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Seismic Response of High-Rise Zipper Braced Frame Structures with Outrigger Trusses

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Abstract – *Concentrically supported casing (CBF) structures give high firmness and moderate pliability, while they are inclined to harm focused inside a solitary floor. To defeat this downside, scientists have proposed to add a vertical part to the CBF framework, named a "zipper segment", with the plan to include the clasping and additionally yielding of a few supports. In this manner, the zipper section individuals are intended to move the unequal powers brought about by locking of supports in chevron arrangement along the structure tallness. By utilizing the zipper supported casing framework (ZBF), the harm is all the more consistently dispersed over the tallness. Anyway structures taller than 8-story are inclined to sidelong float intensification because of the higher mode impacts. In this examination, so as to control the horizontal float, it is proposed to include a lot of outrigger supports more than one story, at the rooftop level, and if vital at another floor among those situated at the mid-stature. As needs be, the motivation behind this examination is two-crease: I) to explore the inelastic conduct of the 12-and 16-story ZBF building structures with flexible zippers situated in a high hazard seismic zone and ii) to consider the conduct of ZBF structures when outrigger supports are included.*

Key Words: ZBF, 12 to 16th story building, Chevron propped framework.

1. INTRODUCTION

To address the above concern, Khatib et al (1988) proposed an adjusted CBF framework marked CBF with zipper segments. By definition, the zipper segment is a vertical part added to a CBF framework in chevron arrangement so as to interface together all support to pillar meeting focuses. Subsequently, all compressive supports will be compelled to clasp at the same time while just a couple of malleable supports will yield. At the point when ground movement turned around supports that acted beforehand in strain lock in pressure while the zipper segment moves the uneven burden upwards or downwards relying upon ground movement signature. This new basic framework can compel practically all supports to clasp or yield and a lot of vitality is dispersed in the framework.

In the previous decade, a few analysts have directed examinations in this theme as follows:

- Sabelli (2001) proposed structure models for CBF with feeble zipper swagger. In this plan strategy, zipper segments are permitted to clasp and to yield while supports act in inelastic range.
- Tremblay and Tirca (2003) proposed plan rules for CBF framework with solid zipper section. In this light, zipper sections were intended to act in flexible range, permitting supports to clasp at the same time upwards or downwards (Tirca and Tremblay, 2004).
- Leon and Yang (2003, 2008) built up a comparable framework marked CBF with suspended zipper swagger. A bracket framework was included at the highest floor while highest floor supports were intended to react in flexible range. Yielding is permitted to happen in the zipper section.
- Tirca and Chen (2012) and Chen (2011) have refined the underlying plan technique proposed by Tremblay and Tirca (2003). The framework is marked CBF with versatile zipper segments.

Objectives and Scope

The point of this examination venture is two overlay:

- To research the inelastic conduct of the 12-and 16-story ZBF building structures with versatile zippers situated in a high hazard seismic zone.
- To accentuate the impact of adding outrigger brackets to the zipper supported casing building structure.

2. LITERATURE REVIEW

Tension Zipper swagger methodology

As indicated by Khatib and Mahin (1988), the zipper impact is activated when the structure is avoided looking like the principal vibration mode. The support part at the ground floor clasps right off the bat and triggers pliable powers in the above zipper section, which causes the upper floor support to clasp. A similar procedure is step by step spread upwards. Nevertheless, in light of this plan approach, zipper segments are proportioned to convey just ductile powers, which implies that consistently the first clasped support is at the ground floor. Furthermore, so as to have the zipper propped outline framework diverted in the primary mode, it requires supports on one half-range of the propped casing to clasp, at that point, after ground movement turned around sign, the staying half-length supports will clasp. For this situation, the ductile powers in zipper sections can be determined as the summation of every single vertical part of the un-adjusted burdens came about because of interior powers created in supports.

In addition, comparing to the restrictions of strain zipper swagger, Khatib and Mahin (1988) called attention to a few inquiries in regards to the framework plan and conduct:

- "What occur if the clasping of supports starts from different stories rather than the principal story?"
- "Could the zipper components be enacted in pressure rather than strain?"
- "What if the structure isn't in a first mode redirected shape when the zipper impact is enacted?"
- "How to extent the supports to expand the adequacy of zipper impact?"
- "How to pick the general solidness of the zipper components and bars?"

Until this point, a few scientists proposed forms of ZBF frameworks by attempting to fit the reaction of the above inquiries in the proposed plan rules: Sabelli (2001), Tremblay and Tirca (2003), Yang and Leon (2003).

Weak Zipper swagger methodology

To forestall the development of powerless story component and interest a uniform float distribution along the structure stature, a plan strategy called "frail zipper swagger methodology" is proposed by R. Sabelli (2001). As indicated by his proposition, the plan of support individuals ought to follow a similar code prerequisites as accommodated CBF's supports. He suggested that the compressive and ductile limit of zipper sections must arrive at the quality of supports situated at the level underneath. In addition, the inelastic interest in the two situations when zipper segments act in pressure and pressure ought to be considered in structure.

Subsequent to applying the powerless zipper swagger methodology in a 3-and a 6-story zipper propped outlines, R. Sabelli (2001) presumed that by having zipper segment introduced, the interstorey float request is more consistently circulated than that in a chevron propped outlines with solid bars. Between the two examined outlines, the 3-story zipper outline shows better seismic execution that the 6-story casing, and match the normal conduct of zipper propped outline. Support individuals have clasped at all floor levels and floats are almost equivalent created at each floor. Then again, for the 6-story outline, a few disparities have been watched. Rather than diverting on the principal mode, the disfigured state of the 6-story outline approximated the state of the second method of vibration. What's more, there are critical clasping and strain yielding saw in zipper segments of the 6-story outline, which was made a decision about conflicting with the normal execution of zipper supported casing.

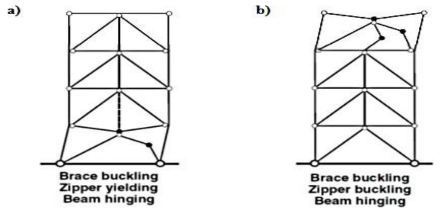


Figure 2.3 Behavior of zipper braced frame system with weak zipper column (Tirca & Tremblay, 2004): a) zipper yields in tension; b) zipper buckles in compression

Generalities with respect to the outrigger and belt frameworks

The outrigger support framework was applied in the Place Victoria Office tower in Montreal in 1965. From that point forward, the outrigger idea has been broadly utilized in the plan of elevated structures. In outrigger structures, "outriggers" are utilized to associate outside sections at the detachable of the structure to the horizontal burden opposing center which can be either shear divider or supported casing. This methodology activates the hub quality and solidness of outside sections to give (Taranath B. , 1975) protection from the upsetting second brought about by horizontal powers. In the meantime, by including outrigger supports the general solidness of the structure inwrinkles. Nonetheless, the traditional outrigger brackets have hindrances with the end goal that space-arranging confinements and the prerequisite of creating unique subtleties for interfacing these supports to the auxiliary framework.

The advancement of outrigger supported edge framework began during the '70s. In this manner, Taranath (1974) analyzed the ideal area of a solitary belt bracket added to the auxiliary framework with the intend to lessen the structure's float under the breeze load and has introduced a basic technique for investigation. He likewise reasoned that the ideal area of the belt support is at 0.445 occasions the structure stature estimated from the top. McNabb et al (1975) confirmed Taranath's (1974) method and suggested the ideal area of two outrigger brackets. He examined the controlling components of float decrease in outrigger structure and expressed that the ideal areas for two outriggers added to the propped outline framework ought to be 0.312 and 0.685 occasions the structure tallness, separately, estimated from the top of the structure. Later on, Smith at al. (1991) proposed basic rough rules for deciding the area of the outriggers for primer examination of outrigger propped outlines.

3. STRUCTURE METHODOLOGY OF ZIPPER BRACED FRAME AND OUTRIGGER TRUSSES

Design of braces in chevron configuration
Brace members resist the combination of story shear, Fi and gravity load component transferred from the above story to the CBF's columns in agreement with the NBCC 2005 loading

combination: 1.0E + 1.0DL +0.5LL + 0.25SL. Based on this design requirement, the story shear in the i^{th} floor is equally distributed among the tensile and compressive brace as follows:

$$T_{f(i)} = C_{f(i)} = V_i / 2\cos\theta_i$$

Following the design regulation, the compressive and tensile resistance of braces should be larger than the factored loads, while the C_r and T_r are given below

$$C_r = 0.9AF_y(1 + \lambda^{2n})^{-1/n}$$

$$T_r = 0.9AF_y$$

where, A is the cross-sectional area of the brace member; Fy is the strength of steel material, n= 1.34 for hot-rolled, fabricated structural sections, and hollow structural sections manufactured according to CSA Standard G40.20, Class C (cold formed non stress relieved) and λ is the slenderness ratio.

Design of beams and columns in concentrically braced frame

The beams and columns in CBF shall be designed by applying the capacity design concept.

Beam design

The beams in braced frames are not only carrying gravity loads from the floor, but also an extra portion of load transferred from the braces in the same floor. Therefore, depending on braces buckled or not, two scenarios should be considered:

In the first scenario, braces have buckled and beam has lost its support from the braces. In this case, the beam should carry the entire gravity component DL+0.5LL without considering braces support. In addition, it should carry the axial load developed when the compressive brace reached the probable post-buckling strength Cu' = 0.2AFyRy, and the tensile brace may reach the probable yielding strength Tu = ARyFy.
In the second scenario, braces are on the verge of buckling and support beams at their mid-span. The compression braces reach their probable compressive strength Cu = 1.2(Ry/ϕ)Cr whit Ry = 1.1 and ϕ = 0.9 and the tensile braces have their probable tensile strength as Tu = ARyFy.

Column design

In this study, columns of CBF are designed as continuous columns over two adjacent stories and should be proportioned to resist the gravity load in addition to the vertical projection of braces capacity in compression. Herein, the vertical projection of tensile forces acts as uplift forces. In addition, a fraction of bending moment computed as 0.2ZFy must be considered in interaction to the axial force, where Z is the plastic section modulus of the column section.

4. Comparative Study of Time-History Response of ZBF Building Structures with and without Outrigger Trusses under various Ground Motions

The time-history response of braces buckling and beams hinging under the N6, N1 and N7 records is illustrated in Figure 5.3.

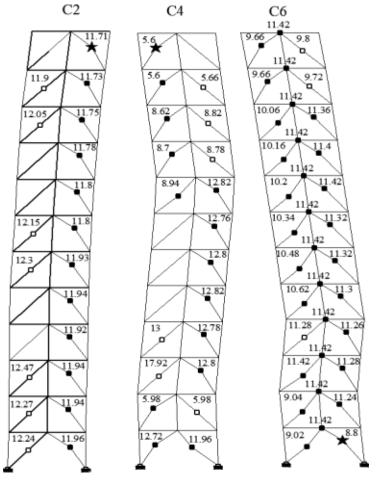


Figure 5.2 Time-history response of brace buckling and beam hinging for 12-storey building without outrigger truss under motions C2, C4, and C6 (the first buckled brace; ● subsequently buckled brace and beam hinging; ○ yielding of brace)

Under movement N6, kicking of supports started at the top level and advanced descending until the base floor in just 0.31 s. At the point when ground movement turned around, supports having a place with the other half-length came to clasping beginning from the base and advancing toward the top. After practically all supports have clasped and a couple of arrived at yielding, bars began pivoting in all the floors start to finish. Along these lines, the 12-story building has arrived at the breakdown status while exposed to 88% of the scaled ground movement N6. Likewise, under the ground movement N7, the breakdown status is arrived at when the structure was exposed to 96% of the scaled ground movement. The main support clasping happens at the ground floor and spreads upward. Also, all light emissions 12-story building are pivoted during the N7 ground movement excitation. The structure reaction under the ground movement N1 shows bigger parallel power request forced at lower floors. In this way, 9 supports in the left half-length clasped, and 7 supports in the correct half-range have arrived at yielding. The greater part of the locking and yielding occurred in the lower 7 stories of the structure.

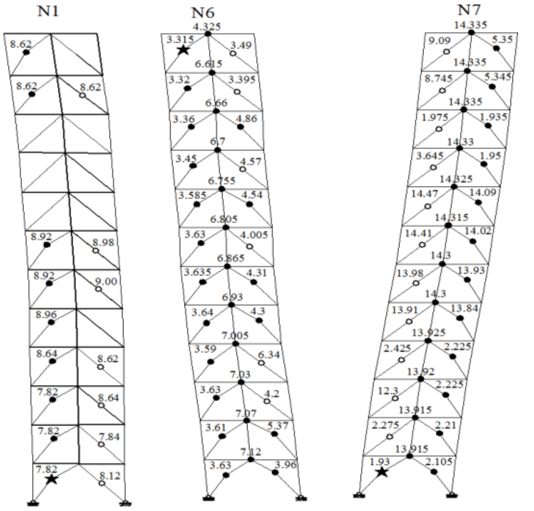


Figure 5.3 Time-history response of brace buckling and beam hinging for 12-storey building without outrigger truss under motions N1, N6, and N7 (the first buckled brace; ● subsequently buckled brace and beam hinging; ○ yielding of brace)

Under subduction ground movements, the higher methods of the 12-story building are additionally initiated. The time history of supports clasping and pillars pivoting came about under motions S2, S4, and S7 is appeared in Figure 5.4. Inside this group, four ground movements portrayed by enormous PGV/PGA proportion (S4 to S7) drove the 12-story working to crumple. As to this, the examined assembling can convey about 70% of S4, S5, S6 and 53% of the S7 request. Under movement S7, the 12-story building arrives at the disappointment status when exposed to 47% of the scaled ground movement. The primary support clasping happens at the highest floor at 109.8 s and advances descending at the same time. Inside 1.1s, all supports on the correct half-range clasped from the twelfth to second floor. After ground movement re-versed, the clasping of supports begins from the base floor level and spreads upward yet not in succession. After all supports clasped or yielded, shaft pivots begin to frame at all floors. Underground movement S4, the 12-story constructing additionally arrives at the disappointment status while exposed to 63% of the scaled ground movement. The first clasped support was between cepted at the ground floor and in both half-ranges clasping of supports proliferated upward.

From that point forward, the pillar pivoting begins from the base to the highest floor level. Under the S2 ground movement, half of supports have either clasped or yielded. Be that as it may, supported having a place with the fifth floor stayed to carry on in flexible range. The primary support clasping has started at the ground floor and clasping of supports advances upward.

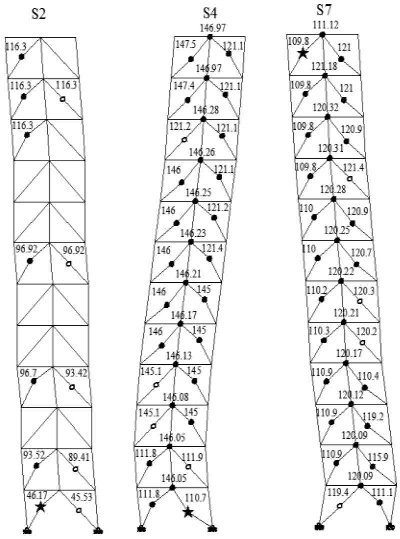


Figure 5.4 Time-history response of brace buckling and beam hinging for 12-storey building without outrigger truss under motions S2, S4, and S7 (the first buckled brace; ● subsequently buckled brace and beam hinging; ○yielding of brace)

The conduct of rooftop outrigger brackets added to the 12-story building

The geometrical arrangement of diagonals in outrigger brackets has a significant effect in plan if the investigated rise bolsters auxiliary bars. As to, under the gravity load segment, diagonals of outriggers could be exposed to strain or to compression. In the event that the geometry picked for outrigger diagonals is inclined to improvement of pliable powers, as is appeared in Figure 5.8a, the framework is cost-proficient. The hub powers created in diagonals from the gravity load segment (DL+0.5LL) are appeared in Figure 5.8b. For examination reason, a geometrical setup of diagonals stacked in pressure from the gravity load part (DL +0.5LL) is appeared in Figure 5.9. As is normal, the hub power in the inside outrigger boards is twice that that in the outside outrigger board. On the off chance that the time-history stacking is applied to the structures notwithstanding the gravity part, as is appeared in Figure 5.8, the powers created are bigger in pressure than in pressure. Time-arrangement of pivotal power created in slanting of rooftop outriggers under the crustal ground movement C2 are appeared in Figure 5.10a for the outside board and in Figure 5.10b for the interior board. What's more, the most extreme worth came to under the C4 and C6 ground movements is likewise demonstrated in the chart.

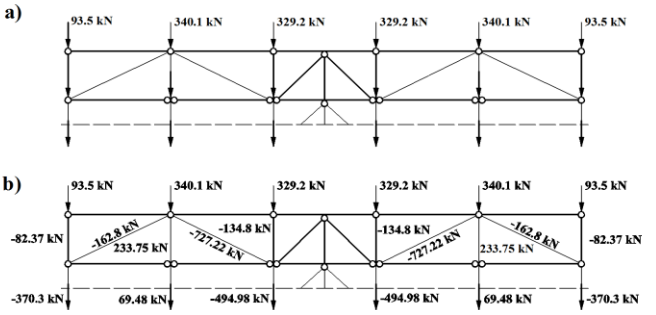


Figure 5.8 Outrigger truss configuration 1 and axial loads developed in the outrigger diagonals under the gravity component

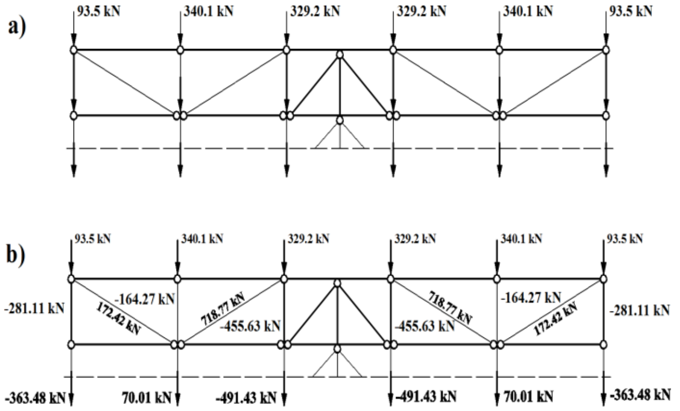
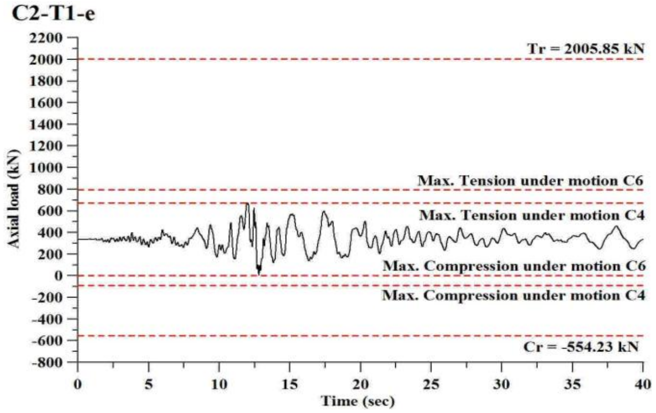


Figure 5.9 Outrigger truss configuration 2 and the axial loads developed in the outrigger diagonals under the gravity component



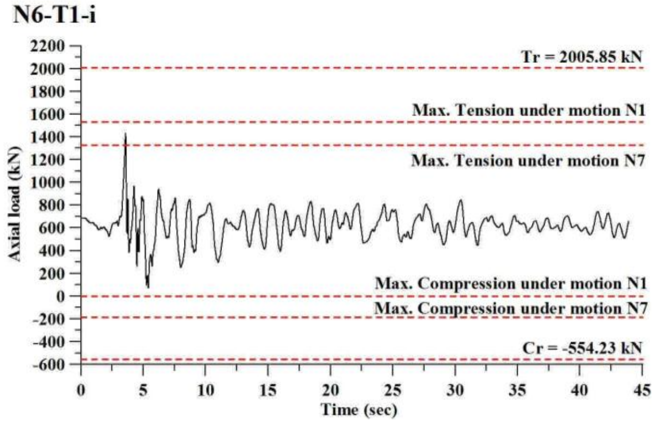
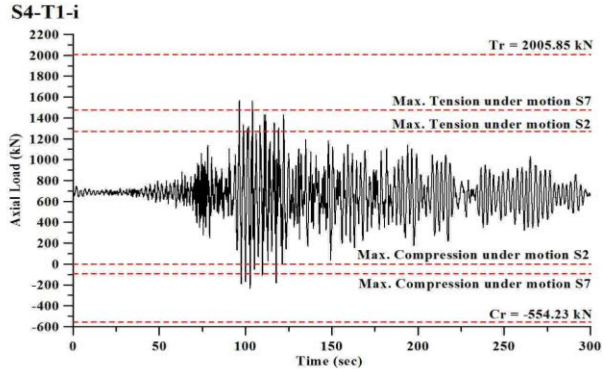


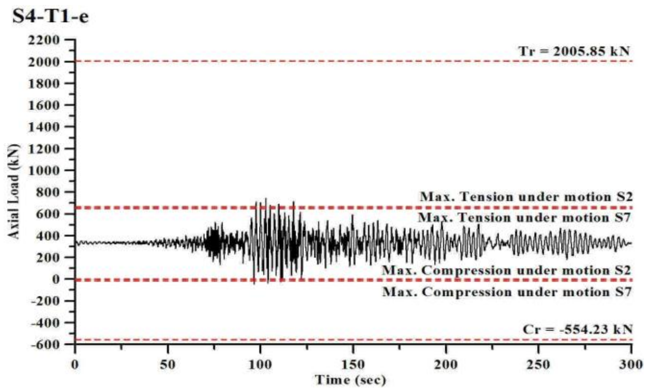
Figure 5.10 Time-history axial load in outrigger truss elements: a) exterior panel T1-e and b) interior panel T1-i under ground motion C2

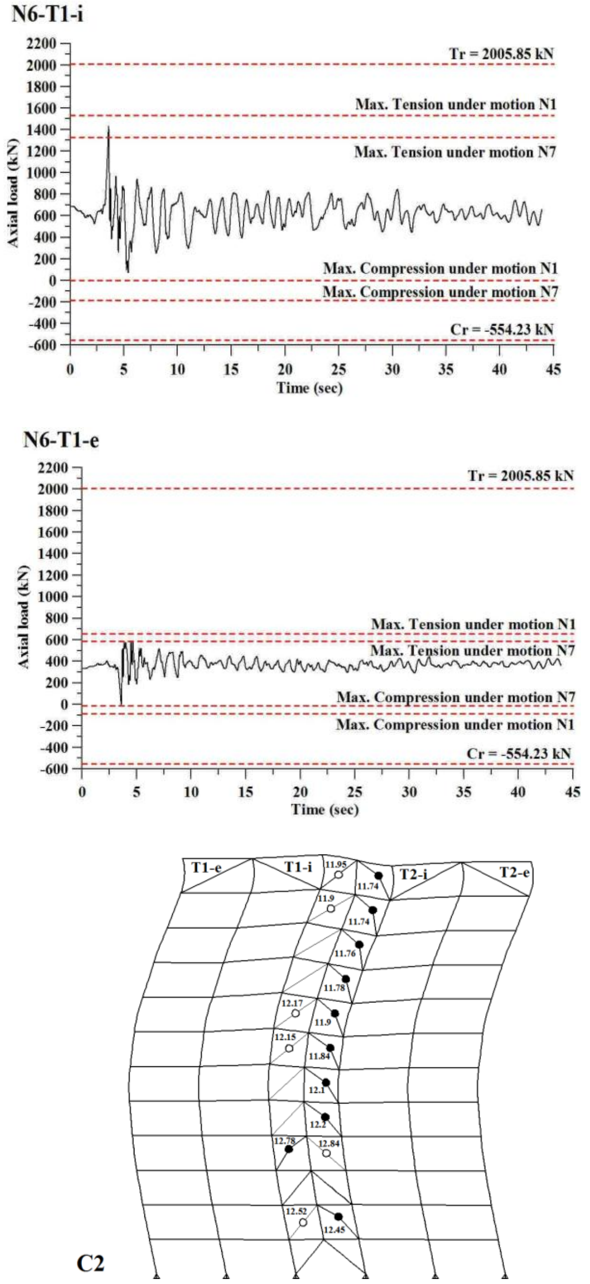
The time-history series of axial force developed in diagonal of outriggers under the subduction ground motion S4 and near-field ground motion N6 is shown in Figures 5.11 and 5.12

Time-history axial load in outrigger truss elements: a) exterior panel, T1-e and b) interior panel T1-i under ground motion S4.

The deflected shape of the entire elevation under the crustal ground motion C2 is shown in Figure 5.13.







Time-history axial load in outrigger truss elements: a) exterior pane T1-e and b) interior pane T1-i under ground motion N6 and Deformed shape of the 12-storey ZBF-RT under ground motion C2

CONCLUSIONS

a. In this exploration, the structure of the outrigger support components follows the idea of removal similarity technique proposed by Stafford and Salim (1981) and the realistic strategy created by Hoenderkamp and Bakker (2003). Likewise, to enhance the size of outrigger bracket diagonals, two outrigger supports arrangements were thought of. It was discovered that the ideal arrangement of outrigger bracket diagonals is that when the corner to corner are stacked in pressure under the gravity load segment. Subsequently, diagonals function as pre-stress individuals and are intended to react generally in pressure under all ground movements considered.

b. The consequences of the nonlinear powerful examinations introduced in Chapter 4 and 5 have demonstrated that for the 12-story constructing, the interstorey float proportion is all around controlled when the considered structures were exposed to Crustal and Near-field ground movements. Be that as it may, when the solid excitations like Subduction ground movements is applied, the structure can't convey 100% the heap came about because of scaled ground movements and enormous interstorey float is watched.

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