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COMPARATIVE ANALYSIS OF A REINFORCED CONCRETE FRAMED STRUCTURE UNDER PERFORMANCE BASED ANALYSIS CONSIDERING POST TENSIONED MEMBERS AT THE EDGES USING ETABS AS A TOOL

M Mahammad Yousuf[1], Dr. H Sudarsana Rao[2], Dr. Vaishali G Ghorpade[3]

[1]M. Tech (Structural Engineering), Civil Engineering Department, JNTUA College of Engineering, Ananthapuramu, India.

[2]Professor in Civil Engineering Department, JNTUA College of Engineering, Ananthapuramu, India.

[3]Professor in Civil Engineering Department, JNTUA College of Engineering, Ananthapuramu, India.

mmd.yousuf142@gmail.com1, sudarsanarao123@gmail.com2, ghorpadevaishali1@gmail.com3

ABSTRACT:

The modern building has resulted in the usage of post-tensioning technology in many commercial and residential constructions. Looking at the defects of the usual technique of building, post-tensioning as an upgrade may overcome the inadequacies of the conventional method of construction, such as more thin structural components, lower weight, and smaller floor-to-floor heights. Post-tensioning ensures that every design is both cost-effective and safe. A Symmetrical arrangement of multi-story floors will be considered in this comparative analysis considering Pushover Analysis according to I.S. 1893-2016. The analytical tool ETabs structural programming will be used for the analysis of the case study on the parameters namely parable drift, maximum lateral displacement, story shear, target displacement, and performance point. The Analysis results will be used to study the stability of the Post-tensioned Structure as far as resisting seismic forces against the corners of the structure.

Keywords: Pushover Analysis, Maximum story displacement, Post Tensioning Cables, Target Displacement, Story drift, Stability, Performance point.

I. INTRODUCTION

In contrast to low-rising assemblages, raised architectures are taller structures. They are identified by their elevation unambiguously in diverse contexts and are inferred to be elevated tall structures. Steel and RCC are the main components of tall structure support systems. A tall structure must typically withstand both vertical loads and lateral pressures brought on by wind and earthquakes, but the structure's design differs depending on how well it can withstand each load. The foundation of the structure is affected by earthquake forces, whereas the exposed section of the structure is affected by tiny wind breezes, which are characterized as coercing loading. In the event of an earthquake, the ground normally moves irregularly near the appropriate location of the structure, but tectonic forces, even for a little time, have devastating effects on the structure at greater scales. The employment of post-tensioning technology in numerous projects in the commercial and residential sectors is a result of the modern building. It is possible to reinforce concrete or other materials using high-quality steel strands or bars,

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commonly referred to as tendons, via a process called post-tensioning. Post-tensioning, which is an improvement above the conventional building, may address the shortcomings of conventional construction while also improving upon them.

It is possible to run beams and sections constantly, i.e., a single beam can run continuously from one end of the working to the other. Fundamentally speaking, this is a lot more successful than having a beam that just moves from one portion to the next. It is sometimes required to transmit loads from the upper floor to the nearest supports through the heavily loaded slab or long-span beams when erecting reinforced concrete structures since there is no way to keep the supports of the higher floors in the lower tier (transfer elements). The difficulty stems mostly from the requirement to find sizable, support-free areas on the lower floors. Long-span components that are heavily stressed, bent and sheared frequently need enormous cross-sectional heights. Pre-tensioning drastically lowers the height of an element's cross-section. In every aspect of development, post-tensioning applications are present. In the construction of buildings, post-tensioning allows for longer clear traverses, thinner sections, fewer beams, and more dramatic, thin components. Straight-line cables can be used to execute the prestressing of transfer components at their upper and lower surfaces, in the span, and over the columns. Along with utilizing the favorable effects of tendons for bending, prestressing significantly minimizes shear pressures and support displacement. Strong prestressing and the gradual application of stresses while creating the structure are often necessary for slender components.

If the creation, collection, and introduction of post-tensioning frameworks involve specialized knowledge and skills, the principle is not at all challenging to explain. It helps to have a basic knowledge of concrete in order to fully appreciate the benefits of post-tensioning. Concrete is incredibly strong under pressure but weak under strain; as a result, it will crack when forces act to tear it apart. Conversely, post-tensioning tendons are seen as "dynamic" strengthening during normal RCC growth. Despite the fact that the concrete may not be shattered, the steel serves as a good fortification since it is prestressed. Even when fully loaded, post-tensioned structures can be designed to significantly reduce and straighten the structure. By doing this, post-tensioning may significantly reduce the weight of a building compared to a standard RCC structure with the same number of stories. This lowers startup costs and may be a significant advantage in seismically affected areas.

II. LITERATURE REVIEW

Veerat Srilaxmi et. al. (2018) The researcher discusses the implementation of pre-tensioning and post tensioning sections in recent structural advancements. which was before the operation employs the pre-tensioning and post-tensioning techniques. It has specific benefits over part of the non-structures, such as a larger range to-depth proportion, higher minute, and shear limit. PSC supports, sleepers, bridges, building slabs, concrete piles, repair and restoration, nuclear power plants, and other structures were often used to source these techniques. The best concrete from the different kinds of cement, such as normal concrete, reinforced bond concrete, and pre-stressed cement, was used to create critical parts of a structure with a high level of quality and to extend the structure's life.

Boskey et. al. (2013) The author of this article took into account a contextual study for the implementation of the structural approach in four different business (G+4) floor framework scenarios. For the analogous piece, shaft, and section, the amounts of strengthening steel, prestressing steel, and concrete were evaluated and shown in an unimaginable construction. Moreover, the budget correlation of all four samples was finished along with the computation of the structure's true cost per square meter.

The results prompted the conclusion that, while contrasting the reinforced firm level portion with the post-tensioned level section, the reinforced solid level chunk had such a thickness that was 12.5% greater and an expense that was 27% more. Especially financially, the four-story superstructure with the post-tensioned level piece was the least economical option, whereas the reinforced solid piece with a stronger solid bar was the least expensive option for this budget range. So because post-tensioning enables for the prior evacuation of the formwork, the post-tensioned level segment takes less time to construct compared to the other three situations. The construction for the portion could be emptied previously, but not the formwork for the reinforced solid pillars because of the post-tensioned component with improved solid shafts. The worker's wages were not factored into the cost analysis for each structure, although as the span of time shortens, they also will if a post-tensioned level plate section or, more particularly, a post-tensioned plan of level plate section, allows for about a 70% lower in steel and a 30% slight decrease in concrete when compared to a reinforced bond solid level plate section.

Sridhar and Rose (2019- The results of tests on the flexural behavior of post-tensioned solid pillars with fortified framework checking were examined by the author. Subsequent research was done on four rectangular post-tensioned. Neither single-point nor two-point monotonic stacking were used to test the shafts. The tests show pile diversion, stress-strain, and split occurrence behavior. Because of the proximity of the tendons, the post-pressure framework managed redirection and split efficiently despite the strengthening steel. Whenever the four findings were reviewed, it was found that they were all superior than the typical bars.

Singh et. al. (2018) Using ETABS and SAFE, the researcher worked to build a post-tensioned structure. Prolonged Contact Analysis of Structure Frameworks is recognized by the term ETABS. This software's prime purpose would be to effectively plan highrise structures in compliance with Indian Standard structural norms. The author's project supervised the construction of a tremor- and wind-resistant superstructure, necessitating that the minimal section and bar sizes be C500*500 and B300*500, respectively. Seismic performance evaluation was then performed using the ETABS software, with the participation of the whole community. The construction worked well because it was tensioned.

Tanyeri and J.P. Moehle (2012- The developer oversaw a three-dimensional seismic activity simulation assessment on a full-scale, four-story prestressed structural system using the E-Defense vibrating table office. Two post-tensioned (PT) outlines were arranged in a single heading and two unbonded PT precast dividers were arranged in the opposite direction for the seismic forces opposing the arrangement of the test building. A number of seismic ground movements, ranging from beneficial to nearly crumpling, were applied to the test building.

Using nonlinear response history analysis of feasible basic building models, the behaviour of the structure's division heading was reenacted under various ground motions, and the outcomes of the 2D reenactment were compared to the test results. The test results for the important architectural parameters with particular inconsistencies had a close relationship with directed logical recreations.

M Afrin and VLS Banu (2019) The authors created a three-dimensional RC-framed structure and performed a design study to determine the building's performance in the various seismic zones examined. The research is being conducted in all of India's seismic zones. Pushover analysis is used to examine the modelled structures. Pushover study began with a response spectrum analysis for the definite gravity and live load instances across all zones, followed by a lateral non-linear static pushover analysis for zone v. The tool Etabs does the analysis, and the outcomes of Story displacement, Story drift, Story shear, Target displacement, and Performance point have been discovered. When comparing the different zones of the RC framed structure, all of the obtained data show a significant variation.

III. METHODOLOGY

3.1. PERFORMANCE-BASED DESIGN ANALYSIS:

A relatively new idea, performance-based seismic design analysis was first created to help determine the best upgrading plan for existing structures. It is now an emerging approach, and the main challenges are coming up with specific definitions of performance targets that are acceptable internationally and quantifying performance levels. It is now widely acknowledged that during an earthquake, lateral displacements—not forces—always result in structural damage. The need for performance-based design has increased as a result of this awareness. This process aids in determining the anticipated hierarchy of resistance of various structural components to seismic energy dissipation. Given the importance of this strategy, several theoretical and practical efforts have been made over the past 60 years to develop ways to reduce seismic damage. In numerous cases, buildings survived earthquakes that were expected to create inertia forces several times larger than the elastic strength of the structures, according to an investigation of the aftereffects of earthquakes. It was discovered that the structures' ductility made it possible for them to disperse seismic energy without breaking, and as a result, an elastic force-based design approach was insufficient. The elastic design premise that all structures of a certain kind have the same ductility and that their parts may be compelled to yield simultaneously needed to be reviewed.

It was determined that a structure's power to withstand an earthquake depends more on its innate inelastic displacement capacity than on its initial yield strength. Both the potential size of inelastic deformations in a structure or its parts as well as the places where crucial displacements are likely to take place cannot be predicted using elastic force-based approaches. Although elastic analysis gives a decent approximation of a structure's elastic capacity, it cannot capture how a structure's elastic capacity degrades or how it fails when it experiences progressive yielding, the requirement for a different strategy evolved as a result, leading to the creation of a performance-based design analysis technique. The idea behind this approach is to provide performance goals for the structure. These goals link the allowable amount of damage

(performance level) in relation to a certain seismic hazard (hazard level). Deformations are thought to be a better indicator of a structure's potential performance during an earthquake than forces.
Therefore, rather than only considering a structure's strength, its components and maximum allowable inelastic displacements (also known as goal displacements or performance points) are considered. The structure is only tested for strength at the global and component levels when it satisfies the specified performance requirements. The development of powerful processing power and the accessibility of advanced analytical tools have made it much simpler to introduce and advance this strategy.
Despite scientists' ability to predict and warn of earthquakes in advance and engineers' ability to build buildings that are earthquake-safe, hundreds of thousands of people have died as a result of earthquakes. As a result of the effects of earthquakes and the damage to the structures, earthquake analysis and design principles have been developed. On the basis of the external action, the behavior of the structure or structural materials, and the kind of structural model used, earthquake analysis or seismic analysis can be carried out. The analytical procedure may look like the one in the figure.

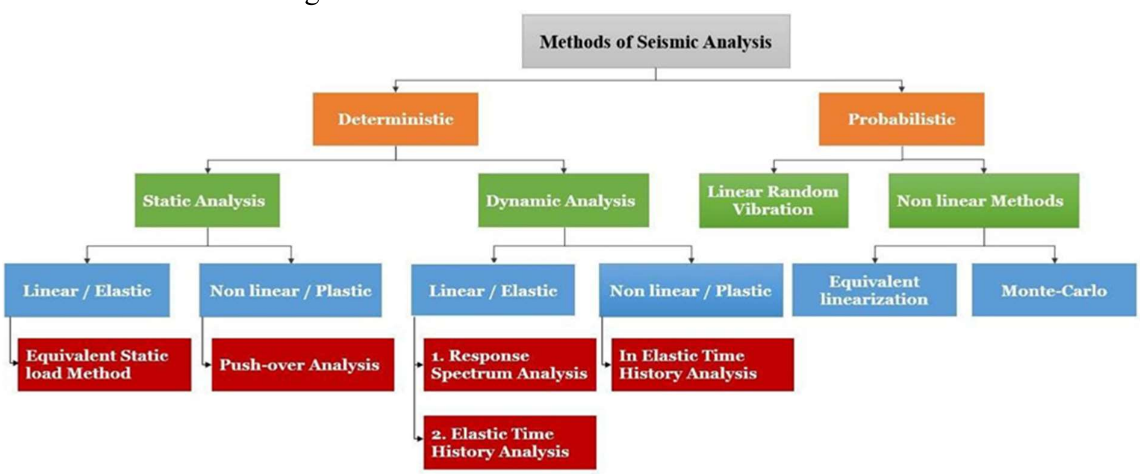


Fig 1. Categorization of seismic analysis methodologies.

a) Linear Static Analysis (Equivalent Static Load Analysis) – This study uses a number of forces to simulate the consequences of earthquake ground motion. It implies that the structure is receptive in a basic way prior to proceeding on. This strategy may be employed in structures that rotate slightly around their axes and conventional low-rise buildings with a definite height. Further study has been carried out to extend its use to the range of motion at low levels and high-rise constructions.

b) Non-Linear Static Analysis (Pushover Analysis) – "Pushover analysis" is another name for this technique. It is superior to linear static and dynamic analysis because it considers the structure's inelastic aspect. The technique is incredibly easy to use and provides data on the structure's strength, deformation, and ductility as well as the distribution of demands. This makes it possible to identify the key components that will likely experience limited states during an earthquake and to which special attention should be paid throughout the design and detailed phases. However, this approach is predicated on a number of misconceptions that ignore variations in loading patterns, the influence of higher modes of vibration, and the impact of resonance. However, one aspect of the approach remains constant: it assumes a set of static incremental lateral loads that are constant over the height of the structure.

Although inherent shortcomings, the overall displacement ability could be determined analytically using this strategy, notably for structures that predominantly react to the first type. A sequence of forces is applied to a structural equation model with non-linear parameters, and the resultant force is shown in ratio to displacement to display a capacity curve. Combining this with a demand curve, typically depicted by an ADRS, may then result in the difficulty becoming simplified to an SDOF System (Acceleration-Displacement Response Spectrum).

The most exact method for calculating perfectly elastic lateral displacement is a response history analysis. Unfortunately, it is technically expensive and labor-intensive to thoroughly examine the enormous amounts of information generated. This strategy also gave data on strength, deformation, ductility, and demand distribution and is simple to grasp. It has several disadvantages in addition to its advantages, such as the fact that it disregards changes in loading patterns, resonance effects, and the influence of modal analysis on structures.

c) Linear Dynamic Analysis – When structures are either too irregular or too tall, the response spectrum analysis is no longer applicable, and more complex analysis, such as non-linear static analysis or dynamic analysis, is typically required. This investigation may be conducted using either the elastic history time technique or the response spectrum methodology. The linear static analysis differs from dynamic static analysis in terms of the force distribution over the height of the structure and the degree of force. Additionally, all phase information is kept since the structure's response to the ground motion is approximated in the time domain. The response spectrum of analysis is utilized when modes other than the fundamental one significantly influence how the structure reacts. Throughout this instance, the Multiple-Degree-of-Freedom System's (MDOF) response will be shown as the superposition of sinusoidal responses, each of which is taken from the response of the Single-Degree-of-Freedom System's (SDFS) spectral analysis (SDOF). The final step is to add up all of these to determine the total response.

d) Non-Linear Dynamic Analysis (In elastic Time History Analysis) – This strategy is determined by direct computation of the motion ordinary differential equation and taking into account the elastoplastic distortion of the framed structure. Its merits comprise slightly uncertain outcomes and analysis that's also focused on the temporal domain. This method also accounts for the lengthening of motion, differences in displacements at various building levels, and resonance-induced amplification. Seismic activity analyses at designated locations are essential. Although important, measuring dynamic earthquake characteristics is computationally intensive, moment, and unsuitable again for the bulk of real-world applications.

Many crucial components that have a meaningful effect on a structure's seismic response are thought to be hard to account for using such a traditional elastic design analysis. The capability of a structure to tolerate inelastic deformations governs how well that structure will perform during tectonic ground vibrations. As a result, the inelastic deformation triggered by seismic loads should then be addressed while evaluating a building. Pushover analysis, a nonlinear static procedure, is widely applied by structural engineers to ascertain the structures' seismic needs. It is a regular method that yields satisfactory results.

3.2. OBJECTIVES OF STUDY:

The destinations of the investigation are as per the following:

1. To decide the capacity of post-tensioned structure compared to conventional reinforced concrete structure as a parallel load opposing individuals.
2. Dynamic investigation of the tall framed structure considering response spectrum examination.
3. Utilization of Advanced diagnostic applications of software like Staad.Pro, Etabs for story response plot examination of horizontal load opposing structure and the inter story displacements.
4. To decide the capacity and dynamic investigation in the terms of maximum story displacement and story drift of the tall framed structure subjecting to IS load combinations.
5. To set up a reference study for the usage of post-tensioning members in the framed structures according to seismic code 1893-section 1:2016.

3.3. STEPS INVOLVED IN PROJECT:

Following steps will be considered for study as follows:

Step 1: Select geometrical data & Sectional data as per considerations.

Step 2: Defining the load pattern and load cases & assign loading conditions as per Indian Standards.

Step 3: Defining response spectrum and nonlinear push cases for dynamic motion and analyzing the structure.

Step 5: Comparison of the findings and the creation of comparison graphs.

IV. BUILDING MODELING & ANALYSIS

In all of India's seismic zones, a study of G+15 RC-framed concrete structures is conducted, and outcomes are derived. The tables below contain the input data needed for the design of the G+15 building. Building information is included in Table 1 along with parameters like importance factor and response reduction factor values obtained from IS 1893 (Part 1): 2002. The material parameters and section properties are displayed in Table 2. Table 3 displays the building's loading information for design purposes. The load situations that were used for the analysis are displayed in Table 3.

Building type	G + 15
Plan dimensions	40 x 30 m
No. of bay in X direction	8 Bays
No. of bay in Y direction	6 Bays
Typical storey height	3.3 m
Bottom storey height	3.0 m
Building height	52.5 m
Soil type	Type II (Medium Soils) RCC footings that are combined or isolated from the beams

Design criteria	As the height of the structure exceeds 40m and reaches 90m, an analysis of all zones is required. The most deformed zone requires a modal analysis utilizing the Response spectrum approach and performance Time history or Push-over analysis.
Zone considering	II, III, IV & V
Importance Factor, I	1
Response Reduction Factor, R	5 (SMRF) RC Structure with Unique Moment Resisting Frame
Performance factor, K	1.0 (Moment-resistant frame in reinforced concrete or steel with appropriate ductility details as specified in IS: 437.6-1976*.)

Table 1. Geometrical properties & location factors.

Column size	500 x 500 mm
Beam size	300 x 400 mm
Thickness of slab	150 mm
Grade of concrete	M-30
Grade of steel	Fe-500
Post-tensioning wire	As tendons

Table 2. Section & material properties.

Wall load on external beams	13.34 kN/m
Wall load on internal beams	8.7 kN/m
Floor & Terrace finish load	1.5 kN/m^2
Live load on floor	2 kN/m^2
Dead and live load factors	1 and 0.25 (i.e., 25%) respectively
Load combination I	$1.2[DL + IL \pm (EL_X \pm 0.3\ EL_Y)]$ $1.2[DL + IL \pm (EL_Y \pm 0.3\ EL_X)]$
Load combination II	$1.5[DL \pm (EL_X \pm 0.3\ EL_Y)]$ $1.5[DL \pm (EL_Y \pm 0.3\ EL_X)]$

Table 3. Loading data necessary for the design.

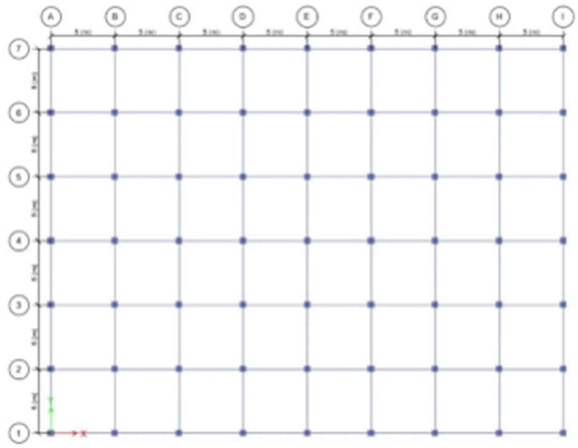


Fig 2. Grid Plan layout.

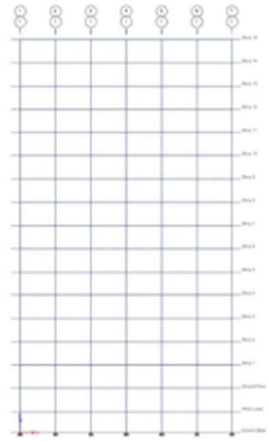


Fig 3. Elevation layout.

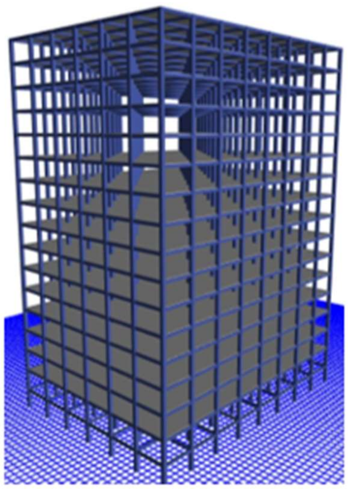


Fig 4. 3D view of Conventional structure.

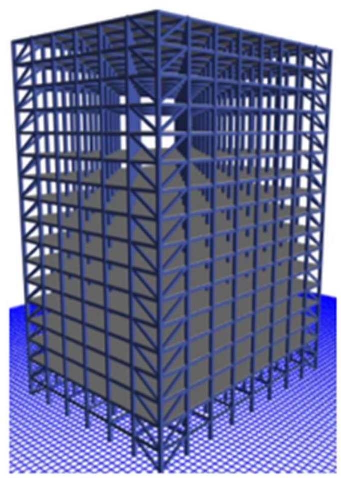
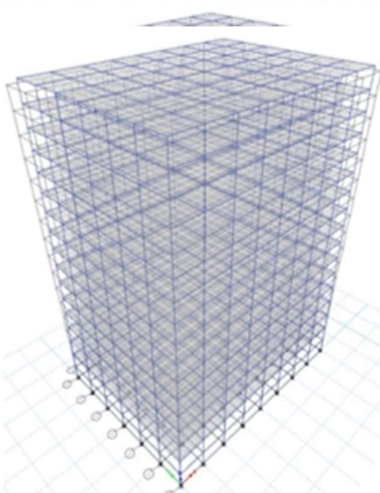


Fig 5. 3D view of post-tensioned structure.



'ig 6. Deformed shape of conventional structure.

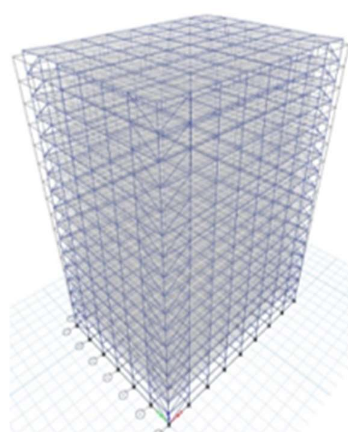


Fig 7. Deformed shape of post tensioned structure.

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The chosen building model prototypes are reviewed through pushover analysis. In order to specify gravity and imposed types of loads for the distinct earthquake regions (II, III, IV, and V), pushover analysis was first undertaken utilizing response spectrum analysis. For the zone where response spectrum analysis disclosed the finest seismographic effect on the RC framed structure, a lateral non-linear pushover analysis was then accomplished using displacement control.

Performance levels:

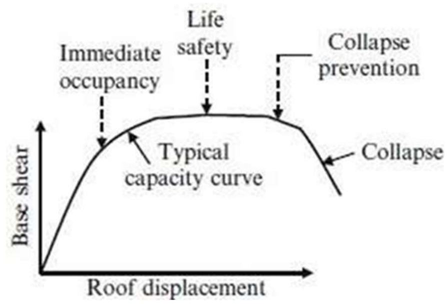

Fig 8. Qualitative performance level

V. RESULTS FROM RESPONSE SPECTRUM ANALYSIS

5.1. CONVENTIONAL STRUCTURE:

1. MAXIMUM STORY DISPLACEMENT - (Response Spectrum)

STORY	ZONE II (mm)	ZONE III (mm)	ZONE IV (mm)	ZONE V (mm)
Story 15	15.58	24.929	37.393	56.09
Story 14	15.349	24.559	36.839	55.258
Story 13	15.001	24.002	36.003	54.004
Story 12	14.534	23.255	34.883	52.324
Story 11	13.958	22.333	33.5	50.25
Story 10	13.281	21.25	31.874	47.812
Story 9	12.509	20.015	30.023	45.034
Story 8	11.649	18.639	27.958	41.938
Story 7	10.706	17.13	25.695	38.543
Story 6	9.685	15.497	23.246	34.869
Story 5	8.592	13.747	20.621	30.931
Story 4	7.429	11.886	17.83	26.744
Story 3	6.199	9.919	14.879	22.319
Story 2	4.905	7.848	11.772	17.658
Story 1	3.547	5.675	8.512	12.769
Ground Floor	2.136	3.417	5.126	7.689
Plinth Level	0.725	1.168	1.752	2.628
Column Base	0	0	0	0

Table 4. Maximum story displacement of Conventional Structure - (Response spectrum)

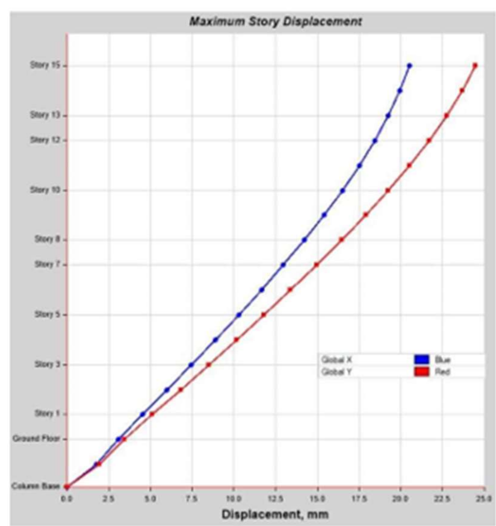

Fig 9. Maximum story displacement forzone V of conventional Structure

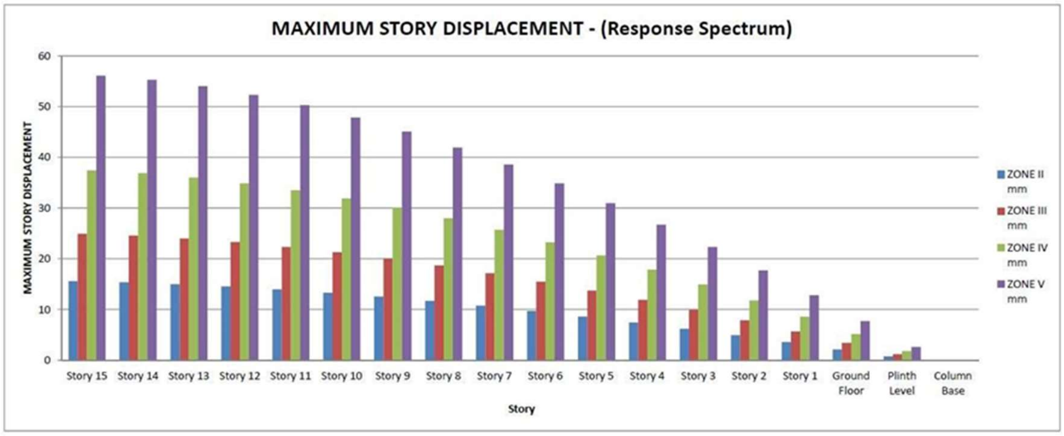

Fig 10. Maximum story displacement of Conventional Structure - (Response spectrum)

2. MAXIMUM STORY DRIFT- (Response Spectrum)

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STORY	ZONE II (Unitless)	ZONE III (Unitless)	ZONE IV (Unitless)	ZONE V (Unitless)
Story 15	0.000098	0.000158	0.000236	0.000355
Story 14	0.000150	0.000240	0.000360	0.000539
Story 13	0.000193	0.000310	0.000464	0.000696
Story 12	0.000228	0.000364	0.000547	0.000820
Story 11	0.000256	0.000409	0.000614	0.000920
Story 10	0.000280	0.000448	0.000672	0.001008
Story 9	0.000302	0.000484	0.000726	0.001088
Story 8	0.000323	0.000517	0.000775	0.001163
Story 7	0.000342	0.000547	0.000821	0.001231
Story 6	0.000360	0.000575	0.000863	0.001294
Story 5	0.000376	0.000601	0.000901	0.001352
Story 4	0.000390	0.000624	0.000936	0.001405
Story 3	0.000404	0.000646	0.000970	0.001454
Story 2	0.000418	0.000668	0.001002	0.001503
Story 1	0.000429	0.000687	0.001031	0.001546
Ground Floor	0.000428	0.000690	0.001036	0.001554
Plinth Level	0.000242	0.000389	0.000584	0.000876
Column Base	0	0	0	0

Table 5. Maximum story drift of Conventional Structure - (Response spectrum)

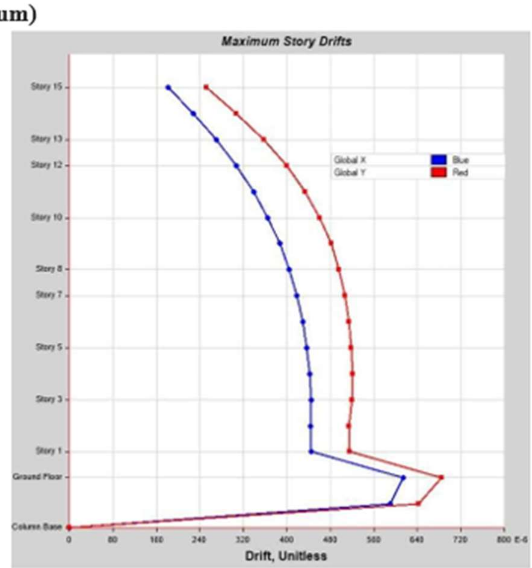

Fig 11. Maximum story drift for zone Vof conventional Structure

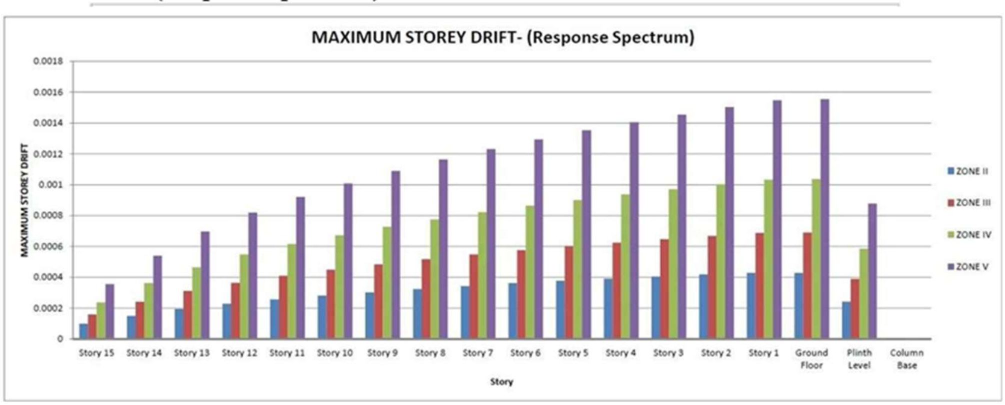

Fig 12. Maximum story drift of Conventional Structure - (Response spectrum)

3. MAXIMUM STORY SHEAR- (Response Spectrum)

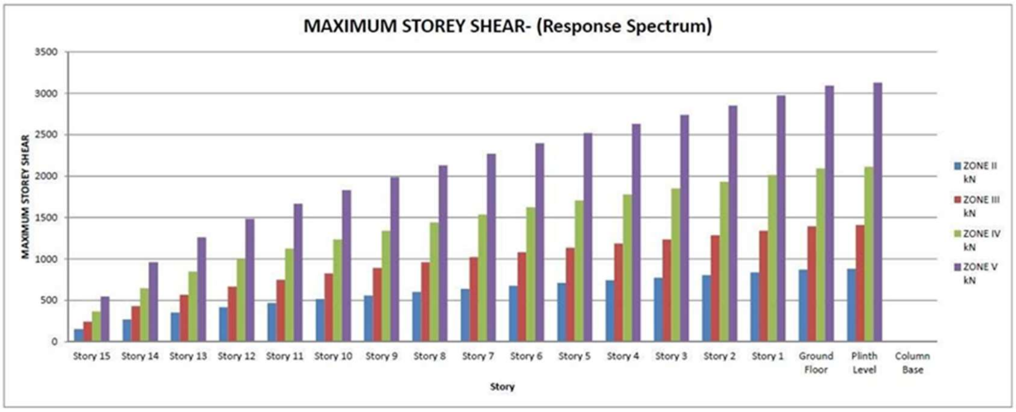

Fig 13. Maximum story shear of Conventional Structure - (Response spectrum)

STORY	ZONE II (kN)	ZONE III (kN)	ZONE IV (kN)	ZONE V (kN)
Story 15	152.1359	243.4245	365.1368	545.2204
Story 14	268.9106	430.2553	645.383	960.7272
Story 13	353.4796	565.5627	848.3441	1260.0857
Story 12	416.73	666.7625	1000.1437	1483.3979
Story 11	468.4338	749.4872	1124.2308	1666.083
Story 10	514.7835	823.6451	1235.4677	1830.0486
Story 9	558.3823	893.4023	1340.1034	1984.1167
Story 8	599.7686	959.6202	1439.4303	2130.0237
Story 7	638.8576	1022.1632	1533.2448	2267.7318
Story 6	675.4831	1080.765	1621.1474	2397.0446
Story 5	709.4711	1135.1481	1702.7221	2517.4622
Story 4	741.0352	1185.6504	1778.4756	2629.5149
Story 3	771.4762	1234.3507	1851.526	2737.5683
Story 2	803.1872	1285.0396	1927.5595	2850.1212
Story 1	837.6753	1340.0449	2010.0673	2972.7507
Ground Floor	871.3627	1393.4792	2090.2188	3092.5483
Plinth Level	881.014	1408.5528	2112.8293	3126.4556
Column Base	0	0	0	0

Table 6. Maximum story shear of Conventional Structure - (Response spectrum)

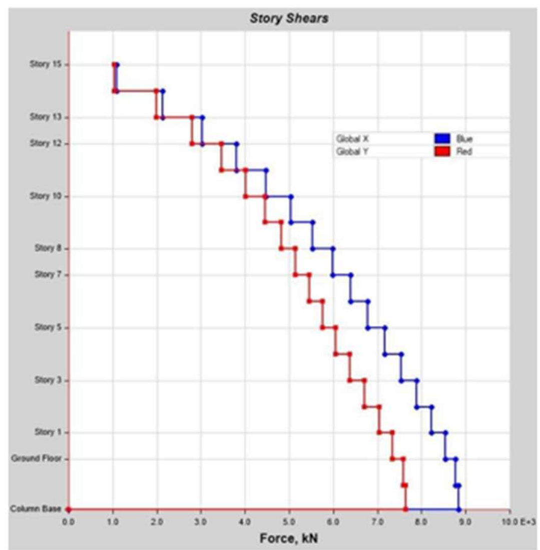

Fig 14. Maximum story shear for zone Vof conventional Structure

5.2. POST-TENSIONED STRUCTURE:

1. MAXIMUM STORY DISPLACEMENT - (Response Spectrum)

STORY	ZONE II (mm)	ZONE III (mm)	ZONE IV (mm)	ZONE V (mm)
Story 15	6.793	10.869	16.303	24.455
Story 14	6.576	10.522	15.783	23.675
Story 13	6.32	10.113	15.169	22.753
Story 12	6.028	9.644	14.466	21.699
Story 11	5.702	9.124	13.686	20.529
Story 10	5.349	8.558	12.837	19.256
Story 9	4.971	7.953	11.93	17.895
Story 8	4.572	7.315	10.972	16.458
Story 7	4.155	6.648	9.972	14.958
Story 6	3.723	5.956	8.935	13.402
Story 5	3.278	5.244	7.866	11.799
Story 4	2.822	4.515	6.772	10.158
Story 3	2.358	3.772	5.659	8.488
Story 2	1.889	3.023	4.534	6.801
Story 1	1.422	2.275	3.413	5.119
Ground Floor	0.952	1.523	2.284	3.426
Plinth Level	0.536	0.857	1.286	1.929
Column Base	0	0	0	0

Table 7. Maximum story displacement of post-tensioned Structure - (Response spectrum)

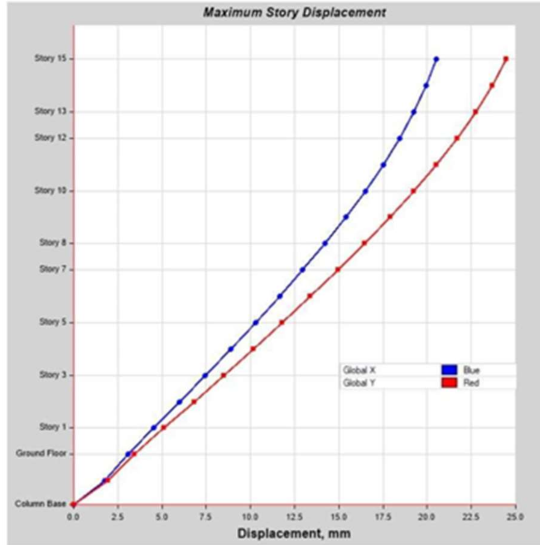

Fig 15. Maximum story displacement zone v of post-tensioned structure – (Response spectrum)

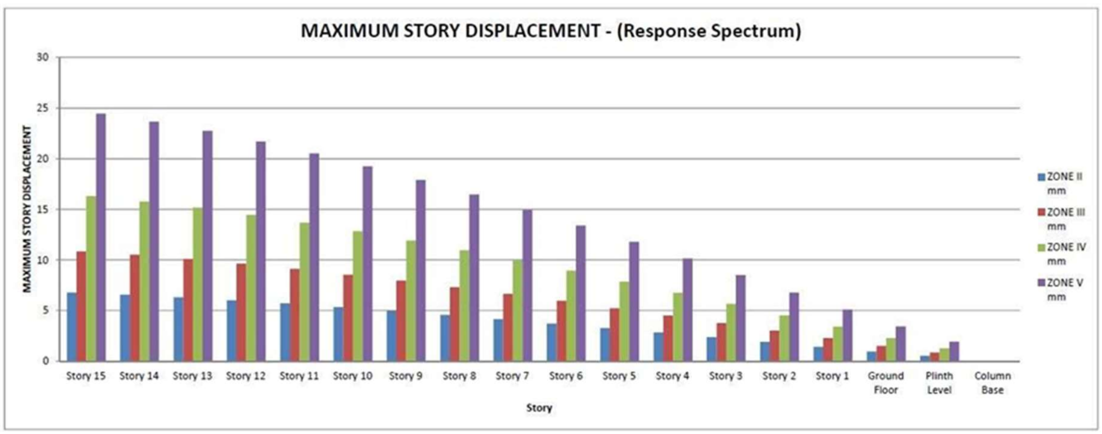

Fig 16. Maximum story displacement of Post-tensioned Structure - (Response spectrum)

2. MAXIMUM STORY DRIFT- (Response Spectrum)

STORY	ZONE II (mm)	ZONE III (mm)	ZONE IV (mm)	ZONE V (mm)
Story 15	0.000070	0.000112	0.000168	0.000253
Story 14	0.000085	0.000137	0.000205	0.000307
Story 13	0.000099	0.000159	0.000238	0.000357
Story 12	0.000111	0.000178	0.000266	0.000399
Story 11	0.000120	0.000193	0.000289	0.000434
Story 10	0.000128	0.000205	0.000307	0.000461
Story 9	0.000134	0.000214	0.000321	0.000481
Story 8	0.000138	0.00022	0.000331	0.000496
Story 7	0.000141	0.000225	0.000338	0.000507
Story 6	0.000143	0.000228	0.000343	0.000514
Story 5	0.000144	0.000231	0.000346	0.000519
Story 4	0.000145	0.000232	0.000347	0.000521
Story 3	0.000145	0.000231	0.000347	0.00052
Story 2	0.000143	0.000229	0.000343	0.000515
Story 1	0.000143	0.000229	0.000343	0.000515
Ground Floor	0.000190	0.000304	0.000456	0.000684
Plinth Level	0.000179	0.000286	0.000429	0.000643
Column Base	0	0	0	0

Table 8. Maximum story drift of post-tensioned Structure - (Response spectrum)

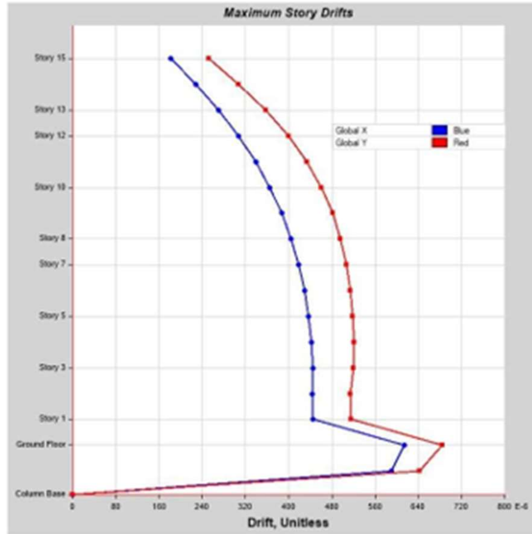

Fig 17. Maximum story drift zone v of post tensioned structure – (Response spectrum)

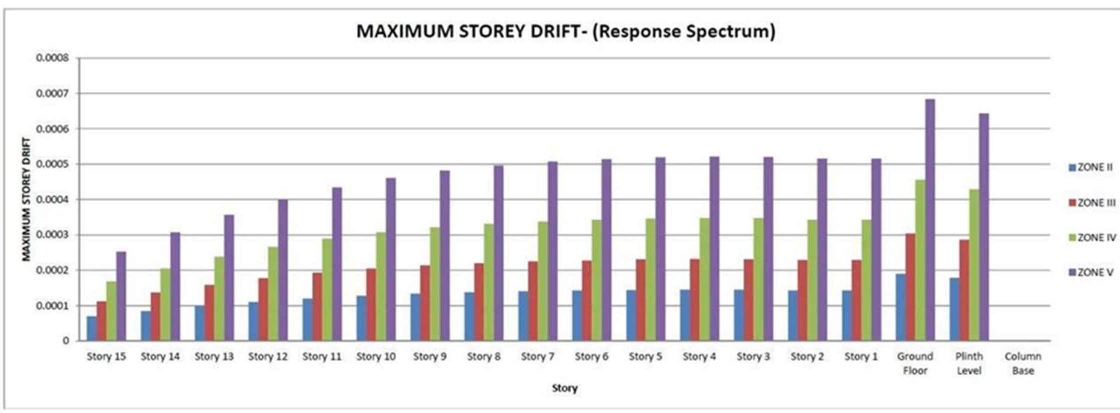

Fig 18. Maximum story drift of Post-tensioned Structure - (Response spectrum)

3. MAXIMUM STORY SHEAR- (Response Spectrum)

3. **MAXIMUM STORY SHEAR- (Response Spectrum)**

STORY	ZONE II (kN)	ZONE III (kN)	ZONE IV (kN)	ZONE V (kN)
Story 15	301.7484	482.7974	724.1961	1086.2941
Story 14	589.3011	942.8818	1414.3226	2121.484
Story 13	839.9486	1343.9178	2015.8767	3023.8151
Story 12	1055.92	1689.472	2534.208	3801.3119
Story 11	1240.7027	1985.1243	2977.6864	4466.5296
Story 10	1399.4358	2239.0973	3358.6459	5037.9688
Story 9	1537.815	2460.5041	3690.7561	5536.1341
Story 8	1661.3605	2658.1768	3987.2652	5980.8978
Story 7	1775.1985	2840.3176	4260.4763	6390.7145
Story 6	1883.4001	3013.4402	4520.1604	6780.2405
Story 5	1988.6021	3181.7634	4772.6451	7158.9676
Story 4	2091.6862	3346.698	5020.047	7530.0705
Story 3	2191.7441	3506.7906	5260.1859	7890.2789
Story 2	2285.9551	3657.5282	5486.2922	8229.4384
Story 1	2369.7502	3791.6003	5687.4004	8531.1007
Ground Floor	2436.4364	3898.2982	5847.4473	8771.1709
Plinth Level	2453.8023	3926.0837	5889.1255	8833.6882
Column Base	0	0	0	0

Table 9. Maximum story shear of post-tensioned Structure - (Response spectrum)

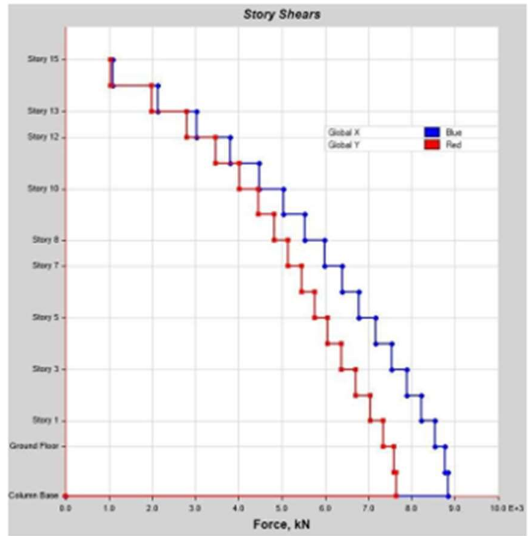

Fig 19. Maximum story shear zone v of post tensioned structure – (Response spectrum)

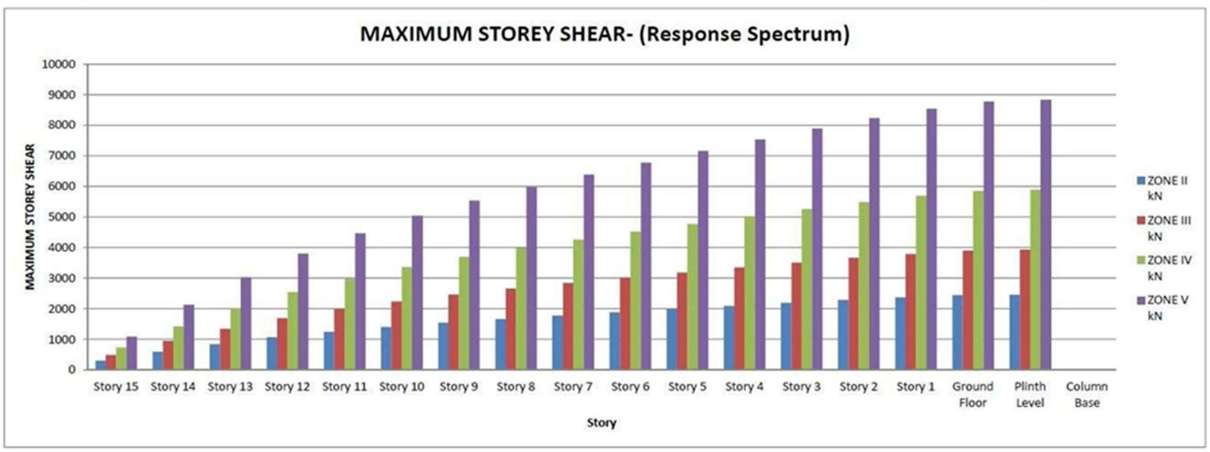

Fig 20. Maximum story shear of Post-tensioned Structure - (Response spectrum)

The maximum story displacement of the RC conventional structure of ZONE II is 15.58mm and for ZONE V is 56.09mm. Coming to a post-tensioned structure the maximum story displacement of ZONE II is 6.793mm and for ZONE V is 24.455mm.

Maximum story drift: The story drift of the RC conventional structure of ZONE II is 0.000429 and ZONE V is 0.001554 which developed at the ground floor story. Whereas for the post-tensioned structure of ZONE II is 0.00019 and for ZONE V is 0.000684.

The maximum story shear of RC conventional structure for ZONE II is 881.014kNand for ZONE V is 3126.4556kN at the base of the structure. Whereas the post-tensioned structure for ZONE II is 2453.8023kN and for ZONE V is 8833.6882kN. This means the story shear increases when compare to ZONE II to ZONE V.

Considering all the above-mentioned results ZONE V will have the maximum effect on the building when it is subjected to seismic effects taking the response spectrum and story response results.

Here, comparison graphs of Conventional structure vs. Post tensioned structure are presented below.

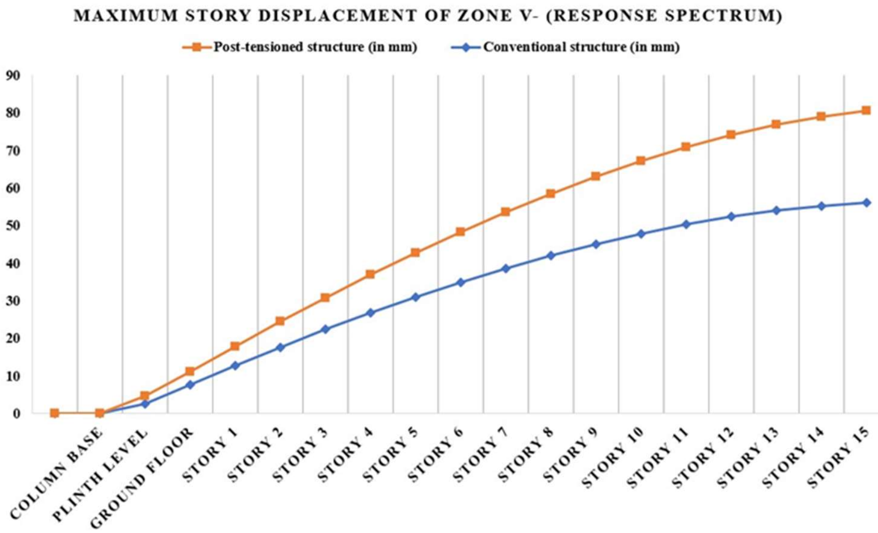

Fig 21. Maximum story displacement for Conventional structure vs. Post-tensioned Structure

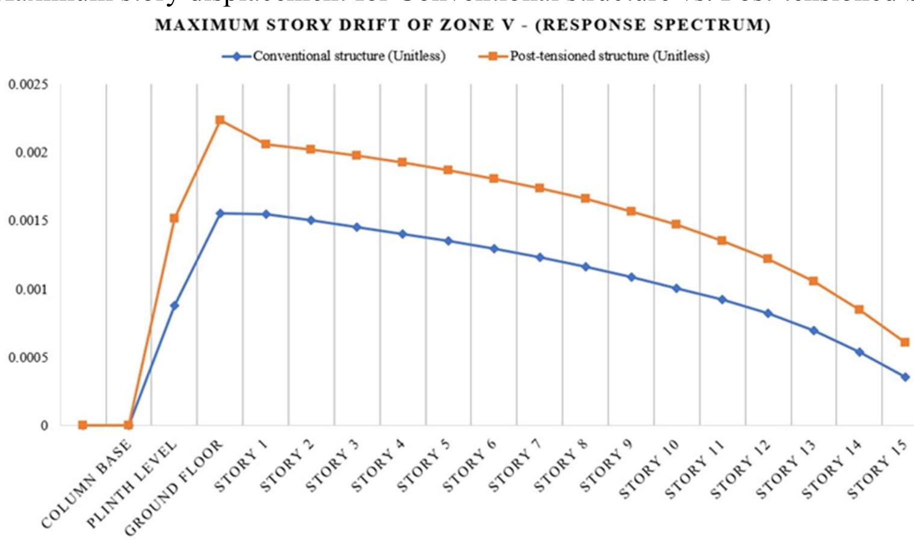

Fig 22. Maximum story drift for Conventional structure vs. Post-tensioned Structure

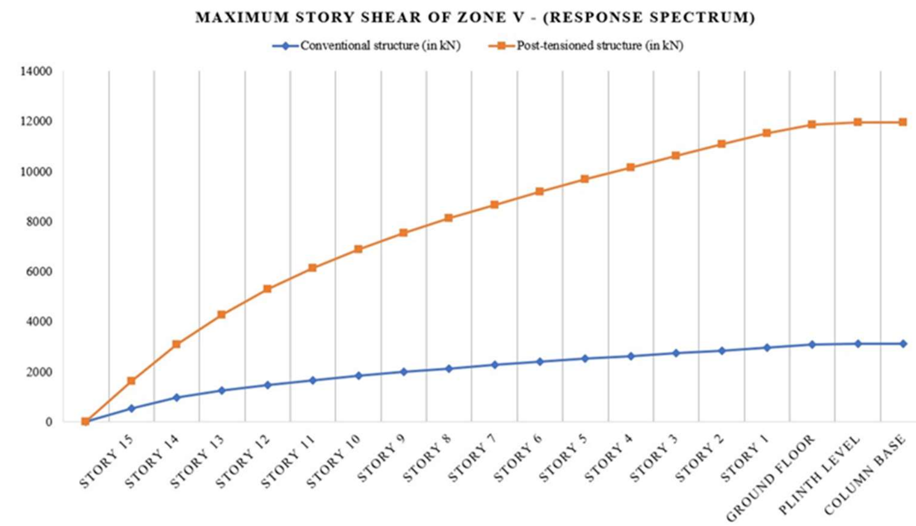

Fig 23. Maximum story shear for Conventional structure vs. Post-tensioned Structure

VI. RESULTS FROM PUSH-OVER ANALYSIS

A non-linear static pushover analysis was performed in a displacement control manner for ZONE V as which have the maximum seismic effect on both the RC framed structure and Post tensioned structure considering response spectrum analysis and story response plots.

6.1. CONVENTIONAL STRUCTURE

a) Target displacement results:

Displacement (mm)	627.399
Shear (kN)	19337.8343
Inherent Damping	0.05

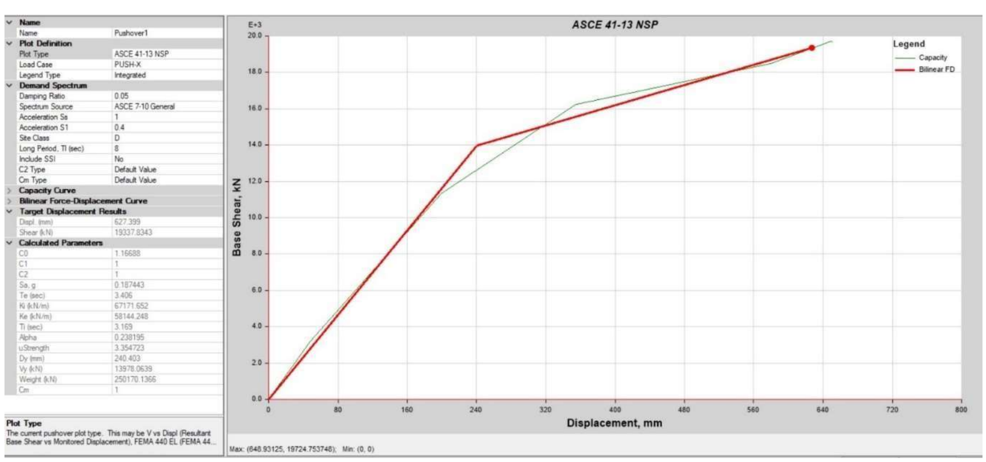

Fig 24. Base shear vs Displacement according to ASCE 41-13 NSP 7-10 Tables)

b) Hinge results:

Step	Displacement mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total Hinges
0	0	0	11764	0	0	0	0	11764	0	0	0	11764
1	47.551	3194.077	11760	4	0	0	0	11764	0	0	0	11764
2	199.396	11335.69	9290	2474	0	0	0	11764	0	0	0	11764
3	355.109	16237.303	8672	3092	0	0	0	11414	346	0	4	11764
4	355.981	16252.8081	8668	3096	0	0	0	11414	346	0	4	11764
5	579.181	18471.3998	8604	2936	0	224	0	11288	112	356	8	11764
6	648.931	19724.7537	8486	3052	2	224	0	11288	4	318	154	11764
7	650.457	19683.7084	8486	3052	2	224	0	11288	4	318	154	11764

Table 10. Hinge results of Conventional structure.

c) Performance point results:

Displacement (mm)	650.261
Shear (kN)	19688.99
Spectral displacement, Sd	558.134
Spectral acceleration, Sa	0.082503
T secant (sec)	5.219
T effective (sec)	5.303
Damping ratio, Beff	0.1997

Table 11. Performance point results of Conventional structure.

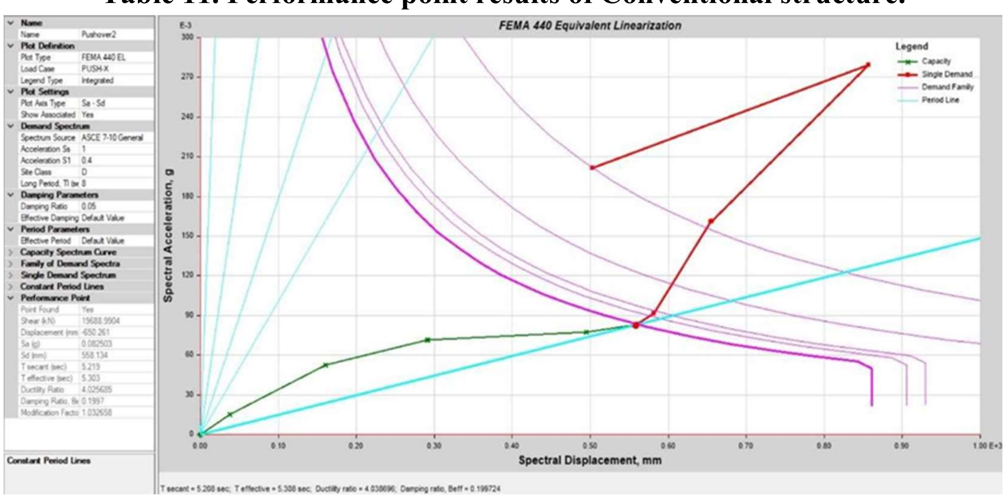

Fig 25. Spectral acceleration vs Spectral displacement.

6.2. POST-TENSIONED STRUCTURE:

d) Target displacement results:

Displacement (mm)	87.571
Shear (kN)	45192.0682
Inherent Damping	0.05

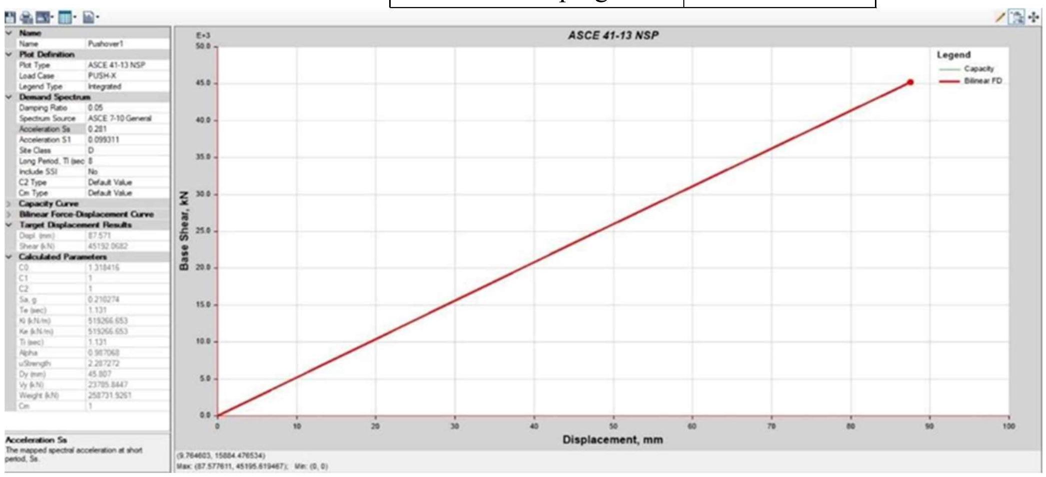

Fig 26. Base shear vs Displacement according to ASCE 41-13 NSP 7-10 Tables)

e) Hinge results:

Step	Displacement mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total Hinges
0	0	0	13668	0	0	0	0	13668	0	0	0	13668
1	42.229	21928.3711	13656	12	0	0	0	13668	0	0	0	13668
2	81.862	42285.1762	13114	546	8	0	0	13656	0	0	12	13668
3	81.864	42285.9629	13114	546	8	0	0	13656	0	0	12	13668
4	87.571	45195.6195	13000	660	8	0	0	13656	0	0	12	13668

Table 12. Hinge results of Post-tensioned structure.

f) Performance point results:

Displacement (mm)	72.111
Shear (kN)	37276.7379
Spectral displacement, Sd	54.686
Spectral acceleration, Sa	0.170978
T secant (sec)	1.134
T effective (sec)	1.254
Damping ratio, Beff	0.0757

Table 12. Performance point results of Post-tensioned structure.

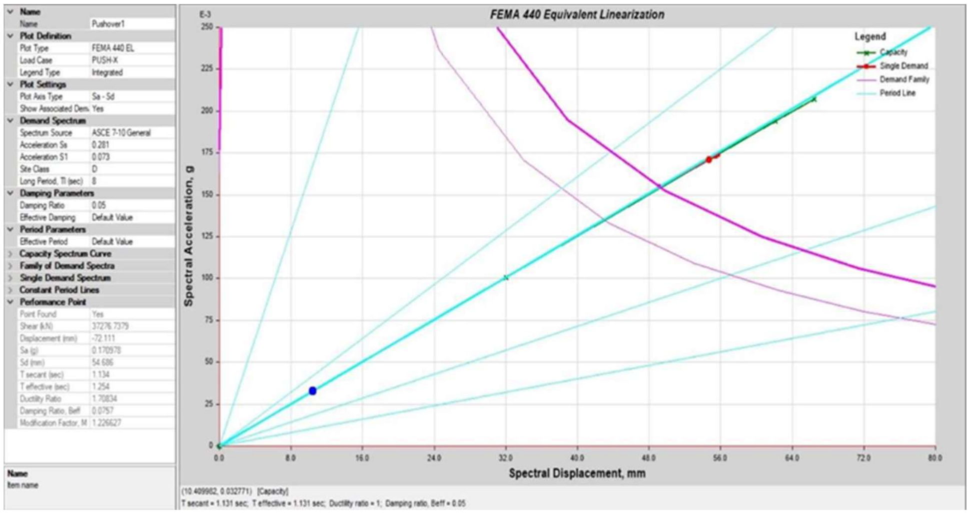

Fig 27. Spectral acceleration vs Spectral displacement

Considering the above shown results of seismic ZONE V when it is subjected to Non-linear static pushover analysis taking the prior ZONE V of response spectrum the target displacement, performance point and the respective shear at these points are plotted together to compare the conventional structure and post tensioned structure shown below.

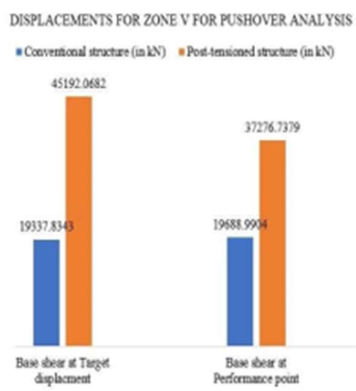

Fig 28. Displacements at performance point & Target displacement point

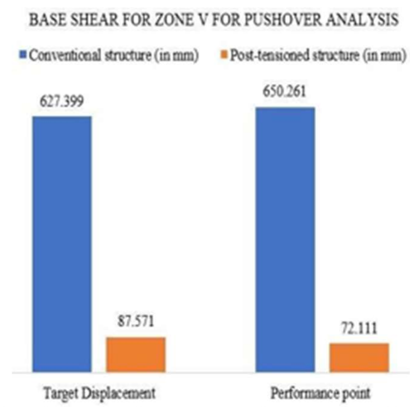

Fig 29. Base shear at performance point &Target displacement point

These allow post-tensioned structures to be designed with a considerable reduction in distortion and structural straightening, even when fully loaded. By doing this, post-tensioning can significantly reduce the displacement of a building compared to a standard RCC structure with a similar number of stories and exposure to seismic forces.

VII. CONCLUSIONS

Examining the nonlinear behavior of the structures is made easier by the pushover analysis. When a structure is subjected to seismic loads, the consequences in terms of pushover demand, capacity spectrum, and plastic hinges affect how the story behaves in the structure.

A. From response spectrum analysis:

1. Maximum Story displacement: Story displacement results from Response Spectrum analysis increases with the increase of seismic zones. displacement is very high at the top roof

and very low at the base of the structure. The maximum story displacement of the RC conventional structure of ZONE II is 15.58mm and for ZONE V is 56.09mm. Coming to a post-tensioned structure the maximum story displacement of ZONE II is 6.793mm and for ZONE V is 24.455mm. This means base shear decreases by more than 56.40% in the case of a post-tensioned structure with the conventional structure when compared to the ZONE V case.

2. Maximum story drift: The story drift of the RC conventional structure of ZONE II is 0.000429 and ZONE V is 0.001554 which developed at the ground floor story. Whereas, for post-tensioned structure is of ZONE II is 0.00019 and ZONE V is 0.000684. It is stated that the story drift grows as the seismic zone factor increases, with the highest story drift possible at ZONE V for the largest seismic effect. This indicates that the tale drift increases from ZONE II to ZONE V, and the maximum story drift falls by more than 55.984% when comparing the post-tensioned structure to the conventional structure in the ZONE V instance.

3. Maximum Story Shear: In all of the building models subjected to seismic loads evaluated, story shear decreases as building height increases and increases at the top level. The story shear is greatest near the structure's base. The maximum story shear of RC conventional structure for ZONE II is 881.014kNand for ZONE V is 3126.4556kN at the base of the structure. Whereas the post-tensioned structure for ZONE II is 2453.8023kN and for ZONE V is 8833.6882kN. This means the story shear is increased when compared to ZONE II to ZONE V, and the maximum story shear in the post-tensioned structure which available at the base is increases by more than 3.6 times in the case of the conventional structure when compared to the ZONE V case.

Considering all the above-mentioned results ZONE V will have the maximum effect on the building when subjected to seismic effects.

B. From pushover analysis:

1. Based on the pushover analysis results, the conventional reinforced concrete structure's goal displacement is 627.399 mm, and the building performance point is 650.261 mm, indicating that the traditional structure is not at all safe. In the case of ZONE V, the target displacement of the post-tensioned reinforced concrete structure is 87.571mm, and the building performance point is 72.11mm, indicating that the conventional structure is safe. When compared to the reinforced concrete structure, the target displacement is reduced by 86.04%, and the performance point is reduced by 88.91%.

2. According to the results of the hinges in a conventional reinforced concrete structure, the hinges formed at a target displacement of 650.261mm are A-B A-IO, and after CP 154 hinges are formed. In the case of ZONE V, the hinges formed at a target displacement of 87.571mm are A-B A-IO and after CP 12 hinges, indicating that the entire strength of the structure is utilized and the safety of the structure is greater in the post-tensioned structure when compared to the conventional reinforced concrete structure.

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