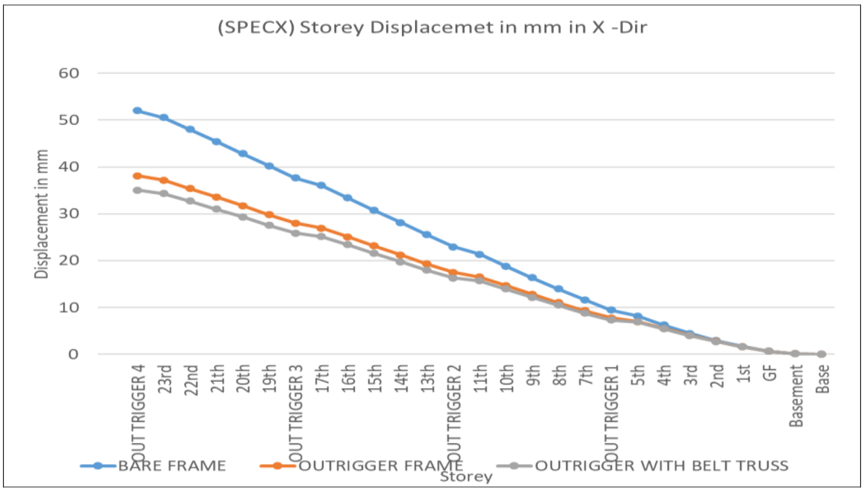

Figure 3: Story displacement for response spectrum analysis in X-Dir

Figure 3 shows the comparison of displacement vs storeys for all three models. We can observe that the storey displacement is increasing as the storey height increases & maximal storey displacement of 51.984 mm for BFS, 38.127 mm for OS and 35.047 mm for OBS frames are observed at top storey level that is at the 24th floor. Where the displacement is reduced by 13.857 mm and 16.937 mm for outrigger frame and outrigger with belt truss respectively when compared to bare frame (BFS) under linear static analysis in X – direction. This may be due to increase in the stiffness in OBS and OS structure when compare to BFS structure.

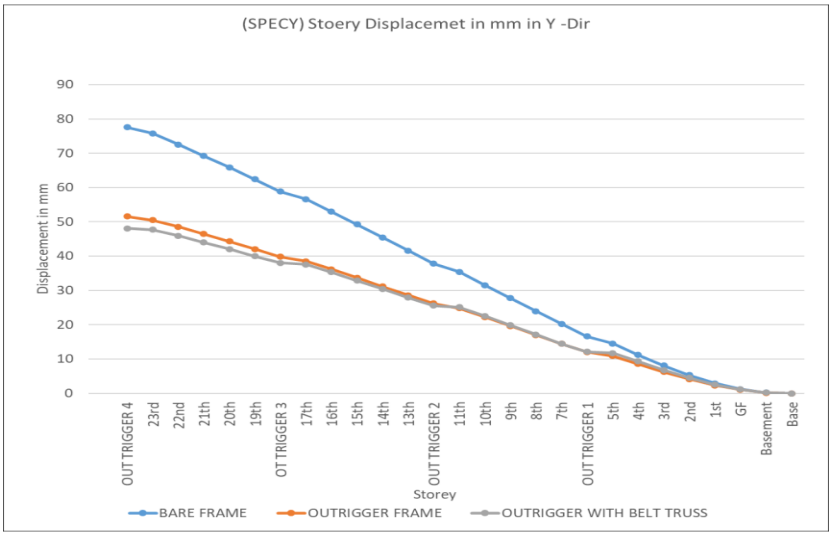

Figure 4: Story displacement for response spectrum analysis in Y-Dir

Figure 4 shows the comparison of displacement vs storeys for all three models. We can observe that the storey displacement is increasing as the storey height increases & maximal storey displacement of 77.611 mm for BFS, 51.594 mm for OS and 48.085 mm forOBS frames are observed at top storey level that is at the 24th floor. Where the displacementis reduced by 26.017 mm and 29.526 mm for outrigger frame (OS) and outrigger with belt truss(OBS) respectively when compared to bare frame (BFS) under linear static analysis in Y – direction. This may be due to increase in the stiffness in OBS and OS structure when compareto BFS structure.

Storey drift

Proportion of story drifting is quantity by which one floor moves laterally with respect to floor below it, expressed as a percentage. Earthquakes can put significant lateral stresses on a building, that can cause floors to shift. Structural & non-structural components, as well as neighboring buildings, might all suffer from structure's deformations.

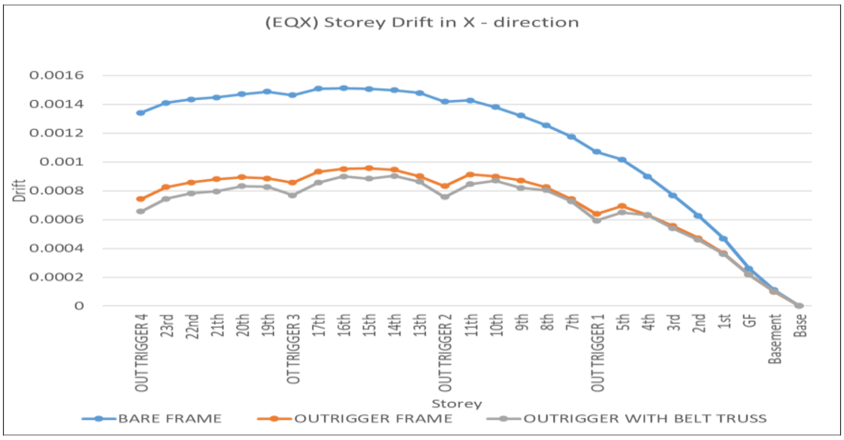

Figure 5: Story drift for static analysis in X-Dir

Figure 5 shows the comparison of storey drift with all three models, we could see with fig as maximum storey drift is observed in the floors between outrigger 2 and outrigger 3. Storey drift reduces at every outrigger storey. The drift is reduced by 0.555 x 10^{-3} and 0.608 x 10^{-3} for outrigger frame and outrigger with belt truss respectively when compared to bare frame under linear static analysis in X – direction. The reduction in storey drift in outrigger storey may be due to decrease in height of the storey and increase in stiffness.

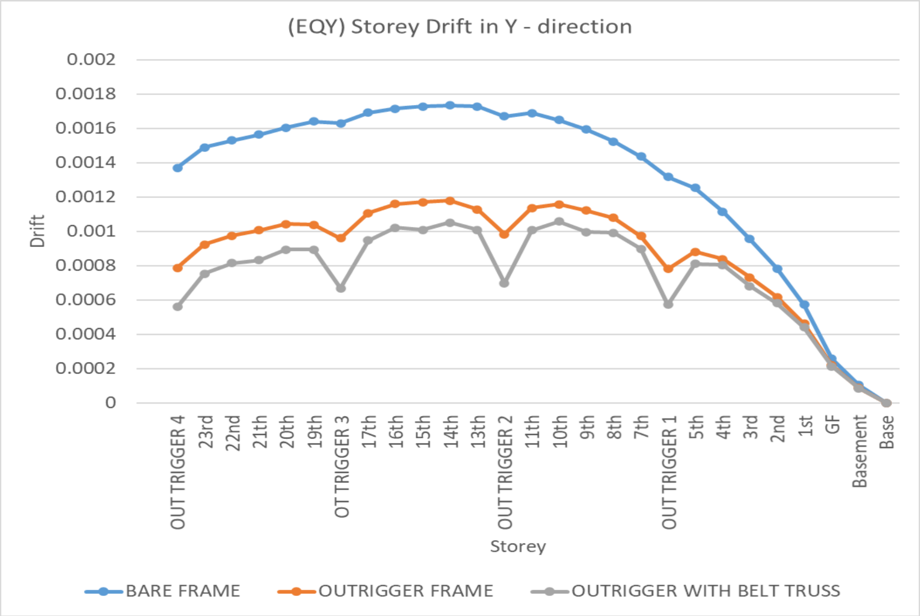

Figure 6: Story drift for static analysis in Y-Dir

Figure 6 shows the comparison of storey drift with all three models, we could see with fig as maximum storey drift is observed in the floors between outrigger 2 and outrigger 3. Storey drift reduces at every outrigger storey. The drift is reduced by 0.556 x 10-3 and 0.676 x 10-3 for outrigger frame and outrigger with belt truss respectively when compared to bare frame under linear static analysis in Y – direction. The reduction in storey drift in outrigger storey may be due to decrease in height of the storey and increase in stiffness.

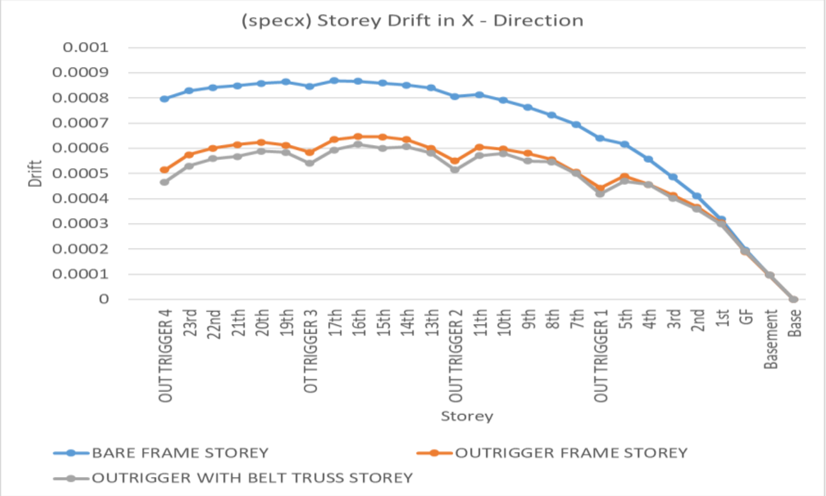

Figure 7: Story drift for response spectrum analysis in X-Dir

Figure 7 shows the comparison of storey drift with all three models, we could see with fig as maximum storey drift is observed in the floors between outrigger 2 and outrigger 3. Storey drift reduces at every outrigger storey. The drift is reduced by 0.221 x 10^{-3} and 0.252 x 10^{-3} for outrigger frame and outrigger with belt truss respectively when compared to bare frame under response spectrum analysis in X – direction. The reduction in storey drift in outrigger storey may be due to decrease in height of the storey and increase in stiffness.

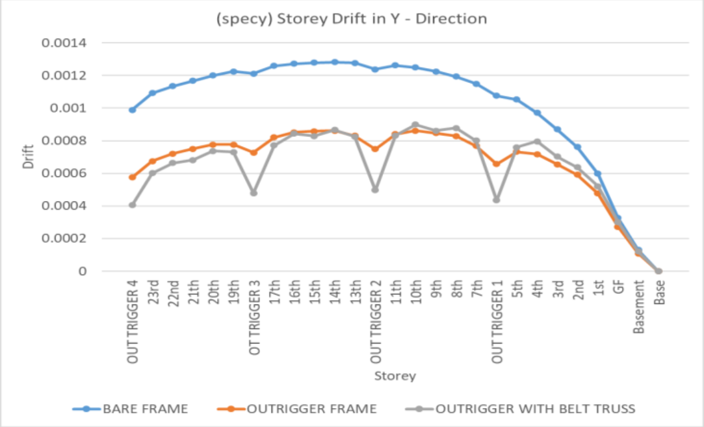

Figure 8: Story drift for response spectrum analysis in Y-Dir

Figure 8 shows the comparison of storey drift with all three models, we could see with fig as maximum storey drift is observed in the floors between outrigger 2 and outrigger 3. Storey drift reduces at every outrigger storey. The drift is reduced by 0.42 x 10-3 and 0.382 x 10-3 for outrigger frame and outrigger with belt truss respectively when compared to bare frame under response spectrum analysis in X – direction. The reduction in storey drift in outrigger storey may be due to decrease in height of the storey and increase in stiffness.

Storey shear

Storey shear is the lateral force acting on a story due to the forces such as seismic, wind force. It is calculated for each storey.

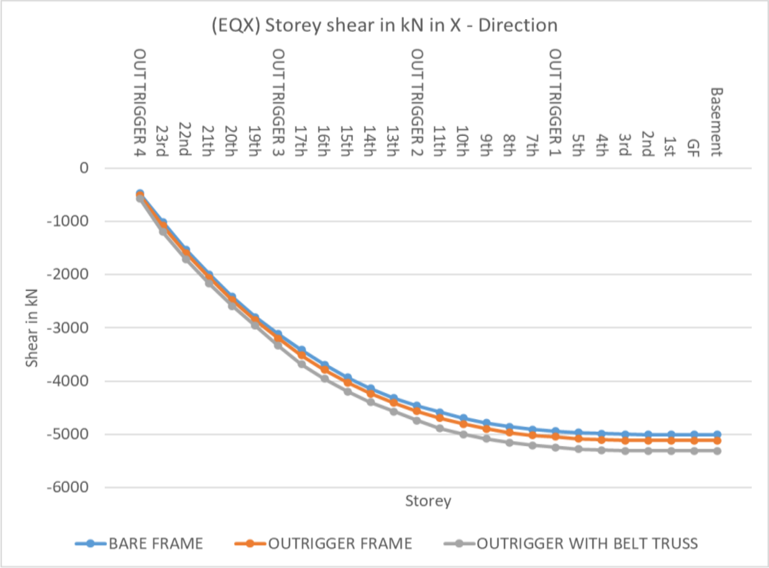

Figure 9: Story shear for static analysis in X-Dir

Figure 9 shows the comparison of storey shear with all three models, we can observe from figure that the maximum storey shear is observed at the basement of the structure. The shear has increased by 113.0735kN and 307.5202kN for outrigger frame (OS) and outrigger with belt truss (OBS)respectively when compared to bare frame under linear static analysis in X – direction. This may be because transfer of axial stress to outer columns.

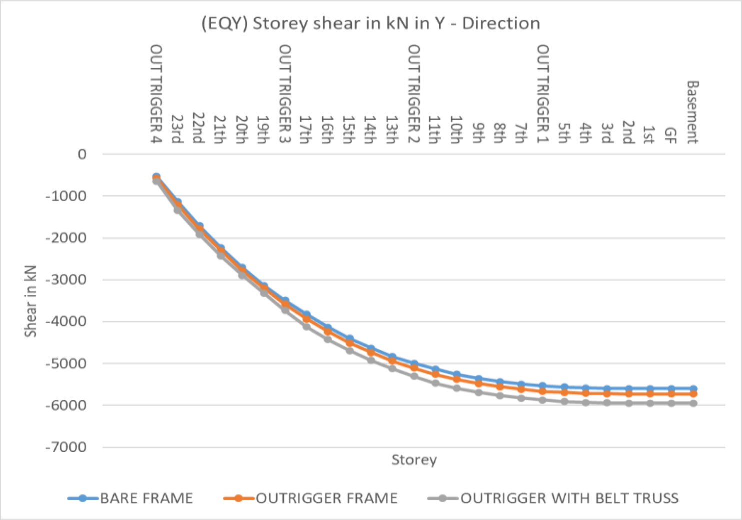

Figure 10: Story shear for static analysis in Y-Dir

Figure 10 shows the comparison of storey shear with all three models, we can observe from figure that the maximum storey shear is observed at the basement of structure. Shear has increased by 126.546kN and 344.1609kN for outrigger frame (OS) and outrigger with belt truss (OBS)respectively when compared to bare frame under linear static analysis in Y – direction. It might be because transfer of axial stress to outer columns.

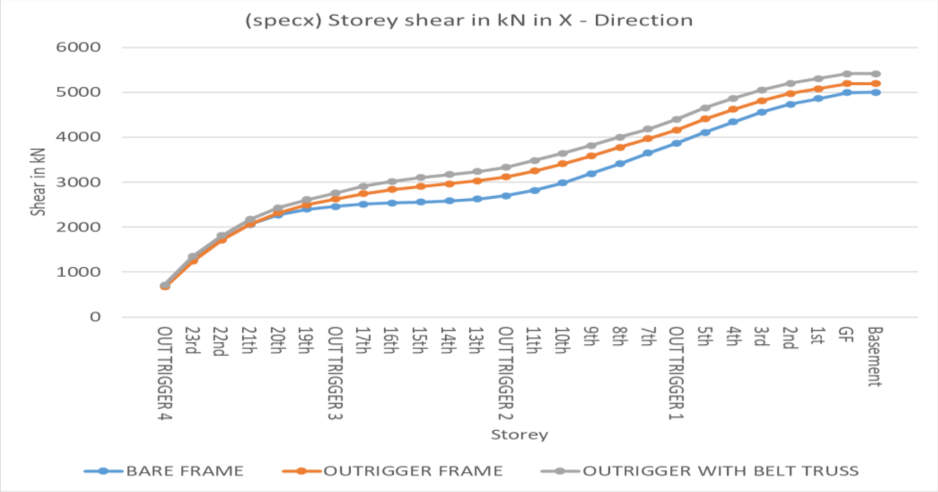

Figure 11: Story shear for RSA in X-Dir

Figure 11 shows the comparison of storey shear with all three models, we could see with fig as maximum storey shear is observed at the basement of structure. Shear has increased by 197.3798kN and 416. for outrigger frame (OS) and outrigger with belt truss (OBS)respectively when compared to bare frame under RSA in X – direction. It might be because transfer of axial stress to outer columns.

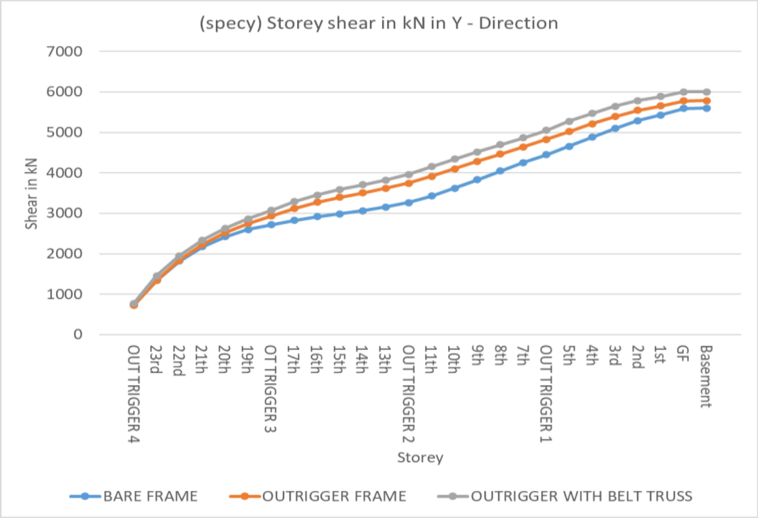

Figure 12: Story shear for RSA in Y-Dir

Figure 12 shows the comparison of storey shear with all three models, we could see with fig as maximum storey shear is seen as basement of structure. Shear has increased by 181.0336kN and 404.7626kN for outrigger frame (OS) and outrigger with belt truss (OBS)respectively comparing to bare frame under RSA in Y – direction. This may be because transfer of axial stress to outer columns.

Base shear

Base shear is an estimate of maximal expected lateral force acting on the base of a structure. This force is typically due to seismic loads (earthquake) or wind loads.

It serves as a critical parameter in the design of structures, helping engineers assess the capacity of a building to withstand lateral forces.During the design process, engineers consider the base shear value as a fundamental criterion. The structure is designed to effectively resist lateral loads up to the calculated base shear.The building is constructed to handle lateral loads, and its response is proportional to the magnitude of the applied force. The lateral force increases from zero to the base shear value.The design philosophy is as building is probable to safely withstand lateral loads up to the base shear value. Beyond this threshold, the structure may experience excessive deformations or failure, leading to collapse.Exceeding the designed capacity, especially the base shear, poses a significant risk to structure reliability of building. The structure may lose its capability for resisting lateral loads, potentially resulting in catastrophic failure.Base shear accounts for different types of lateral loads, including seismic loads from earthquakes and wind loads. Both of these loads exert horizontal forces on a building, and designing for base shear helps ensure structural stability under these conditions.Building codes and standards, especially those related to seismic design, provide guidelines for determining and incorporating base shear into designing procedure. These codes aim to enhance pliability of buildings in seismic regions.

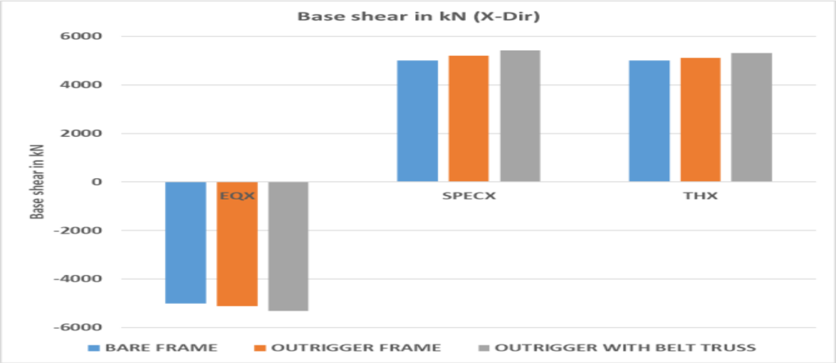

Figure 13: Base Shear in X – Direction

Figure 13 shows the comparison of base shear with every 3 model wrt different static and dynamic analysis, we could see as maximum base shear is observed in structures with OBS. Base shear has increased by 113.0735kN and 307.5202kN under linear static analysis, 197.3798kN and 416.5967kN under response spectrum analysis, 107.1863kN and 301.1972kN under time history analysis for outrigger frame and outrigger with belt truss respectively comparing bare frame in X – direction, this may be because of increase in self-weight of structure.

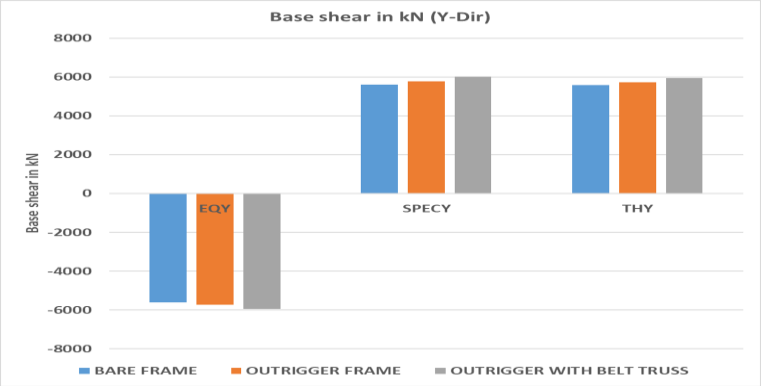

Figure 14: Base Shear in Y - Direction

Figure 14 shows the comparison of base shear every 3 model w.r.t different static and dynamic analysis, we could see by fig as maximum base shear is observed in structures with OBS. The base shear has increased by 126.546kN and 217.6149kN under linear static analysis, 181.0336kN and 223.729kN under response spectrum analysis, 130.3263kN and 216.8164kN under time history analysis for outrigger frame and outrigger with belt truss respectively when compared to bare frame in Y – direction. This may be due to increase in self-weight of the structure.

Time period

The natural period of a building is the time it takes to undergo one complete cycle of oscillation in response to an applied lateral force or disturbance. It is a fundamental dynamic property of a structure.

The natural period is primarily influenced by two key structural properties—mass and stiffness.

Mass: Heavier structures tend to have longer natural periods.

Stiffness: More rigid structures tend to have shorter natural periods.

Table 7: Time Periods

	Time Period in second		
MODE	BARE FRAME (BFS)	OUTRIGGER FRAME(OS)	OUTRIGGER WITH BELT TRUSS(OBS)
1	2.309	1.979	1.816
2	2.173	1.771	1.714
3	1.358	1.219	1.184
4	0.578	0.536	0.512
5	0.491	0.437	0.436
6	0.358	0.334	0.334
7	0.27	0.261	0.259
8	0.217	0.202	0.204
9	0.201	0.201	0.201
10	0.192	0.192	0.192
11	0.182	0.181	0.181
12	0.178	0.174	0.176
13	0.167	0.167	0.167
14	0.163	0.16	0.162
15	0.15	0.15	0.15
16	0.136	0.136	0.136
17	0.136	0.132	0.133
18	0.129	0.127	0.127
19	0.127	0.126	0.125
20	0.125	0.125	0.124
21	0.122	0.122	0.122
22	0.121	0.12	0.121
23	0.119	0.118	0.119
24	0.114	0.114	0.114
25	0.11	0.11	0.11
26	0.109	0.109	0.109
27	0.108	0.106	0.109
28	0.107	0.105	0.102
29	0.102	0.102	0.101
30	0.1	0.1	0.1

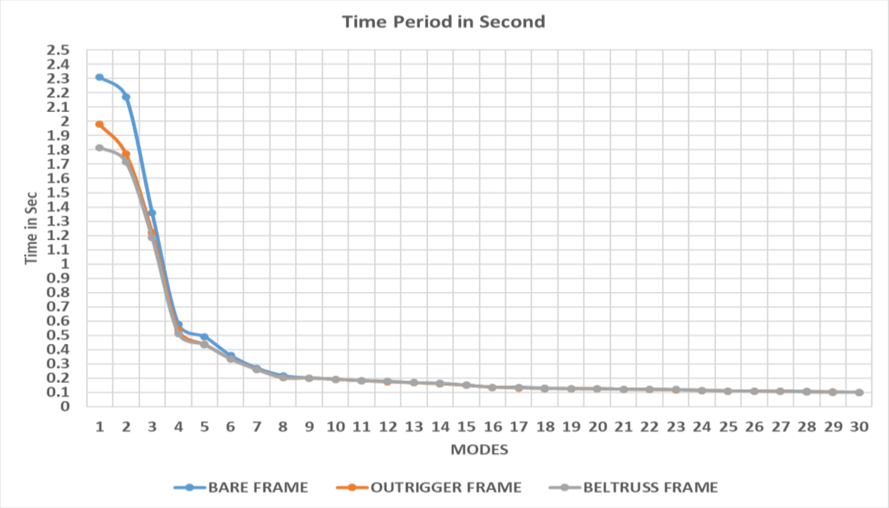

Figure 15: Time Periods

Table 7 shows the values of natural time periods of all three models and Figure 15 show the comparison of natural time period of all three models. The bare frame has the maximum time period & outrigger having belt truss system has least time period. For all the structuresmaximum time period is observed in mode 1. Time period is reduced by 0.33 seconds and 0.493 seconds for outrigger system & belt truss system when compared to thebare frame, this behaviour is may be due to increase in stiffness of OBS structure.

VI. CONCLUSION

This report represents an approach for study on the behaviour of different LFRS for static & dynamic analysis. The following were few findings concluded with our study:

- For all the structure the maximum displacement is observed at outrigger 4 (top storey) level. Maximal storey displacing is decreased with 37 to 46% for outrigger system and42 to 45% for outrigger with belt truss system when compared to bare frame structure under linear static analysis.
- For all the structure the maximum displacement is observed at outrigger 4 (top storey) level. Maximal storey displacing is reduced by 26 to 34% for outrigger system and 32 to 39% for outrigger with belt truss system when compared to bare frame structure under response spectrum analysis.
- For all the structure the maximum displacement is observed at outrigger 4 (top storey) level Maximal storey displacing is reduced by 50 to 66% for outrigger system and 55 to 67% for outrigger with belt truss system when compared to bare frame structure under time history analysis.
- This reduction in displacement is observed due to increase in structural mass and stiffness.
- For all the structure the maximum drift is observed between outrigger 2 and outrigger 3 levels. Maximal storey displacing is reduced by 32 to 42% for outrigger system and 38 to 45% for outrigger with belt truss system when compared to bare frame structure underlinear static analysis.
- For all the structure the maximum drift is observed between outrigger 2 and outrigger 3 levels. Maximal storey displacing is reduced by 25 to 35% for outrigger system and 29 to 30% for outrigger with belt truss system when compared to bare frame structure underRSA.
- For all the structure the maximum drift is observed between outrigger 2 and outrigger 3 levels. Maximal storey displacing is reduced by 48 to 61% for outrigger system and 45 to 60% for outrigger with belt truss system when compared to bare frame structure undertime history analysis.
- At every outrigger level there is a reduction of storey drift due to increase in the stiffnessat that particular level. And also, overall reduction in storey drift is observed due to increased structural mass and stiffness in OS and OBS.
- For all the structure the maximum storey shear is observed at basement level. Maximum storey shear is increased by 2.26% for outrigger system and 6.14% for outrigger with belt truss system when compared to bare frame structure under linear static analysis.
- For all the structure the maximum storey shear is observed at basement level. Maximumstorey shear is increased by 3 to 4% for outrigger system and 7 to 9% for outrigger withbelt truss system when compared to bare frame structure under RSA.
- For all the structure the maximum storey shear is observed at basement level. Maximumstorey shear is increased by 2 to 3% for outrigger system and 6 to 7% for outrigger withbelt truss system when compared to bare frame structure under time history analysis.
- For all the structure the maximum time period is observed in mode 1. Maximum time period is reduced by 14.29% for outrigger system and 21.35% for outrigger with belt truss system when compared to bare frame structure.

Therefore, we can conclude that by adopting lateral force resisting system the structural safety is increased against lateral loads such as earthquake. The overall structural response is improved by increasing its mass and stiffness. Among OS and OBS, outrigger with belt truss system has resulted efficiently under both static & dynamic earthquake loading.

FUTURE SCOPE OF STUDY

- The study can be extended by adopting different shapes, layouts and structuralconfiguration.
- Study can be done by adopting non-linear static and non-linear dynamic analysisprocedures for better understanding of the behaviour.
- Steel outriggers and hybrid outriggers can also be adopted for the study for betterunderstanding.

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