



**Structural Design and Cost Comparison Between a
Concrete Structure and Steel a Structure of a Tall
Residential Building in Dubai Subjected to Seismic and
Wind Loads**

**التصميم الإنشائي ومقارنة التكلفة بين هيكل خرساني و هيكل حديد لمبنى
سكني شاهق في دبي معرض لأحمال الزلازل والرياح**

by

OSMAN OMER MEHMOUD ELNAIM

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of the requirements for the degree of
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ABSTRACT

There are many materials and structural systems of buildings over the world such as Steel structures, Concrete, Wood, Stone and Brick/Masonry. Apparently, each one of them is having its properties and limitation of use.

Nevertheless, the famous structural systems that used for designing and constructing the skyscraper are the steel and concrete structures since the Wood, Stone and Masonry cannot be used in the tall buildings.

It is very significant to compare between the steel structure and concrete structure when designing a skyscraper, to withstand the Seismic, Wind load, Live, Dead loads and to make the cost analysis related each one to choose the better one.

Obviously, each structural system has advantages and disadvantages which should be taken into consideration when selecting one of them.

In this dissertation, a comparison is made between the two tall buildings which made of reinforced concrete and steel in Cross section of structural element, Durability, Resistance to Earthquake and Wind loads, Load carrying capacity, Self-weight, Construction cost, and Construction speed.

However, the steel and reinforced concrete skyscrapers are designed using ETABS program, the post tension slabs and beams are designed by Safe program, and the results compared by Microsoft excel.

المخلص

تتعدد العديد من المواد والأنظمة الإنشائية للمباني في جميع أنحاء العالم مثل الصلب والخرسانة والخشب والحجر
رب / البناء. على ما يبدو ، كل واحد منهم له خصائصه ، ومحدودية الاستخدام
ومع ذلك ، فإن الأنظمة الإنشائية الشهيرة المستخدمة في تصميم وبناء ناطحة السحاب هي الهياكل الفولاذية والخرسانية
حيث لا يمكن استخدام الخشب والحجر والبناء في المباني الشاهقة
من المهم جدًا المقارنة بين الهيكل الفولاذي والهيكل الخرساني عند تصميم ناطحة سحاب ، لتحمل الأحمال الزلزالية
وحمل الرياح والأحمال الحية والميتة
من الواضح أن كل نظام هيكلي له مزايا وعيوب يجب أخذها في الاعتبار عند اختيار أحدها
في هذه الرسالة ، تم إجراء مقارنة بين مبنين شاهقين مصنوعان من الخرسانة المسلحة والفولاذ في المقطع العرضي
للعنصر الهيكلي ، والمتانة ، ومقاومة الزلازل وأحمال الرياح ، والقدرة على تحمل الأحمال ، والوزن الذاتي ، وتكلفة
البناء ، وسرعة البناء
وقد ETABS ومع ذلك ، فقد تم تصميم ناطحات السحاب المصنوعة من الفولاذ والخرسانة المسلحة باستخدام برنامج
تم. Microsoft Excel ، وتم مقارنة النتائج بواسطة Safe تم تصميم ألواح وعوارض ما بعد الشد بواسطة برنامج
تصميم ناطحتي السحاب المصنوعتين من الصلب والخرسانة باستخدام برنامج ايتابس و اكسل

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CHAPTER 1: INTRODUCTION

1.1 Research Background:

The tall buildings (skyscrapers) have been increasing hastily in most of countries due to shortage of lands and significance rise of population. For instance, constructing a big number of apartments in Highrise building vertically in specific area can be more economical than building the same number of apartments in horizontal areas since the first option of building vertically will save the areas for another use. Moreover, skyscrapers similarly allow for a more revenue margin, because they normally create further rent income for its owner. Hence, the Engineers have to think about the advantages of constructing the skyscrapers taking the disadvantages into consideration.

1.2 The skyscrapers importance

Skyscrapers are the greatest system to get maximum units trade space in small urban blocks. Height generates areas for building in crowded towns. Moreover, skyscrapers are likewise inventive in the conservational division. They decrease urban extension, so a better conservation of natural zones. Relying on how skyscrapers are constructed, many of them are similarly energy resourceful even though they are from recycled resources. A lively town Centre with sufficiently of space for cafeterias, shops is supporting people transport, which change to more public with fewer pollution.

Furthermore, Skyscrapers also provide reasonable living. Persons can be living nearby town center and have entree to shop and facilities, which decreases travel-associated costs like insurance of car, oil and maintenances. Many inexpensive housing units are skyscrapers as the capacity can decrease rental costs.

Lastly, everybody like to see a nice view, and skyscrapers offer them. A huge number of travelers are visiting the tall Building to enjoy the fantastic views, having natural lighting, good aeration, not as much of noise and feeling of stylish life.

1.3 Skyscraper drawbacks

One of the main worries of skyscraper is the stability of the structure. These massive tall buildings maybe damaged by natural calamity for the reason that how large they are. The greater the structure meaning that it need a bigger foundation. Additionally, the Initial cost of construction and maintenance is very high. Further, there is vulnerability of the skyscrapers regarding fire accidents since it is extremely difficult to evacuate people during fire. So, the system of suppression of fire, and routs of scape are very important.

1.4 The best materials for constructing skyscrapers.

The selection of materials and structural system which to be used is based on many aspects like Strength, Lifetime of the material, Budget/Cost of material, Local availability, Climate, Skill required and availability, Sustainability and Maintenance.

Hence, the comparison should be done accurately to reach the correct decision.

The main type of materials that are used in skyscrapers are steel structure and concrete.

1.5 Advantages of Steel structures:

1. Reliability because of regularity in properties, improved quality control due to manufacturing in factory, great elasticity, and ductility.
2. Smaller Construction duration / higher Erection Speed.

3. Strength is high, and Weight Nature is Light.
4. The steel structure is ductile and giving Warning Before Failure.
5. It can be constructed in Long Spans.
6. It is easy to add additional steel structure, connections between the existing and new are effective and quick.
7. Steel elements can be used again afterward a construction is taken to pieces.
8. Steel structure has a worth of scrap although it is not used in its current arrangement.

1.6 Disadvantages of steel structures:

1. Cost of maintenance of steel is high, furthermore steels are vulnerable to rust once visible to air and water, so it shall be occasionally painted. This needs additional fee and special care. If not accurately maintained, then about 1 to 1.5 mm of its thickness can be lost yearly. Consequently, such structures can miss mass equal to 35% throughout their lifespan and may have failure due to the exterior forces.
2. Fireproofing is expensive Even though steel elements are fire-resistant, their strength is extremely reduced usual in fires. At around 400°C, creep develops much more obvious. This results in extremely big deflections/buckles of elements forcing the others to more stresses or may be failure. Additional fee is compulsory to accurately fire resistant the steel structure.
3. Weakness To Buckling: The steel elements are generally consisted of a grouping of thin plates. Furthermore, the steel element sizes are lesser than reinforced concrete elements. If these slim elements are under compression, there are more

probabilities of buckling. Buckling is a kind of failure of the element as a result of unexpected great bending due to critical compressive force. Sometimes the steel columns are not very cheap for the reason that extensive material shall be used to harden the columns to resist buckling.

4. High Primary Price / Fewer Availability.
5. Aesthetics
6. In most of housing and workplace constructions, if the false ceiling and cladding not used in steel structures, then it will be poor aesthetically. A significant fee is to be paid to make better look.

1.7 pros of concrete structure

There are many pros concrete such as:

1. Components of concrete are effortlessly accessible in more places.
2. There is no defect in Concrete like the natural stone.
3. Concrete can be factory-made to the wanted strength.
4. The Concrete's durability is so high.
5. The concrete can be poured to any wanted profile.
6. The concrete can be casted in place and that will reduce the cost.
7. The cost of maintenance concrete is tiny.
8. The concrete deterioration is not considerable with time of life.
9. Due to its non-flammable nature, Concrete has a great fire resistant, so it makes a building safe
10. It can resist sever weather, gust and rain. Consequently, it is very beneficial in hurricane housings.

(<https://civiltoday.com> -Civil Engineering)

1.8 Cons of Concrete structure:

1. The concrete's tensile strength is low when it is compared to other materials used in binding construction.
2. Ductile of Concrete is fewer.
3. weight of concrete elements is high which increase the dead loads (self-weight) when designing and analyzing.
4. The raw materials of Concrete may have salts which reduce the durability.
5. The formwork is expensive but it is compulsory for pouring and to keep the concrete in place till hardening.
6. Concrete is virtual-brittle and shows a strain-softening performance
7. When comparing concrete to steel, the concrete has lower toughness about 1-2% of steel toughness.
8. Compared to steel, the concrete has significantly low toughness. Toughness of concrete is only 1-2% of steel.
9. The shrinkage cracks in concrete cause loss of strength.
10. Concrete is vulnerable to different types of cracks.
11. Concrete creep – rise in deformation over period with constant forces.

(<https://civiltoday.com> -Civil Engineering)

1.9 Objectives of research:

The essential objectives of this study are:

1. To conduct a structural analysis and design for seismic loads for two skyscrapers

(55 floors) in Dubai made of reinforced concrete and steel using ACI 318 – 19 requirement and to find out the differences between structural elements (Columns, Beams, and Slabs) in both towers.

2. To conduct a structural analysis and design for wind load for the above-mentioned skyscrapers (55 floors) in Dubai using ACI 318 – 19 requirement and to find out the differences between structural elements (Columns, Beams, and Slabs) in both towers.
3. Comparing the Cost of construction of the reinforced concrete skyscraper with the steel skyscraper.
4. Comparing the time of construction of the reinforced concrete skyscraper with the steel skyscraper.

1.10 Research questions

The fundamental target of this research is to response to the following questions:

1. What are the suitable design and members sections for the reinforced concrete and steel tall buildings to withstand the seismic and wind loads in Dubai?
2. What is the estimated budget for constructing reinforced concrete skyscraper and steel skyscraper to resist the earthquake and wind loads in Dubai? Which one is more expensive (concrete skyscraper or steel skyscraper)?
3. What is the period for constructing the reinforced concrete skyscraper and steel skyscraper to resist the earthquake and wind loads in Dubai?

1.11 Scope of research:

The scope of this research is containing the following:

1. Performing structural analysis and design of two skyscrapers which consist of 55 floors in Dubai, made of reinforced concrete and steel, for resisting seismic and wind loads, to compare the suitable structural elements for both tall buildings.
2. To estimate the cost of constructing the steel and reinforced concrete tall buildings, conduct comparison between budget of both building.
3. To estimate the duration of constructing the steel and reinforced concrete tall buildings, conduct comparison between budget of both building.

1.12 Significance and motivation of the study:

This research is so important since it compares between the design and analysis results of steel structure and reinforced concrete structure for a 55 floors skyscraper in Dubai, estimates the cost for constructing both tall buildings to know which one is cheaper, evaluate the total time of building the reinforced concrete skyscraper and the steel skyscraper in order to distinguish the faster one.

Furthermore, from the business point of view, it is necessary to select which material to be used in construction. However, to achieve that, it is mandatory to compare between them and find the best one. Accordingly, this study will benefit businessmen, students and researchers.

It can be said that, the benefit of this research for businessmen is discovering the better material for building skyscraper for investment.

On the other hand, the benefit for students and researchers' is to differentiate between the two systems in term of resistance to seismic, wind loads, time, cost, lifetime, sustainability, Ease of construction and maintenance.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Skyscrapers have been speedily rising globally as a result of lacking of availability of land-living in occupied zones also their main character as important structures in up-to-date towns. Nevertheless, skyscrapers are very complex because of the vast number of structural mechanisms and members dissimilar small constructions, in addition to these tall buildings required high construction stability for security and needs of design. (Imad Shakir Abbood; Mohammed Ahmed Jasim; Sardasht S. Weli, 2021)

Skyscrapers continually have depended on scientific modernization in engineering field. modern technical advances unceasingly happening in the universe. Thoroughly it is connected to find effective materials for construction. Thus, this allow structures to be built higher, quicker and more secure. (Szolomicki, Jerzy; Hanna Golasz-Szolomicka, 2019)

Innovative progresses of skyscrapers have been endlessly organized international. Therefore, several inventions in structural schemes are occurred. New designs of tube-shaped structural schemes in an improved systems as well as the braced super tubes are presented. Moreover, a structural system of Core-outrigger is presented by importance on their flexibility. However, to resolve current several project's design wants, several structural schemes for skyscrapers are offered. So, the forthcoming of skyscraper is forecast by means of the competition for tallness remains. (Ali, Mir M.; Kyoung Sun Moon, 2018)

The talent of designing sustainable skyscrapers is that specified the comprehensive difficulties of conservative high-rise building, any enhancements in their proposal, erection and related relations through their towns will be important. Subsequently

skyscrapers assist an excessive quantity of persons and create a great claim on the atmosphere at huge and the instant substructure of transport, drain, and electric net, “sustainable” strategy might well help renters, ease environmental influences and improve incorporation with the urban set-up. (Al-Kodmany, 2018)

Steel-concrete composite structure has expanded extensive consent international as an alternate to clear steel and clear concrete structure. Nevertheless, this method is a comparatively novel idea for the building field. Steel-concrete complex fundamentals are used widely in current constructions. comprehensive study on composite (column, beam) and deck-slab in which steel structure sector are enclosed with concrete are executed. Yet, for intermediate to tall buildings Reinforced Concrete structure is not commercial for the reason that the enlarged dead-load, fewer stiffness, span constraint besides risky formwork. The outcome of this effort present that the Composite-structures are the greatest concept for skyscrapers when equated to Reinforced Concrete structure. (S. S. Charantimath; Swapnil B.Cholekar; Manjunath M. Birje, 2014)

2.2 Seismic load on buildings

The requirements of Seismic design for building as per ASCE 7-22

The structural model for buildings should contain comprehensive sideways and perpendicular withstanding arrangements for forces accomplished of as long as satisfactory strengthening, stiffening, and energy squandering capacity to resist the ground moves during the arranged restrictions of deforming and strengthening requirement. The ground movement going to be presumed to happen horizontally in the structure.

A continual force-path with suitable strengths and stiffness to be considered to transmit all loads from application point to resistance ending one. Joining design loads shall not surpass ultimate forces which the structure system may carry to the joining. With regard to chosen of structural systems, the fundamental horizontal and perpendicular seismic load withstand scheme intend to be from the schedule-12.2-1 otherwise a mixture of schemes as allowed in Units 12.2.2, 12.2.3, in addition 12.2.4. Every scheme is split by the kinds of perpendicular elements designed to withstand horizontal seismic-loads. The factors R ; Ω_0 ; and C_d , specified in Table 12.2-1 should be used in calculating the shear force in base, forces-design, and story-drift.

The type of Systems indicated in ASCE 7-22 are as following:

- Dual System.
- System of Cantilever column
- System of Inverted pendulum Form structures, which boosted the limits of structural height for many types of braced frames, special steel plate shear-walls, compound plate shear wall from concrete and steel, Ductile reinforced concrete attached walls, and distinctive shear walls from concrete.
- Particular moment frames which determined to Seismic Design categories D and F.
- Normal moment frames from steel.
- Medium moment frame from steel.
- Interactive system frames from shear walls.

Generally, the diaphragms are classified as fixable or rigid during the structural analysis taking into consideration the stiffness of structure. Furthermore, Buildings be about to grouped by way of having an irregularity subject to their structural formations, however

there are horizontal and vertical irregularity and the types are listed in table 12.3-1. The Ratio of Torsion's irregularity is calculated by the equation:

$$TIR = \Delta_{max} \div \Delta_{avg}$$

However, full details of ASCE 7-22 seismic load will be presented since the analysis and design of the concrete and steel skyscrapers are done using it. (Engineers, n.d.)

Seismic load on steel buildings

The steel is one of the most materials used for construction in the world. By developing the steel as a material of construction, the construction of skyscraper has been commenced. The original characteristics of steel such as strength, hardness, ductileness and other suitable characteristics result in choosing it as a construction substantial as well the properties that are beneficial for design of seismic. Thus, the structural engineer shall distinguish the steel usage and design principles that specified in standards and code of earthquake. The STAAD pro and the codes IS 1893-2002, IS 800- 2007 are used for design and analysis of seismic. However, Equivalent static load technique and Response Spectrum approach are used for the analysis. Further, P- Δ method is used for checking analysis and the desired modifications done accordingly. (I.Anusha & U.Arun Kumar , December, 2016)

Analyzing the high-rise building structure features, by the observation method, gains each remark argument's over-all of subsiding, realize that no settlement happens in the building. Via the software of finite-element to model the structure, modal-analysis displays that the excellence of structural arrangement, the stiffness is extra consistently dispersed the building of the torsion-capacity in order to achieve the wants. The input of model Tianjin movement, analyses characteristically model's dynamic , however, outcomes presents that: buildings under the intermediate and minor classes, with the height of building reduces the displacement in horizontal direction and decreasing the

size of the building of the intermediate and higher classes, with the height of structure rises, the displacement in horizontal direction grows, a smaller amount of shear walls with significant limits in the bottommost of the horizontal displacement, comparing to the higher structure of the horizontal displacement boundary volume.

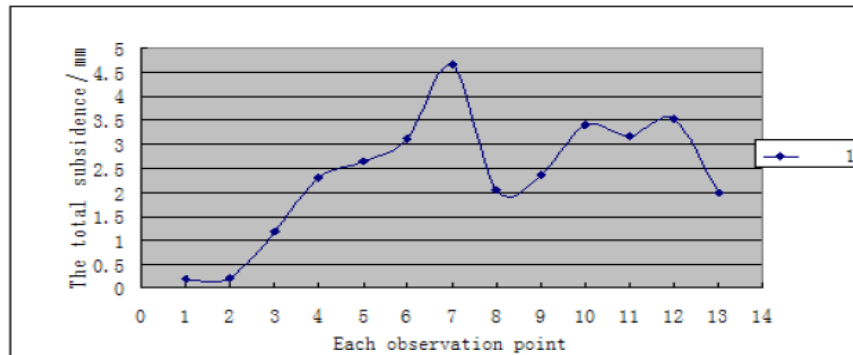
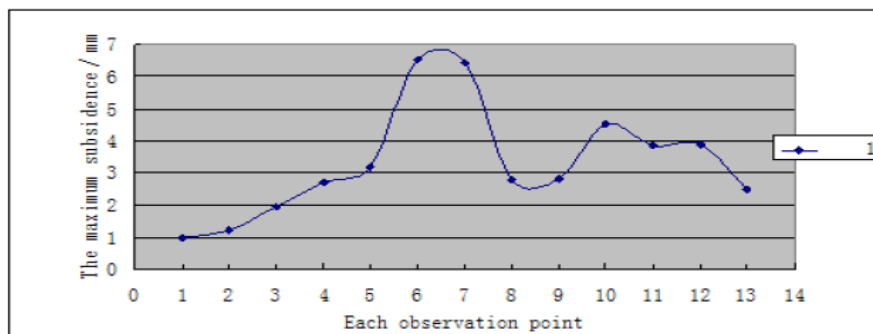


Figure 1: The total subsidence (Zhang Xiang-Dong*, et al., 2013)



**Figure 2: The maximum subsidence of each observation point
(Zhang Xiang-Dong*, et al., 2013)**

As a result of the modal- analysis besides dynamic-analysis observation display that high-level structure of the settlement steady after completion of construction and no extreme settlement happen. Furthermore, the frame-shear wall structure design of the plan regularity, realistic guidelines, the facade quality, the distribution of stiffness is further standardized construction of torsion size to achieve the wants, lead to a great general performance, appropriate for the design and calculation for earthquake. (Zhang Xiang-Dong*, et al., 2013)

2.3 Wind load on tall buildings

The requirements of Wind design for building as per ASCE 7-22

Determination of Wind-forces on structures intend to be done by means of one of the subsequent approaches:

Maneuvering Technique for structures of entirely elevations as stated in 27th Chapter for structures matching the wants detailed there.

Envelope Technique for low structures as detailed in 28th chapter for structures complying with the specifications mentioned there

Directional Technique for structure belongings mentioned in 29th chapter.

Wind-Tunnel Technique for all structures as mentioned in 31st Chapter.

After determining the basic wind-speed, the Directionality Factor K_d shall be picked out from schedule 26.6-1 based on type of structure. For every direction of wind, the exposed revelation will be depended on roughness at ground-surface which is specified from ordinary geography, plants, and built services.

2.4 Wind-Design of Skyscraper

Wind loads may create excessive pressures on the structure and huge side forces on the model, subsequent in higher requirement on structural-members and elevations cladding. Likewise, wind forces may encourage serious responses which may cause extreme acceleration on floors and occupant inconvenience mostly at upper levels of building.

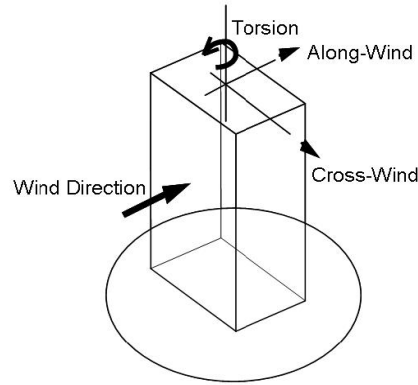


Figure 3: The Wind movement directions (Y. Abu-Zidan, et al., 2022)

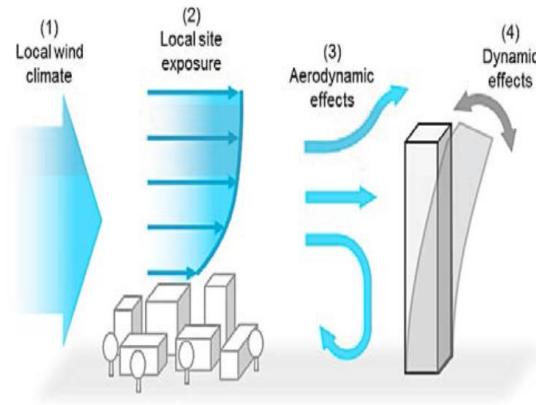


Figure 4: Effects of wind on buildings (Y. Abu-Zidan, et al., 2022)

The Wind-drift define as a horizontal-deflection of the structure subjected to wind-pressure and is frequently computed in relations of the whole structure-deflection or storey-drift. Limits of Drift are stated as a fraction of deflection at top to the height of building, however it is among $H/600$, $H/400$ which are valuable to estimate the structure performance before accomplishment of comprehensive analysis. Furthermore, the fundamental methods to lessen wind effect in skyscrapers are two: adjusting the aerodynamic concert of the structure, also amending of structural characteristics. (Y. Abu-Zidan, et al., 2022)

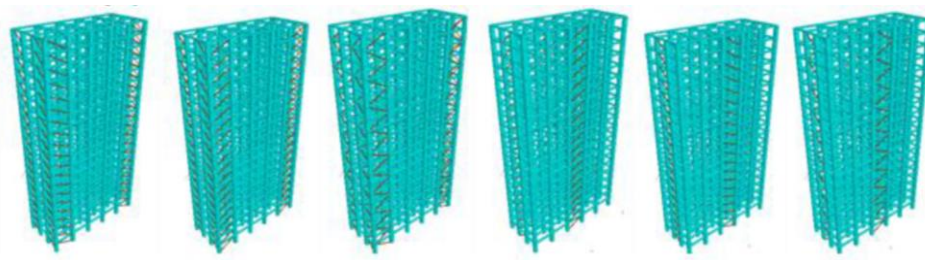


Figure 5: Diverse systems of Bracing in skyscrapers for analysis of wind (1st group)

(P.G, et al., 2016)

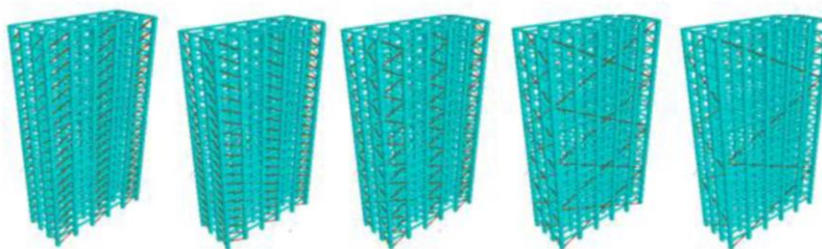


Figure 6: Diverse systems of Bracing in skyscrapers for analysis of wind (2nd group)

(P.G, et al., 2016)



Figure 7: Diverse systems of Bracing in skyscrapers for analysis of wind (3rd group)

(P.G, et al., 2016)

In addition to kind of bracing, the bracing positions are similarly significant for withstanding horizontal forces. However, the study results are as following:

1. The results of analyzing several bracing-models gained that diverse bracing schemes on several positions of the building may be efficiently applied to decrease extreme bending-moment at columns by reason of side (Wind) force.
2. It has been observed that Chevron-Bracing method with alternately way is more efficient in dropping bending-moment in columns by reason of sideways wind-force decreasing bending-moment successfully up to about third in Y and Z direction.
3. From the results of analyzing several bracing schemes gained there is no substantial

discrepancy in Shear-Force at Y and Z way also is not more valuable to decrease shear-force in the building.

4. There is tiny rise in the mass of building because of adding of several braces.
5. Accordingly, the systems of braces may successfully enhance the structure performance without addition of extensive further dead-load to the building. (P.G, et al., 2016)

2.5 Torsion irregularity

Examination of torsion-irregularity factor in this sector, the associated extreme torsion-irregularity constants is specified, then the results is debated. Firstly, horizontal-analysis is performed for ten-floor type A building, subsequently the outcomes of all the buildings in that collection is offered in schedules. The difference of extreme torsion-irregularity constant in addition to outcomes is debated afterward the check-up of wholly building kinds. However, examination is executed for six kinds of buildings taking into consideration dissimilar position of shear-wall also numbers of stories, beside variable grids amount. Results of analyses for horizontal forces are rated, with the subsequent suppositions:

- All of the examined buildings, torsion-irregularity constants rise by way of the floor numbers decline, i.e., extreme irregularity constants happen for one story buildings.
- Floor turnings rise proportionally to the number of floors, i.e., the maximum rotations of floor happen for the highest floor-numbers.
- Torsion-irregularity constants achieve the maximum amounts once shear-walls are located at the nearest position of centers of mass without matching them.

- In contrast as it is predictable, obviously at what time the rigidity centre is near to the mass Centre, torsion-irregularity constants rise as a result of declining torsion-rigidity of construction.
- Rotations of Floor achieve their extreme amounts for the buildings wherever the walls are in furthestmost locations from mass-centers.
- It is realized that outcomes gained of torsion-irregularity constants and rotations of floor are so paradoxical.
- Because the rotations of floor probably took into consideration as the actual demonstrative of torsional performance, torsion-irregularity constants would be fully modified. (Gu“nay O“ zmen, et al., 2014)

2.6 Rating P-Delta influence on skyscrapers:

P-Delta-analysis can be defined as a nonlinear 2nd order outcome which happens in each construction wherever structural members are under horizontal forces. It is an actual “influence” that is related to the size of horizontal force (F) beside a movement (δ). Uncertainty a P-Delta influenced element is exposed to side force at that moment it will be susceptible to bend additional and that might be calculated by P-Delta study.

However, the size of P-delta outcome is associated to the quantity of horizontal force, Stiffening (Dhadve, et al., 2015)

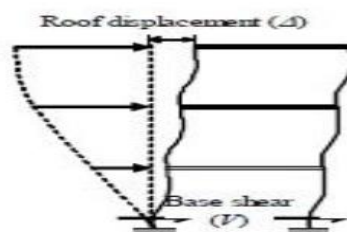


Figure 8: Buckling model and roof displacement
(Dhadve, et al., 2015)

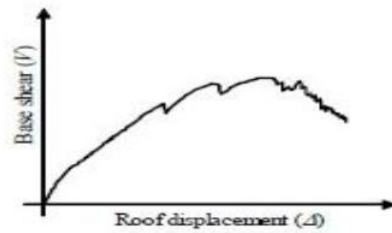


Figure 9: Pushover curve for base shear and roof displacement

(Dhadve, et al., 2015)

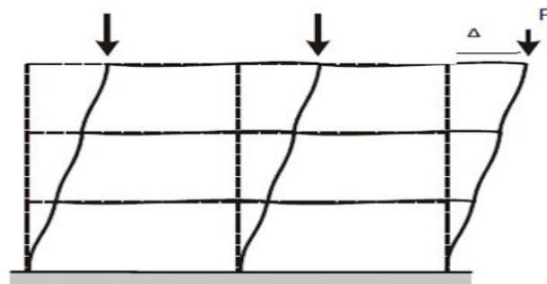


Figure 10: Horizontal displacement due to vertical loads

(Dhadve, et al., 2015)

Moreover, when analyzing by ETAB with confirmation with further writers' subsequent suppositions are achieved:

1. By way floors number rises P-delta influence be supplementary significant.
2. P-delta influence is alone recognized in part of beams /columns (External columns and their close-by beams) in part of load-cases.
3. Consequently, as a minimum it is essential to review the outcomes of analysing by considering P-delta and without it.
4. There is no change observed when Iterative analysis of P-delta approach using ETABS. (Dhadve, et al., 2015)

2.7 Evaluation of Wind-output Dislocation of Structures with several horizontal forces withstanding Schemes

This journal studied the three structure schemes that used for limiting the deflection (shear wall, moment-frame in addition to dual-system) obviously applied in high-rise constructions to find their comparative efficiency.

However, the outcomes of this study as succeeding:

1. The displacement in horizontal direction in moment-frames is the highest amongst the three horizontal force withstanding systems examined; the displacement in horizontal direction in dual-frames is the smallest whereas the displacement in horizontal direction in shear wall systems is a little more than dual-system.
2. Internal-drift is minimum in dual-systems and highest in moment-frames whereas in shear-wall is somewhat more than the internal drift in dual-system.
3. The highest internal-drift happened at the lowest tertiary in moment-frames.

However, in shear-wall besides dual system, the highest drift in floors placed inside the mid third of the structure tallness. (Chinwuba Arum1, & Akinloye Akinkunmi, 2011)

2.8 Investigation on the Dynamical properties of low-weight Steel Housing construction Schemes

A various widespread kinds of low-weight steel Housing construction system were analyzed, and the Dynamical properties are described, also summarize the pros of low-weight Steel Housing construction Schemes.

low-weight steel structure is defined as a construction that has insignificant element magnitude, light-weight beside slight load. It is the system which consist of inexpensive steel composition as housing frame, low-weight wall ingredients by means of covering

inclusion. Cost-effective steel mechanisms principally contain cold twisting crucifixion, hot-rolled or h-shaped joined steel, linking otherwise continuous pipe and its assemblage. The frequently low-weight steel construction scheme can be classified to five-classes due to their withstand of seismic and wind force in addition to durability: context-support structure scheme, staggered-truss scheme and composite structure system from concrete and steel, the shear-wall scheme, purely frame structural scheme.

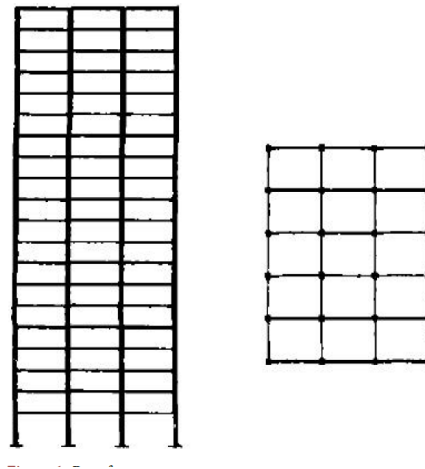


Figure 11: Low-weight Steel Housing construction Scheme 1

(Wenwei Yang & Qili Yang, 2017)

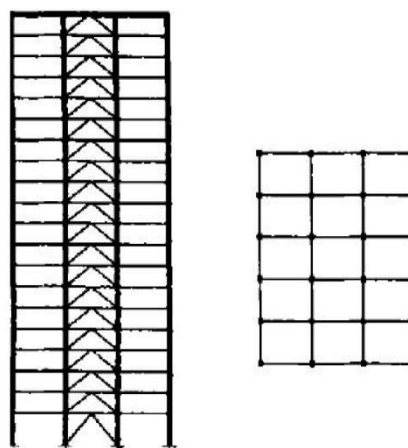


Figure 12: Low-weight Steel Housing construction Scheme 2

(Wenwei Yang & Qili Yang, 2017)

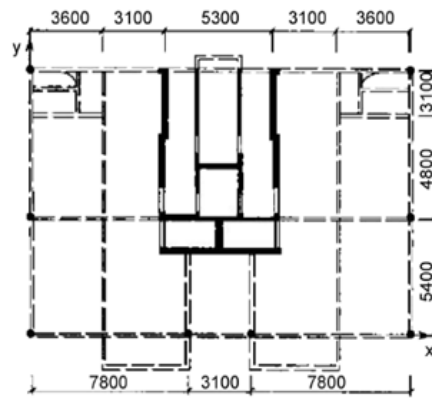


Figure 13: The frame shear-wall structure system
(Wenwei Yang & Qili Yang, 2017)

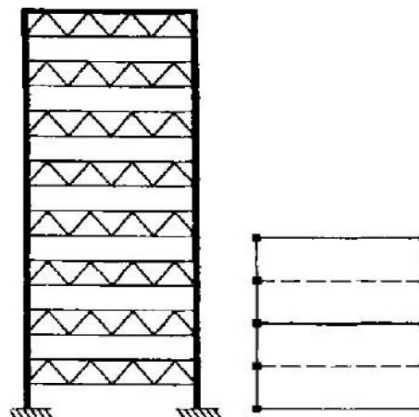


Figure 4. The staggered truss system.

Figure 14: The staggered truss system
(Wenwei Yang & Qili Yang, 2017)

The below are advantages of low-weight Steel Housing construction:

1. Light-Mass, High Strength and Respectable earthquake resistance.
2. The speed of construction is Fast so the recovery of investment is
3. quicker.
4. The easiness for Huge-Scale Manufacture.
5. There are big spaces for different architectural design.
6. The Environmental Protection beside power reserve.
7. The great Fire-resistant.

8. Nevertheless, the low-weight steel Housing construction Schemes similarly has limitations, for instance, price is probably high so the demand is not high, however this will be improved.

(Wenwei Yang & Qili Yang, 2017)

2.9 Sustainability of Concrete Structures.

The valuation of sustainability consists of evaluating the environmentally, socially and economically with considering the technical and practical needs. The necessity of sustainability evaluation is rising.

The pros of concrete constructions as of social standpoint as following:

1. The mass of concrete is big as a result of its density; accordingly, it can assist by storing the thermal-energy which happen by absorbing or releasing hotness and coldness. Thus, participate in saving the energy related to heating and cooling.
2. Acoustical insulation due to high mass of concrete elements, it will decrease the sound movement.
3. The concrete is having high fire resistance when it is compared to timber or steel structure.
4. The concrete having great resistance to abrasion, sun-rays, ice, gust and overflows with good robustness.
5. Durability of concrete is high; hence the maintenance need is less specifically the internal concrete elements.

The pros of concrete constructions as of economic standpoint as following:

1. The concrete has long-lasting service-lifespan when compared to other construction materials. Moreover, the concrete has a great withstanding to weather, so the cost of maintenance and demolition is less.

2. Fewer harm produced throughout disaster as a result of great strength in addition fire resistance, hence minor economical effect, minor price of patch-up besides rebuilding.
3. The cost of concrete ingrediencies, transportation is low.
4. The concrete (precast) can be dismounted so this enable using of precast concrete parts.
5. Slighter dimensions of external concrete elements are resulting in encouraging result effectiveness (specifically in zones with controlled magnitude of urban part)

The pros of concrete constructions as of social standpoint as following:

1. Usage of secondary cement-base materials (microsilica, flyash, ..etc) in concrete mix contribute in decreasing the energy embodied, and emission of (CO₂, Sox).
 2. The concrete which is recycled may use as alternatives of aggregate in building for concrete producing.
 3. The precast members will decrease waste producing in factory and building sites.
- (Hajek, 2017)

2.10 Sustainability of buildings made of steel

Equated to present normal building repetition, up to date steel structure has significant benefits:

1. Effectiveness of Material - subsequent such as fewer ordinary source application, fewer transportations, fewer releases to unhealthy gasses beside a lesser amount of power uses, recyclability is so high - ensuing that the using of natural-resource is fewer, beside fewer waste, energy and gas emissions.
2. Robustness and Quality – consequential in sustainability favors.

3. The construction is dry and that resultant in smaller amount healthiness threats, using of natural-resource is fewer, beside fewer waste, energy and gas emissions. However, enhancements of Sustainability results in creating economic profits, such as but not limited to lesser prices for heating system and upkeep, helpfulness and marketplace rewards, in addition to an upcoming world for better live. The International Commercial Board for Sustainable evolution specified that “Business will have advantage from following sustainability by creating maximum development by invention besides innovative marketplaces, in addition to price effectiveness”. The advantage aimed at man and atmosphere is great excellence existence.

The chief environmental factors are World-wide heating, Acidity, Eutrophication, depletion of Ozone-layer, Poisonousness, reduction of resource. Whereas production fresh steel, approximately more than two thirds the structural steel’s involved energy can be kept and not used. Around 50% of the involved energy in flammable production can be recycled to heat in addition further objectives. The operative stage contains 85-95% of the life cycle power applications in tall building.



Figure 15: Light weight steel framed construction (ArcelorMittal & LoGeCa, 2009)

When using Steel different systems in external walls is so effective when using it properly. Agile steel frame joint with thermal isolation, stopper of wind, humidity insulation will have a U-value less than $0,15 \text{ W/m}^2, \text{ K}$ ($= R > 7$).

Recent knowledge illustrates that steel frames shall be designed to achieve a main execution relating to thermal concert. International construction rules determine the warmness flow limits for dissimilar kinds of structures. Furthermore, with regard to heavyweight transportations, (excluding electrical trains operated by carbon-free energy), produce SOX, CO₂, HC NOX, in addition to more toxins, and apply limited remains sources.

computing of power concert of constructions as stated by the E. P. D. be about to as a minimum include the below:

1. thermal features of the structure cover contain wind-stiffness
2. solar heating setting up in addition to supply of hot water
3. air conditioning fixing
4. freshening and integral light setting up
5. location in addition to direction of structures, as well as outside weather
6. inactive solar equipment and solar defense.
7. Nonetheless, there are many opportunities for steel which shall be recognized. On the other hand, many challenges are there to be included with the purpose of securing a wealthy expansion with regard to sustainability matters for steel.

(ArcelorMittal & LoGeCa, 2009)

2.11 Analysis of cost and seismic performance of skyscrapers in UAE through Ductile Attached Shear-Walls:

The higher mechanical features of extreme high behavior concrete

Enticed the attention of several investigators global. This article discovers an inclusive assessment for performance of seismic in addition to analyzing the cost of four 60 floors model structures. The strengths are 60, 150, 185 and 200 MPA.

The foremost outputs of this paper can be summarized as following:

1. Entirely structures displayed alike seismic retort nonetheless with lesser structural members in UHPC structures.
2. A decrease of self-weight of the structure was noticed as well as a lesser value for turn over moments for the UHPC structure equated to high strength concrete structure and that consequence in cost saving in foundation's design.
3. By growing the concrete strength from high-strength with 60-Mpa to the UHPC of 150-MPA, 185-MPA and 220-MPA, the over-all primary prices were decreased by quarter, third and little above quarter respectively.
4. With regard to economical choices and resistance of seismic loads, the finest outcome noticed when using the UHPC of 185-MPA concrete. Thus, this paper mentions using the UHPC in skyscrapers rather than high strength one.
5. The decrease in price is related to lessening of dead-loads.

(Mohammad AlHamaydeh, et al., 2022)

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction:

This chapter includes the method and strategy used to make structural analysis and design for two skyscrapers (55 floors – 202 m height) constructed from reinforced concrete and steel in Dubai, which are subjected to Seismic and Wind Loads in order to find out the suitable structural elements, to estimate the total budget for construction of both buildings, and to estimate the duration of construction for both structures in order to compare between them.

Many papers have been reviewed and summarized regarding the earthquake load, wind load in high rise building, Torsion irregularity, Rating P-Delta influence on skyscrapers, Rapport among normal shaking period beside structure tallness for skyscraper, Evaluation of Wind-output Dislocation of Structures with several horizontal forces withstanding Schemes, Investigation on the Dynamical properties of low-weight Steel Housing construction Schemes, sustainability of concrete and steel.

3.2 Research Strategy and Approach

To conduct the comparison between the two tall buildings which are made of Reinforced concrete and steel, The ETAB, SAFE and Excel computer program has been used to model, analyze, design the reinforced concrete skyscraper (55 stories). The codes which used are: ACI 318 -19 for concrete design, AISC 360 -16 for steel design.

The foundations and staircases design are excluded from this study.

Table 1: The initial sizes for reinforced concrete members

	from 1st floor to 20th Floor	from 21st floor to 40th Floor	from 41st floor to 55th Floor
Columns size	1.0 m x 1.0 m	0.75 m x 0.75 m	0.6 m x 0.6 m
Wall thickness	0.3 m	0.3 m	0.3 m
Beam size	0.6m x 0.3m	0.6m x 0.3m	0.6m x 0.3m
slab thickness	0.25 m	0.25 m	0.25 m

The primary structural system which selected to resist the lateral loads (seismic and wind) is consist of columns and shear walls which can be used for lifts and staircase (two of them from 1st floor to 20th floor), (one of them from 1st floor to 40th floor) and the last one (from 1st floor to 55th floor) as shown in the drawings.

3.3 The design codes and Material properties:

The code which is used for concrete design is ACI 318- 19 and for the steel is AISC 330-16.

The concrete compressive strength = 60 Mpa.

The minimum yield strength f_y for tendon = 1680 Mpa

The minimum yield strength f_y for rebars = 416 Mpa

The minimum yield strength f_y for steel structure elements = 344.74 Mpa

3.4 Seismic load factors, and other loads values determination:

To determine the seismic factors values, the following shall be found:

Risk Category:

From the International Building Code (IBC) 2012 table 1604.5, the building is Category III

Importance factor:

From the table 1.5-2, I_E The importance factor = 1.25 for Risk Category III buildings from the above schedule 1.5-2 of ASCE 7-10.

Site Coefficients:

From table 20.3-1, the assumption is that the soil is very dense, accordingly the site class is C.

Spectral acceleration factors at 0.2 sec. and 1 sec. S_s and S_1

From Dubai Municipality building code:

$S_s = 0.51$

$S_1 = 0.18$

Long period transition period = 24

Table 2: Response Modification R, System over strength factor Omega, Deflection amplification factor Cd

Type of structure	Response Modification (R)	System over strength factor Omega	Deflection amplification factor Cd
Concrete sky scraper -shear wall	4.5	2.5	4

frame-No. F in the above table			
Steel skyscraper (Steel and concrete composite intermediate moment frame)	5	3	4.5

Table 3: The loads, factors and wind speed which will be used in ETABS

	Value	Reference
Live Load	4.79 KN/m ²	Table 4-1 from ASCE 7 /10
Super Dead load	1 KN/m ²	
Cladding load	5 KN/m	
Wind speed	45 m/s	Dubai Municipality building code
Earthquake load factors:		
0.2 sec. spectrum accel. S _s	0.51	Dubai Municipality building code
1 sec. spectrum accel. S ₁	0.18	Dubai Municipality building code
Response Modification R	5	Table 12.2-1 from ASCE 7 /10
System over strengthening, Omega	3	Table 12.2-1 from ASCE 7 /10
Deflection amplification, C _d	4.5	Table 12.2-1 from ASCE 7 /10
Occupancy Importance, I	1	from ASCE 7 /10

The live load, super dead load, wind load, and seismic loads are assigned in ETABs models using the above values and factors.

The load combinations selected is the default combinations for concrete frame design, shear wall design, concrete slab design and steel structure design.

Defining of Design strips:

The design strips which are consisting from column strip and middle strips are defined for the post tension slabs in X and Y direction.

However, the benefit of defining the design strip is that the ETABs and Safe programs are using them in locating the tendons and steel reinforcement.

Drawing the tendons for post tension:

The tendons in X direction are located in the grid lines which having 6m distance between them, while the distance between the post tension tendons in Y direction was about 1m so it results in two strands in each tendon.

Checking the models and running the analysis:

The design code for concrete tall building is ACI 318-14.

The model checked and found that there are no warning messages. Three slabs are selected to be designed in ETABS which are the master floors in level 20, level 40 and level 55 and all the other floors are similar to them.

The analysis and design are run, consequently, there are some beams, columns and walls did not pass the design with the initial selected dimensions. Accordingly, the sizes are increased with small dimension, and the analysis and design repeated many times for the beams and columns, but also not passing the shear.

Accordingly, the structural resisting system for the concrete tall building is changed from columns, and solid slabs with beams to Post tension slab with beams, and shear wall concrete skyscraper which pass as shown in chapter 4.

There are typical floors from level 1 to 20 (54mx54m), then reducing the area to (42mx42m) from level 21 to 40 (similar floors), and the last typical floors with decreasing dimensions to (30mx30m) from level 41 to 55.

3.5 Post tension slab design by CSI Safe 2020 program

The CSI Safe program can be used in design of several types of slabs such as flat slab, slab with beam, waffle slab, ribbed slab and foundation design. It is giving great detailing for the design and analysis, and generating drawings, sections, tables for steel reinforcement, tendons profile, number of strands, analysis results for each load combination, and reactions.

However, Level 20 is selected to be designed by CSI Safe 2020 program using the post tension slab and beams. Its file exported from ETABS with the same dimensions. Similar steps which were done in the ETABS program are followed here in safe program by defining the materials properties, loads, load combination, design strips, drawing the tendons, checking the model and analysis and design. the results are presented in chapter four.

3.6 Selection of steel member dimensions:

With regard to the design and analysis of steel tall building, the ETABS program is set to select the structural elements (steel columns, main and secondary beams) automatically by defining auto lists consisting from several sections from the ETABS tables which is from the code, so the ETABS selected the specific members based on the different loads, dimensions, height of building...etc.

Initially, the maximum displacement found more than one meter which shall not exceed

the below value:

Maximum displacement = Height/500 = 203.5m x 1000/500 =407 mm.

For that reason, a steel bracing was added in the external elevations and the columns made as composite columns (reinforced concrete and steel section) till getting the maximum displacement less than 407 mm.

However, the selected steel sections are presented in the results.

3.7 Using Microsoft Excel to compare the analysis results:

For comparison and results preview, the Microsoft excel used as shown in chapter 4 to compare between the Lateral Loads to stories (KN), Maximum Story displacement (mm), Maximum Story drifts (unitless), Story shear force (KN), Overturning moments (KN.m) and the Story Stiffness (Kn/m), total duration and cost for the reinforced concrete and steel tall buildings, by plotting diagrams that presented in the 4th unit.

CHAPTER 4: RESULTS AND DISCUSSION:

This unit includes the results for analysis and design of seismic and wind load of two skyscrapers which are from reinforced concrete and steel, and both of them consist of 55 floors, in order to know the suitable structural elements (columns, beams and slabs), to compare between them regarding the estimate of duration for constructing each building, to evaluate the construction cost of each skyscraper. The discussion will cover the comparison to give recommendation for the better option in details since it will help for selection one of them.

The analysis and design are conducted using CSI ETABS and Safe programs. Moreover, the results and comparison are presented by Excel.

4.1 Final computer design output:

The below are the 3D shape and plans of the reinforced concrete tall building that designed by ETABS and Safe program for post tension slabs and beams.

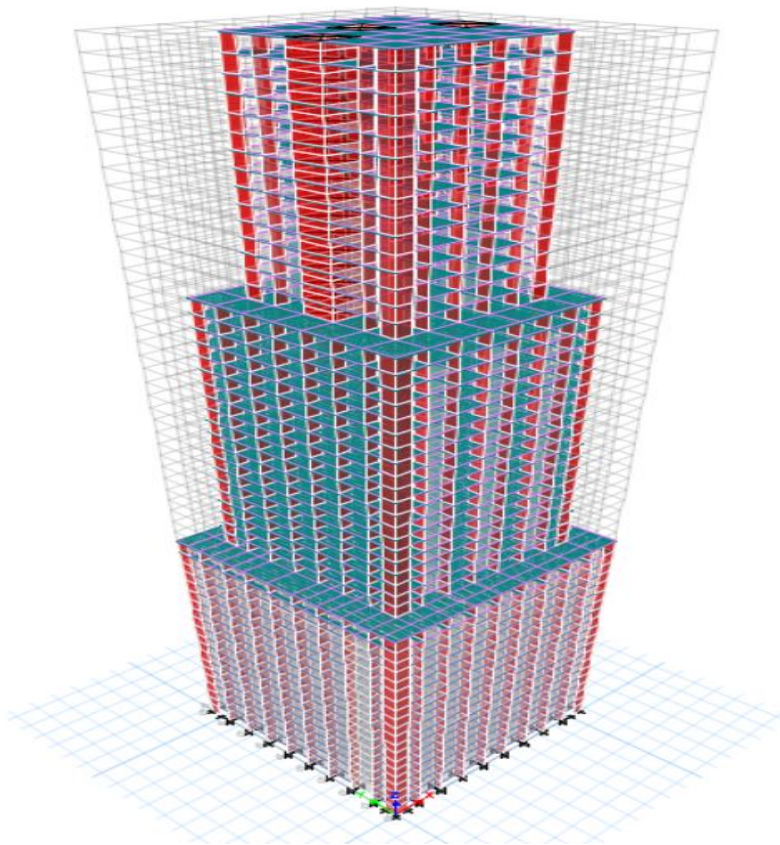


Figure 16: The reinforced Concrete skyscraper (55 floors) 3D model.

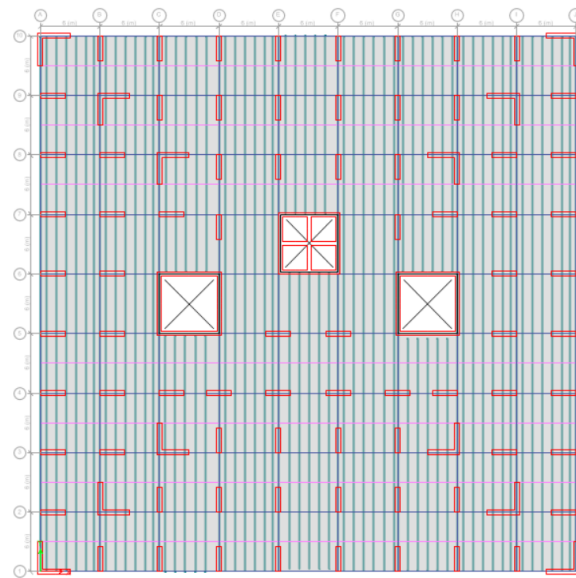


Figure 17: Plan for level 1 to 20 of reinforced concrete skyscraper

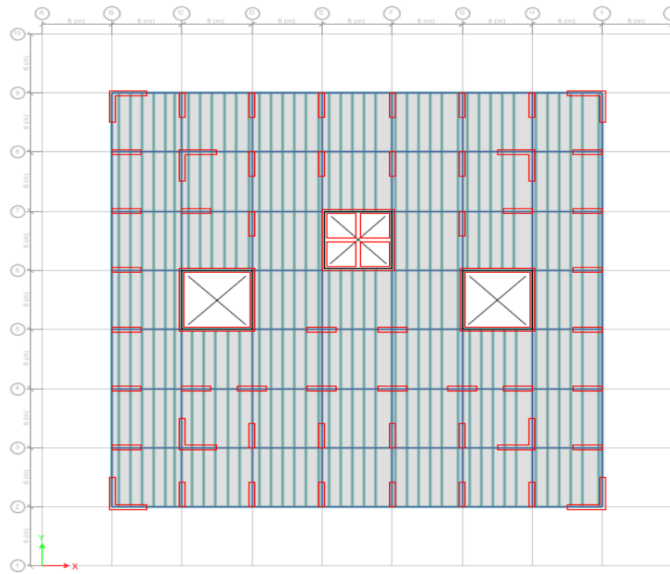


Figure 18: Plan for level 21 to 40 of reinforced concrete skyscraper

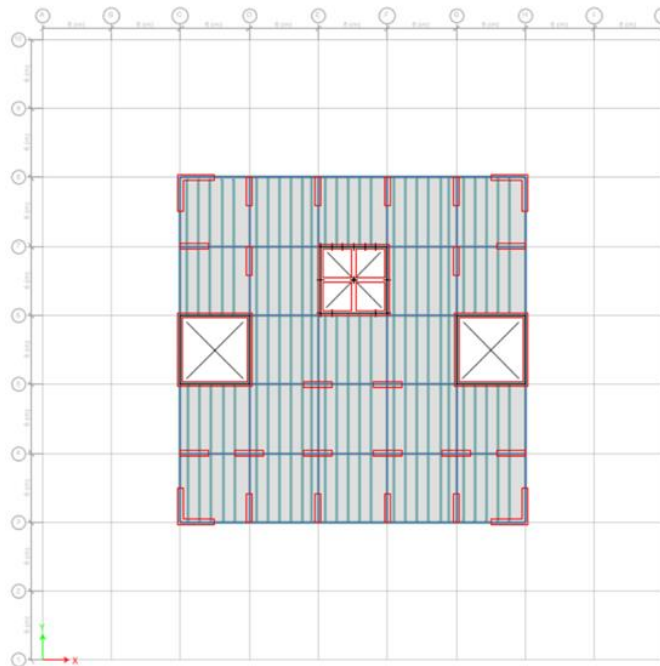


Figure 19: Plan for level 41 to 55 of reinforced concrete skyscraper

As mentioned previously, the overall dimensions for the two high rise buildings which are made from reinforced concrete and steel are same with the below details:

- the slab dimensions of similar floors from (Level1 to level 20) are (54m x54m).
- the slab dimensions of similar floors from (Level21 to level 40) are (42m x42m).
- the slab dimensions of similar floors from (Level41 to level 55) are (30m x30m).

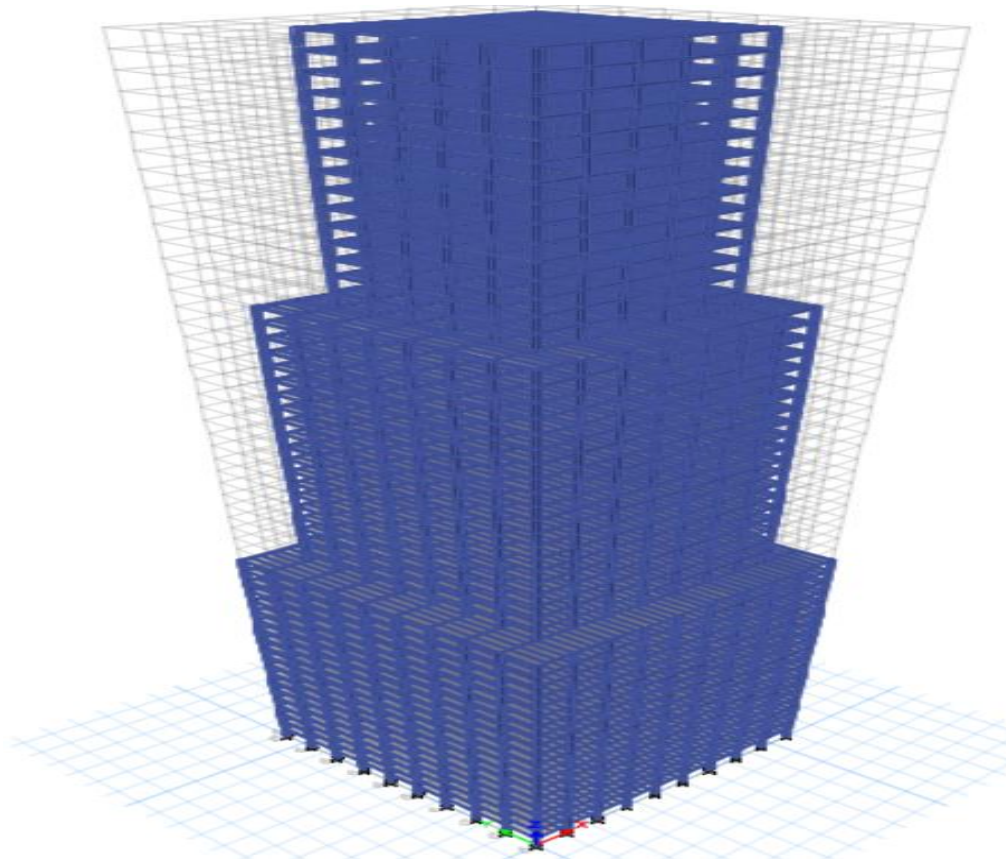


Figure 20: The Steel skyscraper (55 floors) 3D model

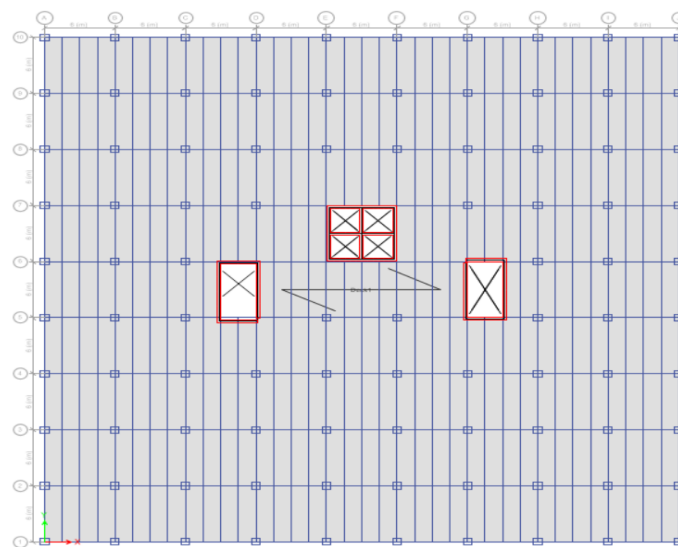


Figure 21: Plan of steel tall building from level 1 to level 20

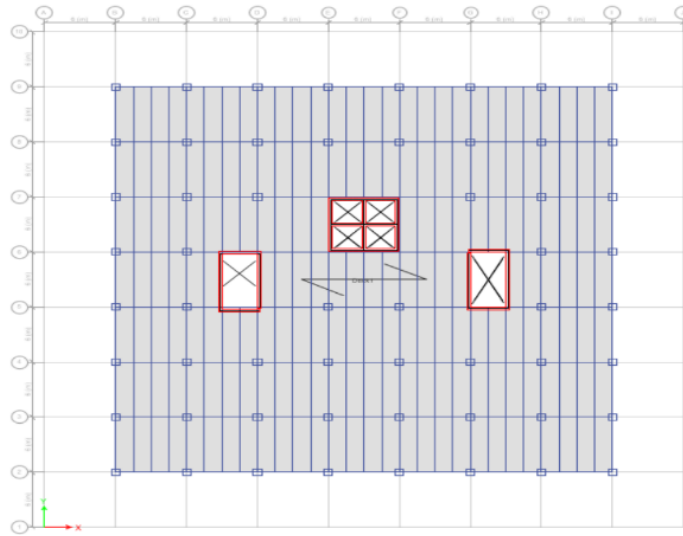


Figure 22: Plan of steel tall building from level 21 to 40

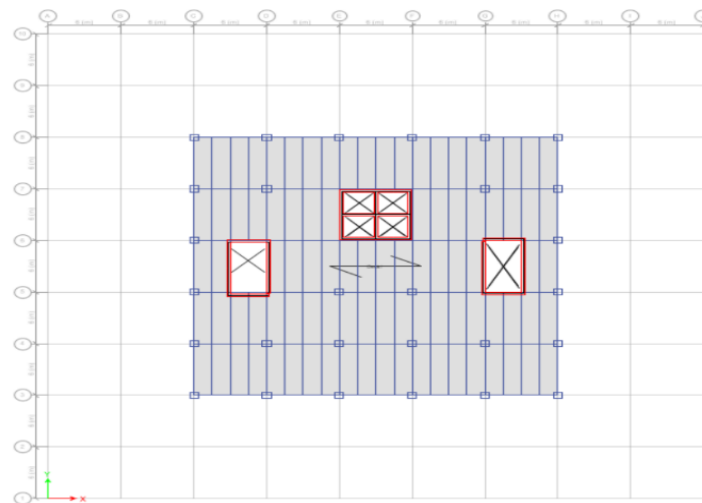


Figure 23: Plan of steel tall building from level 41 to level 55

4.2 Design and Analysis results for Steel skyscraper

The ETABS Design program selected the Main beams and secondary beams automatically as below final sections in the skyscraper, after many trials. With regard to the composite columns, there are two types which mentioned in the below table:

Table 4: initial and final dimensions of Steel structure elements

Steel structure elements	Initial section dimension	Final section dimension
Steel columns	W 24 x 162 From Level 1 to 55	Comp. Colum.2 (1.0x0.6m), 8 T 25 rebars, W 14 x 500, C 60 concrete. From Level 1 to 20
		Comp. Colum.1 (0.9x0.6m), 8 T 20 rebars, W 14 x 500, C 60 concrete. From Level 21 to 55
Main beams	W 30 x 148	Many sections are selected automatically by ETABS: W14 x 370, W16 x45, W 21 x 44, W 18 x 35, W 27 x 539, W 30 x 290,
secondary beams	W 12 x 130	W 14 x 22 From Level 1 to 55
Bracing at external elevations	-	W 14 x 61, W 16 x 40, W 18 x 76
Deck slab	Slab depth 87.5mm, rib depth 75mm, shear stud dia. 19mm	Slab depth 87.5mm, rib depth 75mm, shear stud dia. 19mm

4.3 Discussion of composite columns sizing:

Referring to the above schedule, all of the columns for steel skyscraper are designed as composite columns (reinforced concrete + embedded steel I section), since the steel columns are not passed due to high seismic and wind forces. However, the sizes of composite columns in Level 1 to 20 are bigger than the one in Level 21 to 55 due to higher shear forces and overturning moments.

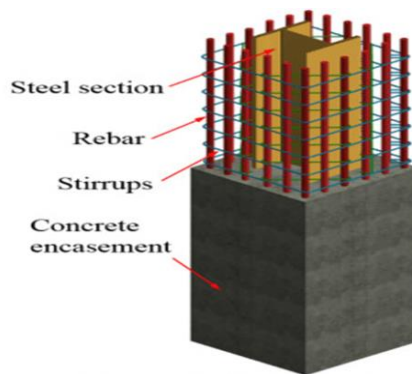


Figure 24: Composite columns shape

4.4 Discussion of main beams sizing:

The ETABS program is set to select the sizes of main beams automatically from predefined list based on the different forces and moments on the main beams, it chooses the most economical section which is safe structurally. However, the main beams are almost similar in all floors.

4.5 Discussion of secondary beams sizing:

The program selected only one size for all of the secondary beams in all floors which is W 14 x 22 since it is safe for the Live and Dead Loads.

4.6 Discussion of bracing at external elevations:

There are Three different steel sections which selected automatically by ETABs program for the bracing in all external elevations from predefined list of different steel sections.

4.7 Analysis results for the reinforced concrete skyscraper and steel skyscraper

The ETABS analyses results for the reinforced concrete and steel tall buildings are summarized in the below tables:

Table 5: The Reinforced concrete structure analysis results

Reinforced Concrete structure analysis results					
	Story response (Maximum values)	Seismic X direction	Seismic Y direction	Wind X direction	Wind Y direction
1	Auto Lateral Loads to stories (KN)	1396.2	1396.2	393.6	393.6
2	Max. Story displacement (mm)	26.3	25.8	10.4	10.4
3	Max. Story drifts (unitless)	0.000628	0.000611	0.000214	0.000214
4	Story shear force (KN)	19689.2	19735.2	5784.4	5784.4
5	Overturning moments (Kn.m)	545528	1165329	209560	209560
6	Story Stiffness (Kn/m)	73724551	74424608	78529482	78529482

Table 6: The Steel structure analysis result (storey response)

Steel structure analysis results					
	Story response (Maximum values)	Seismic X direction	Seismic Y direction	Wind X direction	Wind Y direction
1	Auto Lateral Loads to stories (KN)	713.8	713.8	172	411.4
2	Max. Story displacement (mm)	390.48	350	73.5	122.6
3	Max. Story drifts (unitless)	0.00364	0.00222	0.000751	0.0015
4	Story shear force (KN)	19425	19425	6768	16038
5	Overturning moments (Kn.m)	2700555	2700555	687445	1499686
6	Story Stiffness (Kn/m)	8345914	8683600	11028668	12579813

4.8 Comparison charts for the analysis results for the concrete and steel skyscrapers:

The below charts are reflecting the data from the tables above in order to compare between the ETABS analysis results for the two tall buildings.

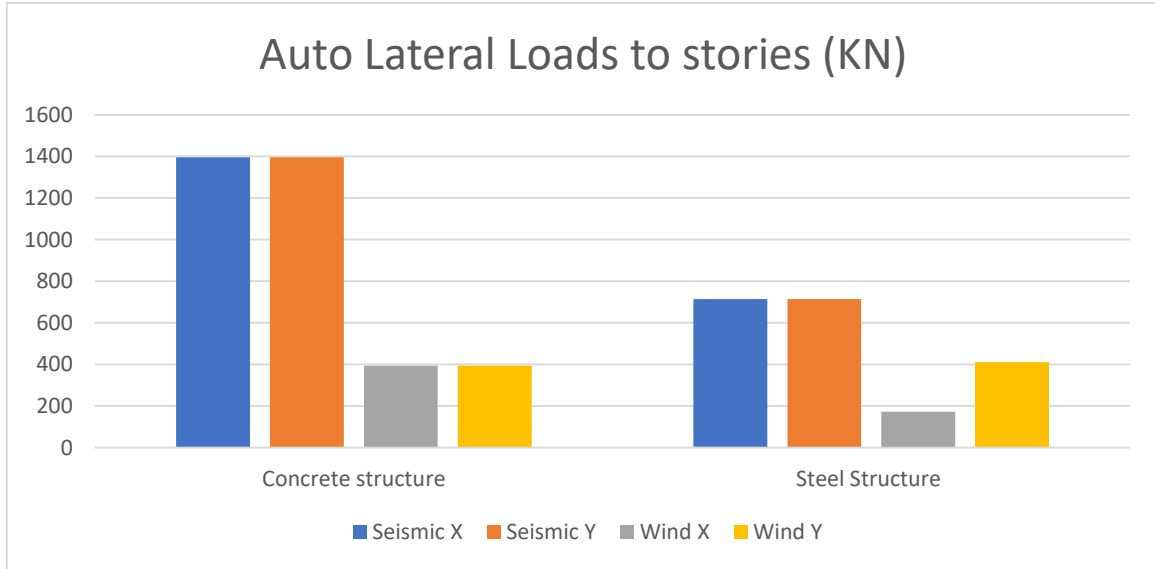


Figure 25: Auto Lateral Loads to stories (KN) in Concrete and steel skyscrapers

4.9 Discussion of Auto Lateral loads in steel and concrete buildings:

The auto lateral loads due to seismic loads are higher than the one from wind loads in both skyscrapers. On the other hand, the lateral loads on the concrete building are in excess of the one in the steel building.

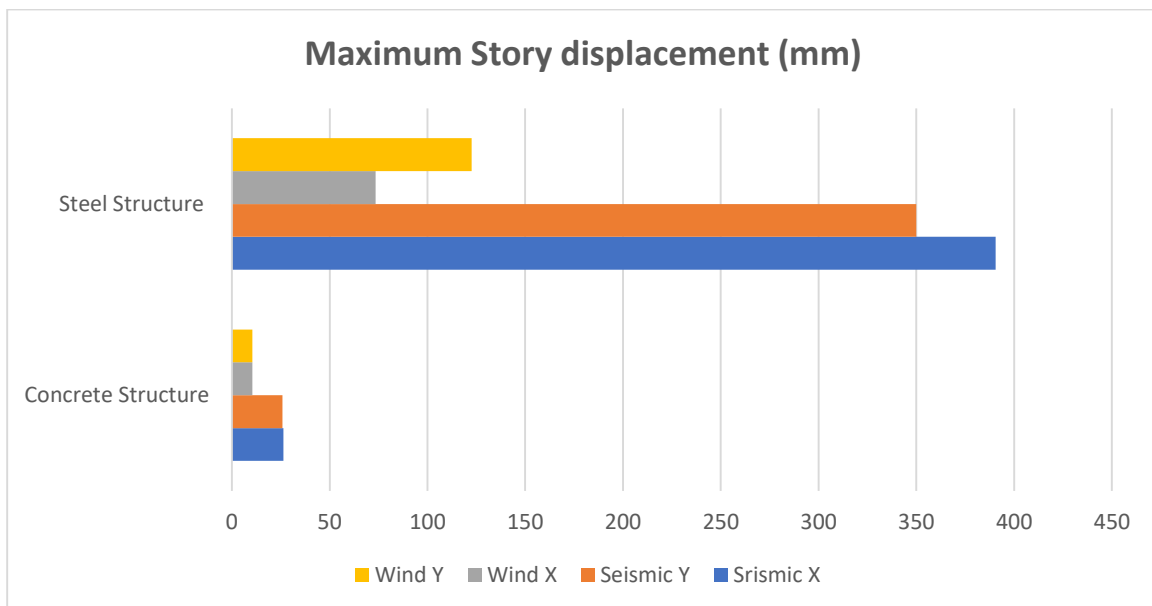


Figure 26: Maximum Story displacement (mm) in concrete and steel tall buildings

4.10 Discussion of maximum storey displacement:

The steel tower is having displacement higher than the concrete tower. However, the displacement due to wind loads in X and Y directions are less than the one attributed to seismic loads.

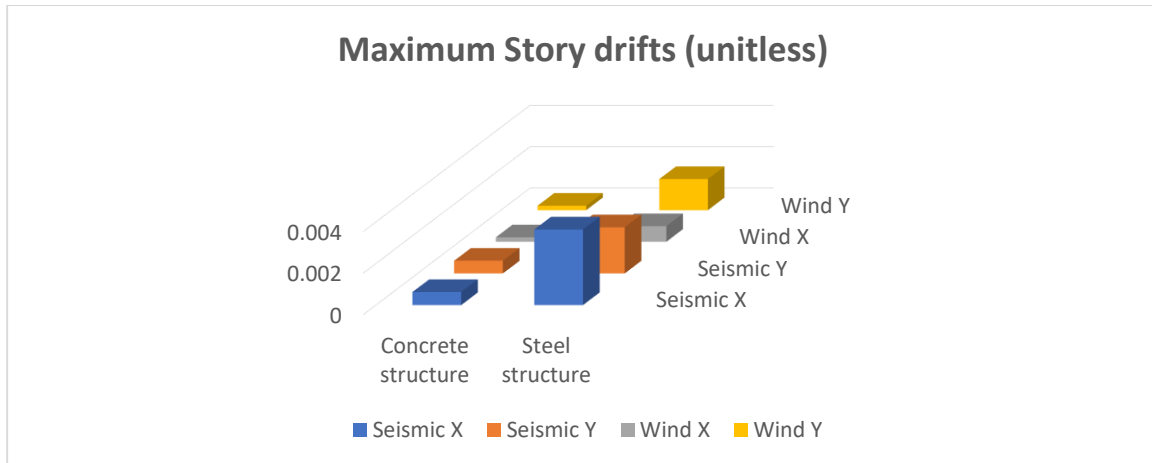


Figure 27: Maximum Story drifts (unitless) in concrete and steel skyscrapers

4.11 Discussion of Story drifts of concrete and steel tall buildings:

All of the values of story drifts related to seismic and wind loads in X and Y directions for the concrete and steel skyscrapers are less than the allowed value by ACI 318-19 which is 2.5%. However, the story drifts in the steel structure is more than the one in concrete structure.

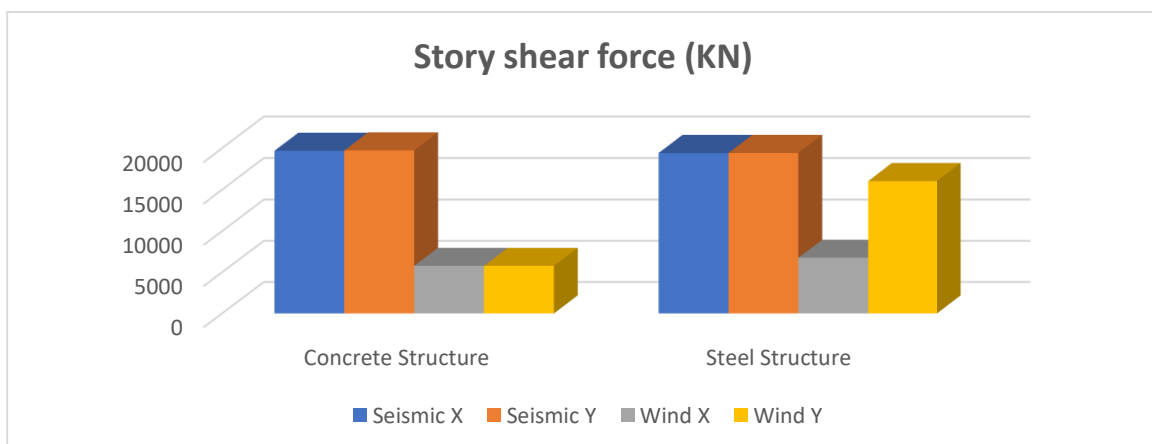


Figure 28: Story shear force (KN) in concrete and steel sky scrapers

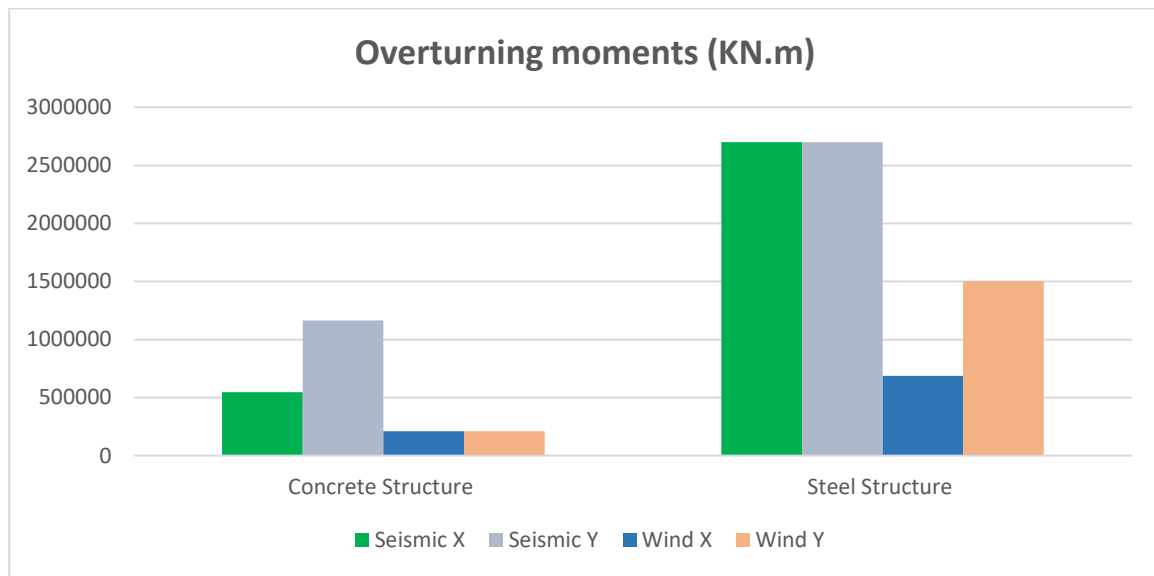


Figure 29: Overturning moments (KN.m) in concrete and steel structures

4.12 Discussion of overturning moments and shear forces:

The minimum overturning moments and shear forces are on the top of building and increasing till the maximum at bottom. Moreover, their values due to wind loads are less than the values due to seismic loads in X and Y directions.

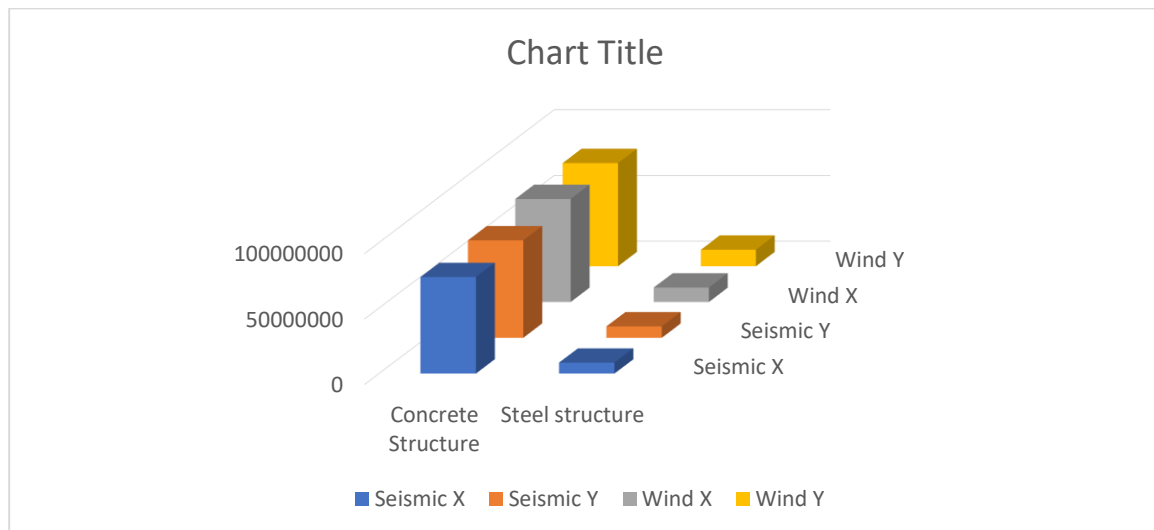


Figure 30: Story Stiffness (Kn/m) in concrete and steel tall building

4.13 Discussion of story stiffness:

The story stiffness in concrete skyscraper is (6 to 8) times the story stiffness in steel skyscraper due to seismic and wind loads in X and Y direction.

4.14 Calculation of Cost of steel skyscraper:

The average cost estimated per KG is AED 10

The Cost estimate of composite columns:

* The length of one column (height of floor) = 3.7 m, so the weight of W14 x 500 for one column = $500 \times 3.7 = 1850$ kg

** Number of columns from level 21 to 55 (Number of columns in typical floors from level 21 to 40 are 64 columns in each floor x 20 floors, and number of columns from level 41 to 55 are 36 columns in each floor x 15 floors = $(64 \times 20 + 36 \times 15) = 1820$ columns

***length of one column (height of floor) = 3.7 m, so the weight of W14 x 500 for one column = $500 \times 3.7 = 1850$ kg, therefor the weight of 1820 columns = $1850 \times 1820 = 3367000$ Kg

Composite Column 1 (0.9 x 0.6 m), 8 T 20 rebars, embedded steel column is W 14 x 500, C 60 concrete. From Level 21 to 55

Composite Column 2 (1.0 x 0.6 m), 8 T 25 rebars, embedded steel column is W 14 x 500, C 60 concrete. From Level 1 to 20

Table 7: Total volume of composite columns

	reinforced concrete volume in one column(m ³) B x L x H, where B=0.6, L=1, H= 3.7 m	Number of columns from level 1 to 20 (100 columns in each floor)	total volume for concrete in composite column 2 (m ³)	for embedded steel column W 14 x 500 weight = 500 kg/m *weight of 2000 columns = 1850x2000=
Comp. Colum.2	2.22	2000	4440	3700000
	reinforced concrete volume in one column(m ³)	**Number of columns from level 21 to 55	total volume for concrete in composite column 1(m ³)	for embedded steel column W 14 x 500 weight = 500 kg/m *** weight of 1820 columns = 1850x1820=
Comp. Colum.1	1.998	1820	3636.36	3367000

So, the total volume of reinforced concrete for 3820 composite columns (m³) = 8076.36

The weight of embedded W 14 x 500 in 3820 composite columns (kg) = 7067000

The average price for reinforced concrete per m³ = AED 1400, so the estimated cost for

8076.36 m³ for the composite columns = AED 11306904

The average cost estimated per KG for steel elements is AED 10, so the cost of

embedded W14x500 in all columns = $7067000 \times 10 = 70670000$

total cost of 3820 composite columns is = AED 81,976,904

The cost estimate of secondary beams W 12 x 130:

firstly: calculation of secondary beams number since they are typical in all floors

Table 8: number of secondary beams in all floors of steel building

	number of secondary beams in each floor	number of typical floors	total number
from level 1 to 20	243	20	4860
from level 21 to 40	147	20	2940
from level 41 to 55	75	15	1125
number of secondary beams in all floors			8925

To calculate the total weight and cost of secondary beams, weight of W 12 x 130 is 130 kg/m, and the length of each secondary beam is 6 m

Then total weight of all beams(kg) = $8925 \times 6 \times 130 = 6961500$ kg

The estimated cost AED = $6961500 \times 10 = \text{AED } 69,615,000$

The cost estimate of main beams and bracing beams (calculated by ETABS):

There are several sections selected for design from auto select list which are mentioned in the below schedule with number of pieces, total length of each type and weight in KN, then the weight converted to kg.

Table 9: Total weight of main beams and bracing(kg)

Material List by Section Property					
Section	Object Type	Number Pieces	Length	Weight	Weight
			m	kN	KG
W14X370	Beam	3370	20220	98504.311	10044644.3
W14X90	Brace	4	28.1965	37.1061	3783.769177
W14X68	Beam	4	24	19.8639	2025.554088
W14X61	Brace	444	3129.8064	2782.1182	283697.1035
W14X53	Beam	12	72	47.1013	4802.995926
W14X53	Brace	92	648.5184	502.4027	51230.81786
W14X48	Beam	40	240	142.0012	14480.09259
W14X48	Brace	172	1212.4475	848.9598	86569.80722
W14X43	Brace	990	6978.6223	4366.6192	445271.2394
W30X124	Beam	4	24	36.2517	3696.644624
W30X116	Beam	16	96	137.2279	13993.35145
W30X108	Beam	28	168	222.2793	22666.1806
W27X114	Beam	4	24	34.0388	3470.991623
W27X102	Beam	12	72	90.5795	9236.538471
W27X94	Beam	160	960	1112.3878	113431.9875
W24X84	Beam	8	48	50.0452	5103.190182
W24X76	Beam	32	192	181.5404	18511.96892
W24X62	Beam	76	456	346.701	35353.66308
W21X68	Beam	32	192	162.0896	16528.53931

W21X62	Beam	28	168	129.773	13233.16321
W18X60	Beam	8	48	35.6597	3636.277424
W18X55	Beam	6	36	24.6174	2510.27619
W18X50	Beam	20	120	73.7299	7518.357441
W24X55	Beam	214	1284	873.1923	89040.83454
W21X50	Beam	4	24	14.892	1518.561384
W18X35	Beam	1660	9960	4272.629	435686.9063
W21X44	Beam	466	2796	1518.6567	154859.8859
W16X36	Brace	6	42.2947	22.2637	2270.265585
W14X38	Beam	12	72	33.5939	3425.624449
W14X38	Brace	112	789.5007	439.1123	44776.99316
W14X34	Brace	190	1339.3315	665.1095	67822.29406
W14X30	Brace	1004	7077.3099	3110.4023	317172.7654
W14X22	Beam	8925	53550	17258.7465	1759902.362
W14X22	Brace	48	338.3574	109.05	11120.0053
W16X40	Beam	316	1896	936.0537	95450.91341
W16X40	Brace	82	578.0273	338.7158	34539.39929
W16X45	Beam	14	84	47.158	4808.777717
W16X50	Beam	46	276	170.8198	17418.77196
W16X67	Brace	8	56.3929	54.889	5597.120321
W18X76	Brace	8	56.3929	62.4503	6368.158342
W18X97	Beam	8	48	57.1783	5830.563954
W21X111	Beam	4	24	33.0258	3367.694371
W24X146	Beam	4	24	43.5616	4442.046978

W27X146	Beam	4	24	42.9061	4375.204581
W27X258	Beam	4	24	77.0939	7861.389975
W27X336	Beam	4	24	100.4956	10247.69927
W27X368	Beam	4	24	110.4236	11260.07352
W27X539	Beam	12	72	473.7546	48309.52466
W30X173	Beam	44	264	564.1792	57530.26773
W30X191	Beam	24	144	336.5386	34317.38667
W30X211	Beam	16	96	248.742	25364.62502
W30X235	Beam	12	72	209.2386	21336.39928
W30X292	Beam	8	48	172.5381	17593.98979
Total weight of main beams and bracing(kg)					14509013.31

The price of main beams and bracing beams (AED 10/kg)

$$= 14509013.31 \times 10 = \text{AED } 145,090,133.1$$

Average of price for decking slab considered is AED 65 /m²

Table 10: The cost Estimate of decking slabs

	area of one floor (m²)	number of typical floors	total area
from level 1 to 20 (54 x 54 m)	2916	20	58320
from level 21 to 40 (42 x 42 m)	1764	20	35280

from level 41 to 55 (30 x 30 m)	900	15	13500
Summation of area for deck slab in all floors			107100
Cost of decking slab in all floors (AED)			AED 6,961,500

Table 11: Total cost of steel skyscraper

Item	Cost (AED)
Composite columns	81,976,904
Secondary beam	69,615,000
Main beams and bracing beams	145,090,133.10
Deck slabs	6,961,500
Total (AED)	303,643,537

Accordingly, total estimated cost for steel skyscraper is **AED 303,643,537**

4.15 The Cost calculation of concrete skyscraper

Table 12: The Cost estimation of Post tension slabs and beams

PT slab area	Area per floor m2	Area of typical floors	Unit price per m2 (AED)	Total Price (AED)
From level 1 to 20	2916	58320	500	29160000
From level 21 to 40	1764	35280	500	17640000

From level 41 to 55	900	13500	500	6750000
Total cost (AED)				53,550,000

Table 13: The Cost estimation of the Shear walls for staircases and Lifts

	Area of one wall in one floor	Area of 3 walls	total height of 55 floors	Volu me m ³	Price for one m ³	total price (AED)
From level 1 to 55	9.6	28.8	203.5	5860 .8	1400	8,205,12 0

Table 14: The Cost estimation of Shear walls at corner of each floor (4 shear walls at corner L shape)

	Area of wall m ²	walls in each floor	Numbe r of floors	Heigh t of floor	Vol ume m ³	Price for one m ³	Total price (AED)
From level 1 to 20	2.4	12	20	3.7	213 1.2	1400	2983680
From level 21 to 40	2.4	8	20	3.7	142 0.8	1400	1989120
From level 41	2.4	4	15	3.7	532. 8	1400	745920

to 55							
Total price (AED)							5,718,720

Table 15: The Cost estimate of Shear walls rectangular shape

	Area of wall m ²	walls in each floor	Numbe r of floors	Heigh t of floor	Vol ume m ³	Price for one m ³	Total price (AED)
From level 1 to 20	1.5	76	20	3.7	8436	1400	11810400
From level 21 to 40	1.5	44	20	3.7	4884	1400	6837600
From level 41 to 55	1.5	20	15	3.7	1665	1400	2331000
Total price (AED)							20,979,000

Table 16: Total cost of reinforced concrete tall building

Total cost of concrete tall building:	Cost
Post tension slabs and beams	53,550,000
Shear walls for staircases and Lifts	8,205,120
Shear walls at corner of each floor (4 shear walls at corner L shape)	5,718,720.00
Shear walls rectangular shape	20,979,000.00
Total	AED 88,452,840

So, the total estimated cost for concrete skyscraper is **AED 88,452,840**

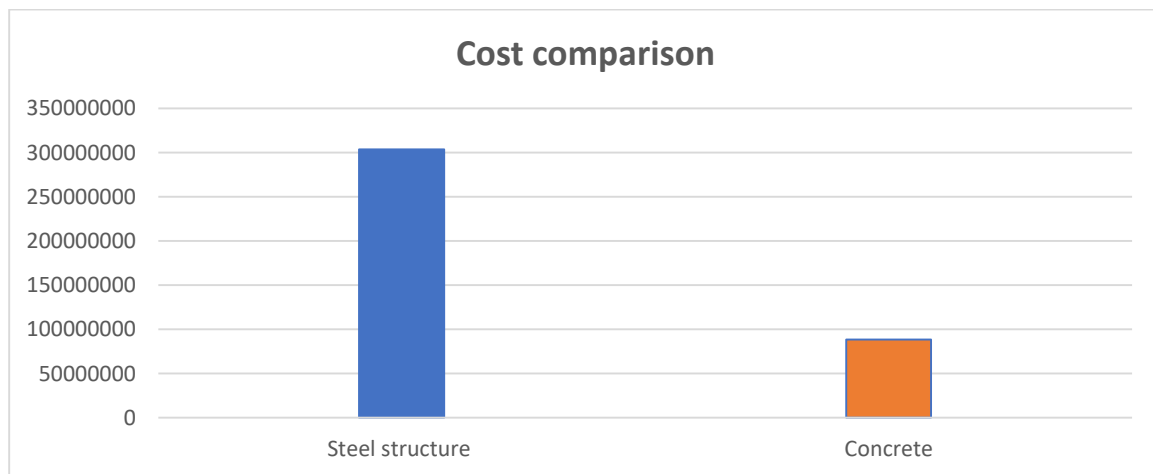


Figure 31: cost comparison between the reinforced concrete and steel skyscrapers

4.16 Discussion of cost comparison:

The estimated total cost of concrete 55 floors structure is AED 88,452,840, while the cost of steel building is AED 303,643,537

The cost estimate of steel tall building is more than three times the cost estimate of the concrete one.

4.17 Roughly Construction Time estimate for construction of the reinforced Concrete Skyscraper:

The time estimate for construction of 55 floors skyscraper, which has three ranges of typical floors, including casting shear walls, and Post tension slabs with beams as below:

Table 17: Total duration for constructing the reinforced concrete tall building

	Area (m ²)	Time for one floor (days)	Total period (days)
From Level 1 to level 20	54x54 m= 2916 m ²	14	280
From Level 21 to level40	42x42= 1764 m ²	10	200
From Level 41 to level55	30x30 = 900 m ²	8	120
Total duration for constructing the reinforced concrete tall building			600 days

4.18 Roughly Construction Time Estimate for construction of the steel skyscraper:

The time estimate for construction of 55 floors skyscraper, which has three ranges of typical floors, including erection of steel columns, main beams, secondary beams and decking slabs as per below.

Table 18: Total duration for constructing the steel tall building

	Area (m ²)	Time for one floor(days)	Total period
From Level 1 to level 20	54 x 54 m= 2916 m ²	9	= 9 x 20 =180
From Level 21 to level 40	42 x 42= 1764 m ²	7	= 7 x 20 =140
From Level 41 to level 55	30 x 30 = 900 m ²	6	= 6 x 15 = 90
Total duration for constructing the steel tall building			410 days

The above time estimate excluding Authority approvals, fabrication and foundation

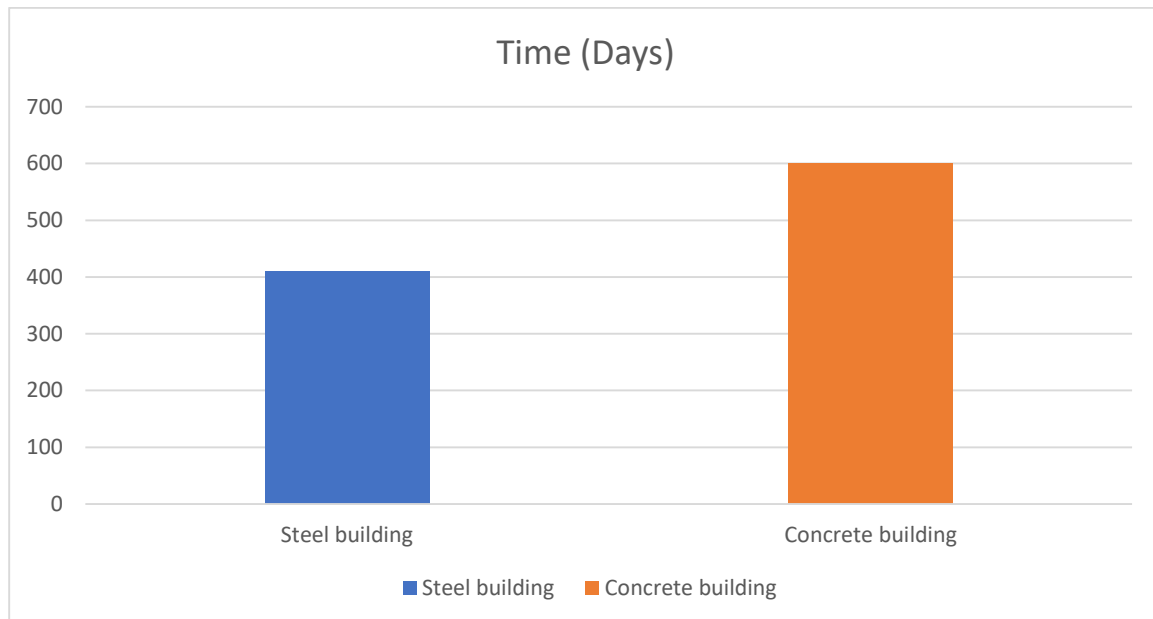


Figure 32: Comparison between the construction time of reinforced concrete and steel tall building

4.19 Discission of Time of construction:

The Estimated time for construction of Steel skyscraper found 410 days, whereas the

estimated time for Concrete structure found 600 days.

Hence, the time estimate of constructing the concrete skyscraper is about one and half the one of steel structure.

4.20 ETABS design output for one of the shear walls in the skyscraper

ETABS Shear Wall Design

ACI 318-19 Pier Design Pier Details

Story	Pier	Centroid X (mm)	Centroid Y	Length	Thickness (mm)	LLRF
Story41	P55	30000	12000	3000	400	0.43

Table 19: Material Properties

Ec (MPa)	f'c (MPa)	Lt.Wt Factor (Unitless)	fy (MPa)	fys (MPa)
24855.58	60	1	413.69	413.69

Table 20: Design Code Parameters

ϕ_T	ϕ_C	ϕ_v	ϕ_v (Seismic)	IPMAX	IPMIN	PMAX
0.9	0.65	0.75	0.6	0.04	0.0025	0.8

Table 21: Flexural Design for Pu, Mu2 and Mu3

Station	Require	Require	Curren	Flexural	Pu kN	Mu2 kN-	Mu3	Pier Ag
Top	3000	0.0025	0.0026	UDWalS1	3465.332	166.512	-	120000
Bottom	3000	0.0025	0.0026	UDWalS1	3549.028	-	15.069	120000

Table 22: Shear Design

Station	ID	Rebar	Shear	Pu kN	Mu kN-m	Vu kN	ϕV_c kN	ϕV_n kN
Top	Leg	1000	UDWalS11	5945.5282	698.6768	384.2968	1389.2771	2133.911
Bottom	Leg	1000	UDWalS11	6081.5345	2131.7459	384.2968	1389.2771	2133.911

CHAPTER 5: CONCLUSION AND RECOMMENDATION

This dissertation is about Structural analysis and design to find out the suitable structural elements for two tall buildings consisting of 55 floors in Dubai, which are designed from reinforced concrete and steel to resist the seismic and wind loads.

Moreover, it includes calculation of the total cost, and estimation of total duration of construction of each skyscraper, in order to make comparison between the reinforced concrete structure and the steel a structure of the above mentioned tall residential building. However, there are few references, journal writing about the same topic.

5.1 Conclusion of Structural analysis and Design results

This study contains a comprehensive investigation for the requirements of lateral loads (seismic and wind loads) of the two skyscrapers from concrete and steel which are consist of 55 floors is reflected in this dissertation.

However, both of the structures passed the design with different results due to difference in materials and codes used for the design. The design output is mentioned in the attached appendixes.

5.2 Conclusion of Lateral loads results:

The lateral loads in Steel frame due to Seismic and wind loads found about 400 KN which are near to the values for wind load in concrete structure, however it is found in concrete due to seismic load about 1400 KN which is 3.5 times more than the one in steel structure.

5.3 Conclusion of Maximum Story displacement

The maximum displacement of concrete structure due to earthquake loads found two and half time the one due to wind load. On the other hand, the extreme displacements in steel structure due to seismic in X direction, wind X and wind Y, are almost equals, while the displacement due to seismic load in Y direction found near to three times the value for the other cases.

Generally, the concrete structure displacements due to seismic and wind loads about 6% of the steel structure displacements

5.4 Conclusion of maximum story drifts

With regard to the maximum story drifts in the reinforced concrete skyscraper, it is found that the drift due to seismic load is almost three times the one due to wind load.

Furthermore, the values of story drift in the steel skyscraper due to wind load in X and Y direction are equal, while the value is little more due to seismic load, but three times due to seismic in Y direction

5.5 Conclusion of maximum shear forces:

The maximum shear forces in the reinforced concrete tall building due to wind load in X and Y direction are equal, however, it is about quarter the value due to Seismic load in X and Y direction.

Moreover, the shear forces in the steel tall building due to wind load is more than the values due to seismic loads.

Nonetheless, the maximum shear force in concrete tall building is 1.14 times the one in

steel tall building.

5.6 Conclusion of maximum overturning moment:

The maximum overturning moments values in the reinforced concrete structure due to seismic in Y direction found more than double the value due to seismic in X direction, and more than 5.5 times the value due to wind load.

On the other hand, the maximum overturning moment values in steel structure are equals for the seismic in X and Y directions and also equal for the wind load in both dictions.

However, the values due to wind are higher than the values due to earthquake loads.

Generally, the maximum overturning moment in steel structure is near to one and half the one in concrete structure.

5.7 Conclusion of maximum story stiffness:

The story stiffness due to wind load is equal in the reinforced concrete structure and greater than the value due to seismic load.

Nevertheless, the story stiffness values in the steel structure due to seismic in X direction is almost six times the value resulted from seismic load in Y direction.

Overall, the maximum story stiffness of the reinforced concrete structure is more than 20 times the one in steel tall building.

5.8 Availability of Raw materials:

The reinforced concrete materials (cement, aggregates, admixtures, reinforcement rebars) and steel structure materials are available in Dubai.

5.9 Conclusion of construction duration comparison:

By assuming good construction conditions of construction of both skyscrapers (reinforced concrete and steel), without any issues, and with availability of the required resources, materials, and fund, it is found that the roughly estimate duration for constructing the reinforced concrete tall building is 600 days, and for steel skyscraper is 410 days. Hence, this mean that the duration of construction of steel building is shorter than the one for constructing the reinforced concrete by 190 days, or it can be said that the total period of steel building is 68% of the concrete one.

5.10The answers to the research questions:

The questions of research will be answered in this part from the results of analysis and design conducted in this research.

The first Research question:

What are the suitable design and members sections for the reinforced concrete and steel tall buildings to withstand the seismic and wind loads in Dubai? With regard to the member sections for the concrete skyscraper (55 floors), located in Dubai in order to withstand seismic and wind load in X and Y direction, the following is the answer for the concrete and steel buildings

The Suitable design and members sections for the reinforced concrete skyscraper:

In the beginning, there were many trials to design the vertical elements as columns but not pass the design, hence most of the vertical elements are designed as shear walls with 40 cm thickness and the length is shown in the drawings, moreover, there are other rectangular shear walls for staircase and lifts which presented in chapter 4.

The Post tension slab with thickness of 20 cm and beams which design by (SAFE 20), the

design details shown in the appendix.

The Suitable design and member sections for steel skyscraper:

After performing many trials of designing and analyzing the steel tall building, and regarding the columns it is found that the normal steel sections did not pass the design due to the high lateral loads (seismic and wind loads).

Therefore, two composite columns which consist of reinforced concrete and embedded steel I section are passed the design. However, their details as following:

The Composite Column 1 (0.9x0.6m), 8 T 20 rebars, embedded steel column is W 14 x 500, C 60 concrete. From Level 21 to 55

The Composite Column2 (1.0x0.6m), 8 T 25 rebars, embedded steel column is W 14 x 500, C 60 concrete. From Level 1 to 20.

The bracing, main and secondary beams are steel sections W with different sizes as explained in chapter 4.

The Deck slab consist of corrugated metal sheet, shear studs and C 60 concrete as shown in the appendix.

The Second Research question:

What is the estimated budget for constructing reinforced concrete skyscraper and steel skyscraper to resist the earthquake and wind loads in Dubai? Which one is more expensive (concrete skyscraper or steel skyscraper)?

The cost calculation and comparison are excluding the cost of foundations, staircase, lift, and finishing materials.

However, the cost calculation and comparison done after computing the total price of reinforced concrete and steel 55 floors buildings, which are having the same dimensions and subjected to seismic, wind, live and dead loads. However, the difference is only in the construction materials. The two skyscrapers are designed from the reinforced

concrete and steel materials since this is the best-known materials suitable for tall buildings to resist the above-mentioned loads in Dubai.

The results of the cost comparison shows that the total budget for construction of the steel skyscraper cost is **AED 303,643,537**, while the total budget for construction of concrete skyscraper cost is **AED 88,452,840**, and that mean the total cost of steel building is more than 3.4 times the cost of concrete building.

The third Research question:

What is the period for constructing the reinforced concrete skyscraper and steel skyscraper to resist the earthquake and wind loads in Dubai?

The estimated total duration to construct the above-mentioned steel sky scraper is **410 days**, while the period to construct the reinforced concrete tall building is **600 days**.

5.11Recommendations:

There are pros and cons for concrete structure and steel structure which mentioned in chapter 1. However, due to the significant difference in cost of materials, the steel structure cost is more than 6 times the concrete structure, While the duration of constructing the Concrete is longer than the steel by about one and half time.

So, it is recommended to use the concrete if there is money constrain, and to use steel if there is time constrain. Moreover, the designer must study all of constrains which contributed and influenced in selection of the best construction materials and structural systems to take the correct decision.

5.12Areas of upcoming researches:

There are very few researches which comparing between the design and analysis results

for steel and concrete materials in high rise structures.

This study is about finding the suitable design and members sections for the concrete and steel tall buildings, in addition to comparing the cost of both buildings.

However, there are many subjects of upcoming researches related to the same subject such as but not limited to:

Comparing between the sustainability of steel and concrete buildings.

Comparing between the fire resistance of steel and concrete buildings

Comparing between the Durability of steel and concrete buildings.

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APPENDIX

Appendix A- Results of post tension slab and beam design

The below results for Post tension slab and design for level 20 by SAFE-CSI rev.20

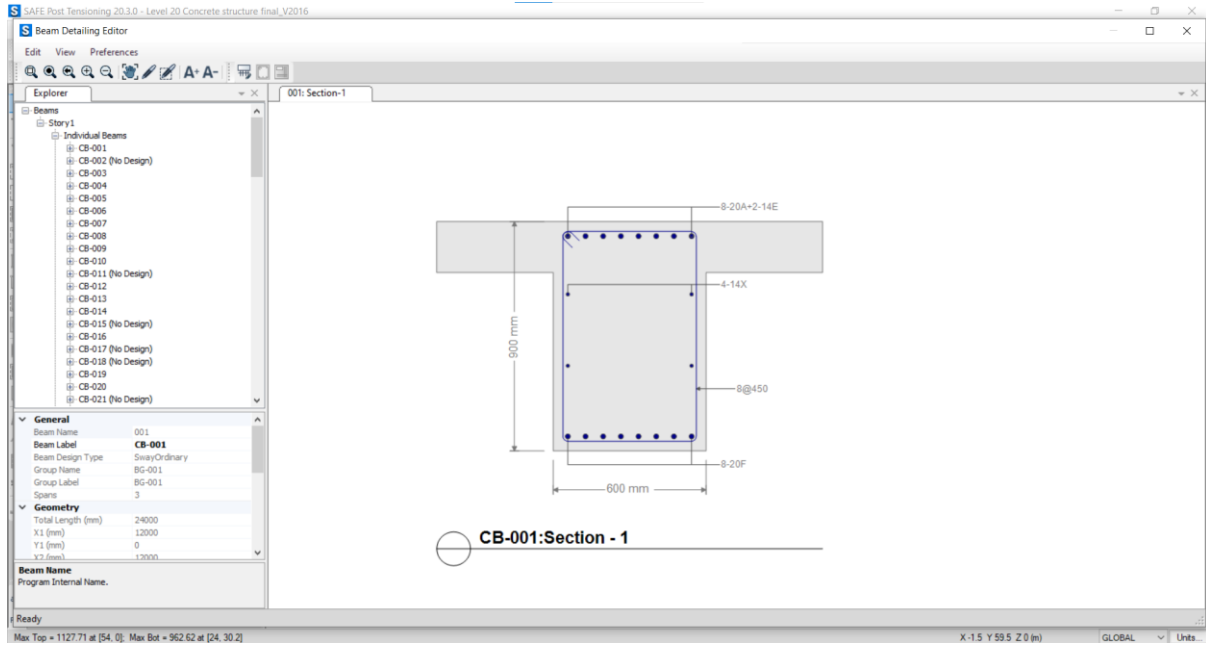


Figure 33: Sample of Beam reinforcement section

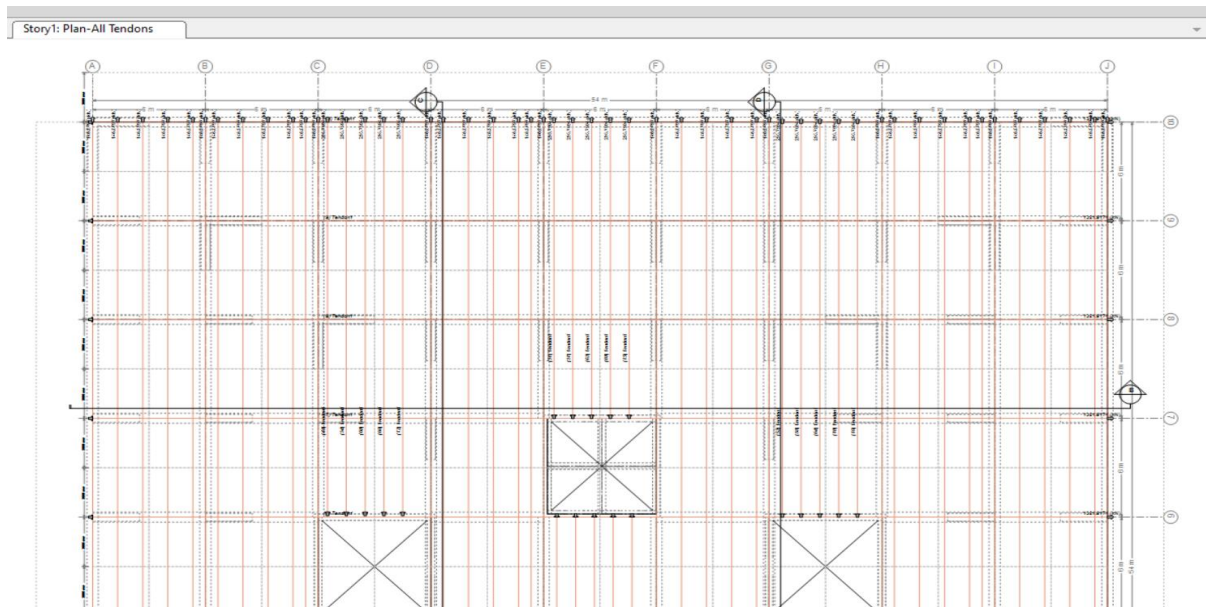


Figure 34: sample of Tendon distribution plan in post tension slabs

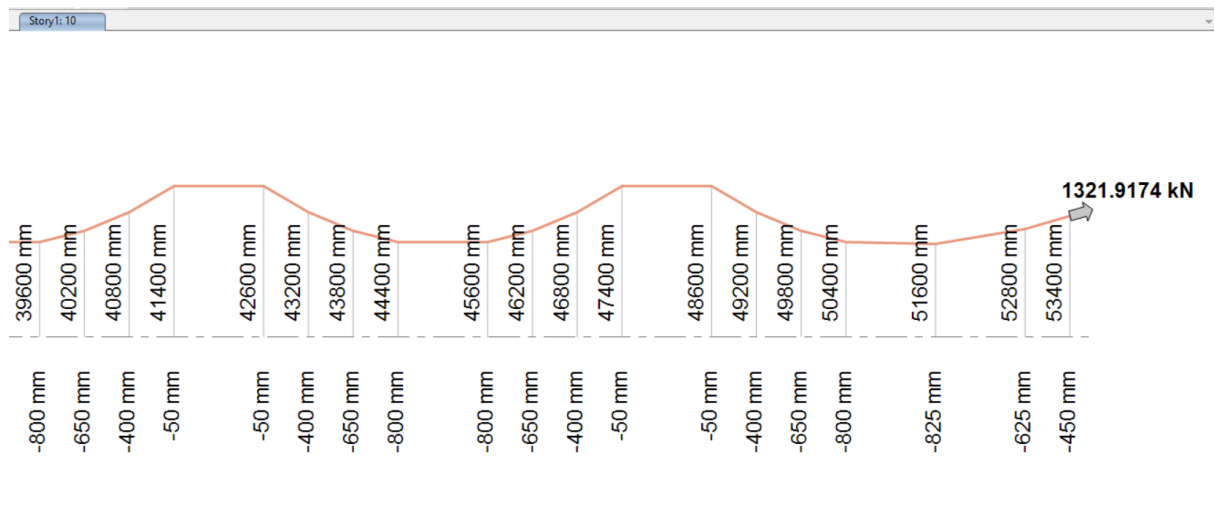


Figure 35: Sample of tendon profile

Table 23: Concrete Beam Design Summary - ACI 318-19 for some of beams

Unique Name	Design Sect	Status	As Min Top	As Top	As Bot Combo	As Min Bot	As Bot	AsTop Total	AsBot Total
			mm ²	mm ²		mm ²	mm ²	mm ²	mm ²
B1	PT beam 0.4x 0.9	No Message	215 2	2152	DConS2	2160	2160	2152	2160
B2	PT beam 0.4x 0.9	No Message	216 0	2160	DConS2	2160	2160	2160	2160
B4	PT beam 0.4x 0.9	No Message	216 0	2160	DConS2	2160	2160	2160	2160
B5	PT beam 0.4x 0.9	No Message	215 1	2151	DConS2	2156	2156	2151	2156
B6	PT beam 0.4x 0.9	No Message	215 6	2156	DConS2	2160	2160	2156	2160
B21	PT beam 0.4x 0.9	No Message	216 0	2160	DConS2	2160	2160	2160	2160
B98	PT beam 0.4x 0.9	No Message	201 3	2013	DConS2	0	0	2013	1264
B90	PT beam 0.4x 0.9	No Message	0 0	0	DConS2	2098	2098	0	2098
B166	PT beam 0.4x 0.9	No Message	0 0	0	DConS2	2158	2158	0	2158
B107	PT beam 0.4x 0.9	No Message	0 0	0	DConS2	2159	2159	0	2159

Shear wall Pier Design summary

Table 24: Shear Wall Pier Design Summary - ACI 318-14

Story	Pier Label	Station	Edge Rebar	End Rebar	Rebar Spacing	Required Reinf. Percentage	Current Reinf. Percentage	Pier Leg	Thickness	Shear Rebar
					mm	%	%		mm	mm ² /m
Story20	P30	Top	14	14	250	0.46	0.3	Top Leg 1	500	1250
Story20	P30	Bottom	14	14	250	0.25	0.3	Bottom Leg 1	500	1250
Story19	P30	Top	14	14	250	0.25	0.3	Top Leg 1	500	1250
Story19	P30	Bottom	14	14	250	0.25	0.3	Bottom Leg 1	500	1250
Story18	P30	Top	14	14	250	0.25	0.3	Top Leg 1	500	1250
Story18	P30	Bottom	14	14	250	0.25	0.3	Bottom Leg 1	500	1250
Story17	P30	Top	14	14	250	0.25	0.3	Top Leg 1	500	1250
Story17	P30	Bottom	14	14	250	0.25	0.3	Bottom Leg 1	500	1250
Story16	P30	Top	14	14	250	0.25	0.3	Top Leg 1	500	1250
Story16	P30	Bottom	14	14	250	0.25	0.3	Bottom Leg 1	500	1250
Story15	P30	Top	14	14	250	0.25	0.3	Top Leg 1	500	1250
Story15	P30	Bottom	14	14	250	0.25	0.3	Bottom Leg 1	500	1250
Story14	P30	Top	14	14	250	0.25	0.3	Top Leg 1	500	1250
Story14	P30	Bottom	14	14	250	0.25	0.3	Bottom Leg 1	500	1250
Story13	P30	Top	14	14	250	0.25	0.3	Top Leg 1	500	1250
Story13	P30	Bottom	14	14	250	0.25	0.3	Bottom Leg 1	500	1250
Story12	P30	Top	14	14	250	0.25	0.3	Top Leg 1	500	1250
Story12	P30	Bottom	14	14	250	0.25	0.3	Bottom Leg 1	500	1250

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Story20	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story19	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story19	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story19	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story19	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story18	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story18	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story18	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story18	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250

Story17	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story17	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story17	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story17	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story16	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story16	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story16	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story16	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story15	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story15	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story15	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story15	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story14	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story14	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story14	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story14	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story13	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story13	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story13	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story13	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story12	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story12	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250

Story12	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story12	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story11	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story11	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story11	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story11	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story10	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story10	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story10	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story10	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story9	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story9	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story9	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story9	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story8	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story8	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story8	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story8	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story7	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story7	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story7	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story7	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250

Story6	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story6	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story6	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story6	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story5	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story5	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story5	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story5	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story4	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story4	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story4	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story4	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story3	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story3	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story3	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story3	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story2	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story2	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story2	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story2	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story1	P129	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story1	P129	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250

Story1	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story1	P129	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story20	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story20	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story20	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story20	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story19	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story19	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story19	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story19	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story18	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story18	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story18	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story18	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story17	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story17	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story17	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story17	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story16	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story16	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story16	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story16	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250

Story15	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story15	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story15	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story15	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story14	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story14	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story14	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story14	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story13	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story13	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story13	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story13	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story12	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story12	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story12	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story12	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story11	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story11	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story11	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story11	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story10	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story10	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250

Story10	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story10	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story9	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story9	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story9	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story9	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story8	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story8	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story8	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story8	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story7	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story7	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story7	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story7	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story6	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story6	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story6	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story6	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story5	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story5	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story5	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story5	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250

Story4	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story4	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story4	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story4	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story3	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story3	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story3	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story3	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250
Story2	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story2	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story2	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story1	P130	Top	20	20	250	0.25	0.54	Top Leg 1	500	1250
Story1	P130	Top	20	20	250	0.25	0.54	Top Leg 2	500	1250
Story1	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 1	500	1250
Story1	P130	Bottom	20	20	250	0.25	0.54	Bottom Leg 2	500	1250

Analysis Results:

Base Reactions from ETABS output

Table 25: Base Reactions

Output Case	Case Type	FX	FY	FZ	MX	MY	MZ
		kN	kN	kN	kN-m	kN-m	kN-m
Dead	LinStatic	0	0	424778.334	11434177	-11482091	0.000002207
Live	LinStatic	0	0	484556.4	13026118	-13083023	0.000003795
SDead	LinStatic	0	0	169948.8	4568659.2	-4588618	0.000001331
EQ X	LinStatic	- 10283.9449	0	0	0.000001774	-1420008	276427.384
EQ Y	LinStatic	0	-10283.945	0	1420008.109	- 0.000003502	- 277803.6252
W x	LinStatic	-17337.12	0	0	0.000001221	-1688714	468102.2403
W Y	LinStatic	-17337.12	0	0	0.000001221	-1688714	468102.2403
W Y	LinStatic	0	- 17337.1201	0	1688713.936	- 0.000004377	- 468102.2424
W Y	LinStatic	-13002.84	0	0	0.00002563	-1266535	264602.8064
W Y	LinStatic	-13002.84	0	0	-0.0000238	-1266535	437550.5541
W Y	LinStatic	0	- 13002.8401	0	1266535.452	- 0.000003254	- 437550.5556
W Y	LinStatic	0	- 13002.8401	0	1266535.452	- 0.000003312	-264602.808
W Y	LinStatic	-13002.84	13002.8401	0	-1266535	-1266535	702153.3621
W Y	LinStatic	-13002.84	- 13002.8401	0	1266535.452	-1266535	-0.0016
W Y	LinStatic	-9760.7986	9760.7986	0	-950745.946	- 950745.9412	397257.0145
W Y	LinStatic	-9760.7986	9760.7986	0	-950745.946	- 950745.9412	656909.233
W Y	LinStatic	-9760.7986	-9760.7986	0	950745.946	- 950745.9412	- 129826.1104
W Y	LinStatic	-9760.7986	-9760.7986	0	950745.946	- 950745.9412	129826.1081
Cladding	LinStatic	0	0	34164	930312	-931626	-9.598E-07
DCmcS1	Combination	0	0	832617.9876	22403971	-22498992	0.000004953
DCmcS2	Combination	0	0	1488962.801	40045192	-40217687	0.00001032
DCmcS3	Combination	-17337.12	0	1198228.961	32229521	-34056587	468102.2403
DCmcS4	Combination	17337.12	0	1198228.961	32229521	-30679159	- 468102.2403
DCmcS5	Combination	0	13002.8401	1198228.961	33918235	-32367873	702153.3621
DCmcS5	Combination	-17337.12	-	1198228.961	30962986	-34056587	-

			17337.1201				468102.2424
DCmcS6	Combination	17337.12	17337.1201	1198228.961	33496057	-30679159	468102.2424
DCmcS6	Combination	0	- 13002.8401	1198228.961	30540808	-32367873	-702153.362
DCmcS7	Combination	-17337.12	0	535254.4206	14402553	-16152352	468102.2403
DCmcS8	Combination	17337.12	0	535254.4206	14402553	-12774924	- 468102.2403
DCmcS9	Combination	0	13002.8401	535254.4206	16091267	-14463638	702153.3621
DCmcS9	Combination	-17337.12	- 17337.1201	535254.4206	13136017	-16152352	- 468102.2424
DCmcS10	Combination	17337.12	17337.1201	535254.4206	15669088	-12774924	468102.2424
DCmcS10	Combination	0	- 13002.8401	535254.4206	12713839	-14463638	- 702153.3621
DCmcS11	Combination	- 10283.9449	0	1257701.674	33829805	-35394952	276427.384
DCmcS12	Combination	10283.9449	0	1257701.674	33829805	-32554936	-276427.384
DCmcS13	Combination	0	-10283.945	1257701.674	35249813	-33974944	- 277803.6252
DCmcS14	Combination	0	10283.945	1257701.674	32409797	-33974944	277803.6252
DCmcS15	Combination	- 10283.9449	0	475781.7072	12802269	-14276575	276427.384
DCmcS16	Combination	10283.9449	0	475781.7072	12802269	-11436559	-276427.384
DCmcS17	Combination	0	-10283.945	475781.7072	14222277	-12856567	- 277803.6252
DCmcS18	Combination	0	10283.945	475781.7072	11382261	-12856567	277803.6252
DSlbS1	Combination	0	0	832617.9876	22403971	-22498992	0.000004953
DSlbS2	Combination	0	0	1488962.801	40045192	-40217687	0.00001032
DSlbS3	Combination	-17337.12	0	1198228.961	32229521	-34056587	468102.2403
DSlbS4	Combination	17337.12	0	1198228.961	32229521	-30679159	- 468102.2403
DSlbS5	Combination	0	13002.8401	1198228.961	33918235	-32367873	702153.3621
DSlbS5	Combination	-17337.12	- 17337.1201	1198228.961	30962986	-34056587	- 468102.2424
DSlbS6	Combination	17337.12	17337.1201	1198228.961	33496057	-30679159	468102.2424
DSlbS6	Combination	0	- 13002.8401	1198228.961	30540808	-32367873	-702153.362
DSlbS7	Combination	-17337.12	0	535254.4206	14402553	-16152352	468102.2403
DSlbS8	Combination	17337.12	0	535254.4206	14402553	-12774924	- 468102.2403
DSlbS9	Combination	0	13002.8401	535254.4206	16091267	-14463638	702153.3621
DSlbS9	Combination	-17337.12	- 17337.1201	535254.4206	13136017	-16152352	- 468102.2424
DSlbS10	Combination	17337.12	17337.1201	535254.4206	15669088	-12774924	468102.2424
DSlbS10	Combination	0	-	535254.4206	12713839	-14463638	-

			13002.8401				702153.3621
DSlbS11	Combination	- 10283.9449	0	1257701.674	33829805	-35394952	276427.384
DSlbS12	Combination	10283.9449	0	1257701.674	33829805	-32554936	-276427.384
DSlbS13	Combination	0	-10283.945	1257701.674	35249813	-33974944	- 277803.6252
DSlbS14	Combination	0	10283.945	1257701.674	32409797	-33974944	277803.6252
DSlbS15	Combination	- 10283.9449	0	475781.7072	12802269	-14276575	276427.384
DSlbS16	Combination	10283.9449	0	475781.7072	12802269	-11436559	-276427.384
DSlbS17	Combination	0	-10283.945	475781.7072	14222277	-12856567	- 277803.6252
DSlbS18	Combination	0	10283.945	475781.7072	11382261	-12856567	277803.6252
DSlbI1	Combination	0	0	424778.334	11434177	-11482091	0.000002207
DSlbN1	Combination	0	0	594727.134	16002837	-16070709	0.000003538
DSlbN2	Combination	0	0	1079283.534	29028954	-29153732	0.000007333
DSlbL1	Combination	0	0	594727.134	16002837	-16070709	0.000003538
DSlbL2	Combination	0	0	837005.334	22515895	-22612220	0.000005435
DSldS1	Combination	0	0	880447.5876	23706408	-23803269	0.000003609
DSldS2	Combination	0	0	1529959.601	41161566	-41335638	0.000009166
DSldS3	Combination	-17337.12	0	1239225.761	33345896	-35174538	468102.2403
DSldS4	Combination	17337.12	0	1239225.761	33345896	-31797111	- 468102.2403
DSldS5	Combination	0	13002.8401	1239225.761	35034610	-33485825	702153.3621
DSldS5	Combination	-17337.12	- 17337.1201	1239225.761	32079360	-35174538	- 468102.2424
DSldS6	Combination	17337.12	17337.1201	1239225.761	34612431	-31797111	468102.2424
DSldS6	Combination	0	- 13002.8401	1239225.761	31657182	-33485825	- 702153.3621
DSldS7	Combination	-17337.12	0	566002.0206	15239834	-16990815	468102.2403
DSldS8	Combination	17337.12	0	566002.0206	15239834	-13613387	- 468102.2403
DSldS9	Combination	0	13002.8401	566002.0206	16928548	-15302101	702153.3621
DSldS9	Combination	-17337.12	- 17337.1201	566002.0206	13973298	-16990815	- 468102.2424
DSldS10	Combination	17337.12	17337.1201	566002.0206	16506369	-13613387	468102.2424
DSldS10	Combination	0	- 13002.8401	566002.0206	13551120	-15302101	- 702153.3621
DSldS11	Combination	- 10283.9449	0	1302114.874	35039211	-36606066	276427.384
DSldS12	Combination	10283.9449	0	1302114.874	35039211	-33766050	-276427.384
DSldS13	Combination	0	-10283.945	1302114.874	36459219	-35186058	- 277803.6252
DSldS14	Combination	0	10283.945	1302114.874	33619203	-35186058	277803.6252

DStdS15	Combination	- 10283.9449	0	503112.9072	13546519	-15021876	276427.384
DStdS16	Combination	10283.9449	0	503112.9072	13546519	-12181860	-276427.384
DStdS17	Combination	0	-10283.945	503112.9072	14966527	-13601868	- 277803.6252
DStdS18	Combination	0	10283.945	503112.9072	12126511	-13601868	277803.6252
DStdD1	Combination	0	0	628891.134	16933149	-17002335	0.000002578
DStdD2	Combination	0	0	1113447.534	29959266	-30085358	0.000006373
DConS1	Combination	0	0	880447.5876	23706408	-23803269	0.000003609
DConS2	Combination	0	0	1529959.601	41161566	-41335638	0.000009166
DConS3	Combination	-17337.12	0	1239225.761	33345896	-35174538	468102.2403
DConS4	Combination	17337.12	0	1239225.761	33345896	-31797111	- 468102.2403
DConS5	Combination	0	13002.8401	1239225.761	35034610	-33485825	702153.3621
DConS5	Combination	-17337.12	- 17337.1201	1239225.761	32079360	-35174538	- 468102.2424
DConS6	Combination	17337.12	17337.1201	1239225.761	34612431	-31797111	468102.2424
DConS6	Combination	0	- 13002.8401	1239225.761	31657182	-33485825	- 702153.3621
DConS7	Combination	-17337.12	0	566002.0206	15239834	-16990815	468102.2403
DConS8	Combination	17337.12	0	566002.0206	15239834	-13613387	- 468102.2403
DConS9	Combination	0	13002.8401	566002.0206	16928548	-15302101	702153.3621
DConS9	Combination	-17337.12	- 17337.1201	566002.0206	13973298	-16990815	- 468102.2424
DConS10	Combination	17337.12	17337.1201	566002.0206	16506369	-13613387	468102.2424
DConS10	Combination	0	- 13002.8401	566002.0206	13551120	-15302101	- 702153.3621
DConS11	Combination	- 10283.9449	0	1302114.874	35039211	-36606066	276427.384
DConS12	Combination	10283.9449	0	1302114.874	35039211	-33766050	-276427.384
DConS13	Combination	0	-10283.945	1302114.874	36459219	-35186058	- 277803.6252
DConS14	Combination	0	10283.945	1302114.874	33619203	-35186058	277803.6252
DConS15	Combination	- 10283.9449	0	503112.9072	13546519	-15021876	276427.384
DConS16	Combination	10283.9449	0	503112.9072	13546519	-12181860	-276427.384
DConS17	Combination	0	-10283.945	503112.9072	14966527	-13601868	- 277803.6252
DConS18	Combination	0	10283.945	503112.9072	12126511	-13601868	277803.6252
DCmpD1	Combination	0	0	628891.134	16933149	-17002335	0.000002578
DCmpD2	Combination	0	0	1113447.534	29959266	-30085358	0.000006373
DCmpS1	Combination	0	0	880447.5876	23706408	-23803269	0.000003609
DCmpS2	Combination	0	0	1529959.601	41161566	-41335638	0.000009166

DCmpC1	Combination	0	0	594689.6676	16007848	-16074928	0.000003089
DCmpC2	Combination	0	0	509734.0008	13721013	-13778509	0.000002648
DWalS1	Combination	0	0	880447.5876	23706408	-23803269	0.000003609
DWalS2	Combination	0	0	1529959.601	41161566	-41335638	0.000009166
DWalS3	Combination	-17337.12	0	1239225.761	33345896	-35174538	468102.2403
DWalS4	Combination	17337.12	0	1239225.761	33345896	-31797111	- 468102.2403
DWalS5	Combination	0	13002.8401	1239225.761	35034610	-33485825	702153.3621
DWalS5	Combination	-17337.12	- 17337.1201	1239225.761	32079360	-35174538	- 468102.2424
DWalS6	Combination	17337.12	17337.1201	1239225.761	34612431	-31797111	468102.2424
DWalS6	Combination	0	- 13002.8401	1239225.761	31657182	-33485825	- 702153.3621
DWalS7	Combination	-17337.12	0	566002.0206	15239834	-16990815	468102.2403
DWalS8	Combination	17337.12	0	566002.0206	15239834	-13613387	- 468102.2403
DWalS9	Combination	0	13002.8401	566002.0206	16928548	-15302101	702153.3621
DWalS9	Combination	-17337.12	- 17337.1201	566002.0206	13973298	-16990815	- 468102.2424
DWalS10	Combination	17337.12	17337.1201	566002.0206	16506369	-13613387	468102.2424
DWalS10	Combination	0	- 13002.8401	566002.0206	13551120	-15302101	- 702153.3621
DWalS11	Combination	- 10283.9449	0	1302114.874	35039211	-36606066	276427.384
DWalS12	Combination	10283.9449	0	1302114.874	35039211	-33766050	-276427.384
DWalS13	Combination	0	-10283.945	1302114.874	36459219	-35186058	- 277803.6252
DWalS14	Combination	0	10283.945	1302114.874	33619203	-35186058	277803.6252
DWalS15	Combination	- 10283.9449	0	503112.9072	13546519	-15021876	276427.384
DWalS16	Combination	10283.9449	0	503112.9072	13546519	-12181860	-276427.384
DWalS17	Combination	0	-10283.945	503112.9072	14966527	-13601868	- 277803.6252
DWalS18	Combination	0	10283.945	503112.9072	12126511	-13601868	277803.6252

Appendix B: Story stiffness from ETABS output

Table 26: Story Stiffness

Story	Output Case	Case Type	Shear X	Drift X	Stiff X	Shear Y	Drift Y	Stiff Y
			kN	mm	kN/m	kN	mm	kN/m
Story55	EQ X	LinStatic	356.2077	5.471	65109.764	0	0.02	0
Story54	EQ X	LinStatic	716.0557	5.832	122776.113	0	0.024	0
Story53	EQ X	LinStatic	1062.6994	6.204	171295.111	0	0.029	0
Story52	EQ X	LinStatic	1396.3857	6.562	212811.627	0	0.033	0
Story51	EQ X	LinStatic	1717.3612	6.903	248793.818	0	0.037	0
Story50	EQ X	LinStatic	2025.8729	7.226	280360.947	0	0.04	0
Story49	EQ X	LinStatic	2322.1675	7.53	308382.278	0	0.044	0
Story48	EQ X	LinStatic	2606.4919	7.814	333549.25	0	0.047	0
Story47	EQ X	LinStatic	2879.0928	8.078	356421.528	0	0.051	0
Story46	EQ X	LinStatic	3140.2171	8.319	377460.64	0	0.054	0
Story45	EQ X	LinStatic	3390.1115	8.538	397057.791	0	0.056	0
Story44	EQ X	LinStatic	3629.023	8.733	415570.936	0	0.059	0
Story43	EQ X	LinStatic	3857.1982	8.896	433571.464	0	0.061	0
Story42	EQ X	LinStatic	4074.8841	8.988	453373.078	0	0.062	0
Story41	EQ X	LinStatic	4282.3273	8.591	498463.589	0	0.053	0
Story40	EQ X	LinStatic	4675.0374	7.018	666139.688	0	0.03	0
Story39	EQ X	LinStatic	5055.0414	7.234	698805.711	0	0.031	0
Story38	EQ X	LinStatic	5415.8079	7.431	728811.652	0	0.031	0
Story37	EQ X	LinStatic	5757.8365	7.614	756235.594	0	0.031	0
Story36	EQ X	LinStatic	6081.6269	7.778	781949.358	0	0.031	0
Story35	EQ X	LinStatic	6387.6788	7.923	806269.304	0	0.031	0
Story34	EQ X	LinStatic	6676.4919	8.049	829493.202	0	0.031	0
Story33	EQ X	LinStatic	6948.5658	8.157	851878.49	0	0.031	0
Story32	EQ X	LinStatic	7204.4002	8.246	873659.611	0	0.031	0
Story31	EQ X	LinStatic	7444.4948	8.317	895054.346	0	0.031	0
Story30	EQ X	LinStatic	7669.3493	8.37	916270.026	0	0.031	0
Story29	EQ X	LinStatic	7879.4633	8.405	937508.993	0	0.031	0
Story28	EQ X	LinStatic	8075.3365	8.421	958973.843	0	0.031	0
Story27	EQ X	LinStatic	8257.4686	8.418	980872.858	0	0.031	0
Story26	EQ X	LinStatic	8426.3593	8.398	1003426.202	0	0.03	0
Story25	EQ X	LinStatic	8582.5082	8.358	1026882.526	0	0.03	0
Story24	EQ X	LinStatic	8726.4151	8.298	1051579.724	0	0.029	0
Story23	EQ X	LinStatic	8858.5795	8.212	1078766.67	0	0.029	0
Story22	EQ X	LinStatic	8979.5012	8.047	1115816.741	0	0.028	0
Story21	EQ X	LinStatic	9089.6799	7.248	1254021.333	0	0.019	0
Story20	EQ X	LinStatic	9254.4612	5.071	1825102.55	0	0.001	0
Story19	EQ X	LinStatic	9405.216	5.133	1832320.281	0	0.004	0

Story18	EQ X	LinStatic	9540.4608	5.182	1841014.341	0	0.015	0
Story17	EQ X	LinStatic	9660.8344	5.217	1851852.656	0	0.023	0
Story16	EQ X	LinStatic	9767.463	5.221	1870850.318	0	0.023	0
Story15	EQ X	LinStatic	9861.1794	5.209	1893022.728	0	0.023	0
Story14	EQ X	LinStatic	9942.8169	5.184	1918042.384	0	0.022	0
Story13	EQ X	LinStatic	10013.2084	5.146	1945939.224	0	0.022	0
Story12	EQ X	LinStatic	10073.187	5.096	1976870.956	0	0.021	0
Story11	EQ X	LinStatic	10123.5856	5.034	2011066.09	0	0.021	0
Story10	EQ X	LinStatic	10165.2374	4.961	2048825.711	0	0.021	0
Story9	EQ X	LinStatic	10198.9753	4.879	2090529.93	0	0.02	0
Story8	EQ X	LinStatic	10225.6325	4.786	2136649.298	0	0.02	0
Story7	EQ X	LinStatic	10246.0418	4.683	2187761.644	0	0.02	0
Story6	EQ X	LinStatic	10261.0365	4.571	2244579.461	0	0.019	0
Story5	EQ X	LinStatic	10271.4494	4.45	2308031.304	0	0.019	0
Story4	EQ X	LinStatic	10278.1137	4.319	2379769.52	0	0.019	0
Story3	EQ X	LinStatic	10281.8624	4.168	2467064.546	0	0.019	0
Story2	EQ X	LinStatic	10283.5284	3.908	2631198.251	0	0.018	0
Story1	EQ X	LinStatic	10283.9449	2.714	3789179.154	0	0.014	0
Story55	EQ Y	LinStatic	0	0.001	0	356.2077	6.419	55493.611
Story54	EQ Y	LinStatic	0	0.001	0	716.0557	8.104	88356.583
Story53	EQ Y	LinStatic	0	0.001	0	1062.6995	9.751	108988.341
Story52	EQ Y	LinStatic	0	0.001	0	1396.3857	11.335	123196.2
Story51	EQ Y	LinStatic	0	0.001	0	1717.3612	12.856	133584.928
Story50	EQ Y	LinStatic	0	0.001	0	2025.8729	14.314	141534.522
Story49	EQ Y	LinStatic	0	0.001	0	2322.1675	15.707	147843.229
Story48	EQ Y	LinStatic	0	0.001	0	2606.4919	17.035	153005.58
Story47	EQ Y	LinStatic	0	0.001	0	2879.0928	18.298	157344.966
Story46	EQ Y	LinStatic	0	0.001	0	3140.2171	19.494	161082.525
Story45	EQ Y	LinStatic	0	0.001	0	3390.1116	20.624	164375.424
Story44	EQ Y	LinStatic	0	0.001	0	3629.023	21.687	167339.201
Story43	EQ Y	LinStatic	0	0.001	0	3857.1982	22.681	170064.452
Story42	EQ Y	LinStatic	0	0.001	0	4074.8841	23.607	172615.601
Story41	EQ Y	LinStatic	0	0.001	0	4282.3273	23.918	179041.105
Story40	EQ Y	LinStatic	0	0.002	0	4675.0374	16.893	276746.287
Story39	EQ Y	LinStatic	0	0.002	0	5055.0414	17.99	280995.76
Story38	EQ Y	LinStatic	0	0.002	0	5415.8079	18.945	285872.991
Story37	EQ Y	LinStatic	0	0.002	0	5757.8365	19.843	290165.525
Story36	EQ Y	LinStatic	0	0.002	0	6081.627	20.683	294042.192
Story35	EQ Y	LinStatic	0	0.002	0	6387.6789	21.465	297590.31
Story34	EQ Y	LinStatic	0	0.003	0	6676.4919	22.19	300881.644
Story33	EQ Y	LinStatic	0	0.003	0	6948.5658	22.859	303974.487
Story32	EQ Y	LinStatic	0	0.003	0	7204.4002	23.473	306917.357
Story31	EQ Y	LinStatic	0	0.003	0	7444.4948	24.034	309751.56

Story30	EQ Y	LinStatic	0	0.003	0	7669.3493	24.541	312513.097
Story29	EQ Y	LinStatic	0	0.003	0	7879.4633	24.996	315234.129
Story28	EQ Y	LinStatic	0	0.003	0	8075.3365	25.399	317944.129
Story27	EQ Y	LinStatic	0	0.003	0	8257.4686	25.751	320670.828
Story26	EQ Y	LinStatic	0	0.004	0	8426.3593	26.052	323441.036
Story25	EQ Y	LinStatic	0	0.004	0	8582.5082	26.304	326281.391
Story24	EQ Y	LinStatic	0	0.004	0	8726.4151	26.506	329218.694
Story23	EQ Y	LinStatic	0	0.004	0	8858.5795	26.659	332289.097
Story22	EQ Y	LinStatic	0	0.004	0	8979.5013	26.767	335470.291
Story21	EQ Y	LinStatic	0	0.008	0	9089.68	26.043	349021.115
Story20	EQ Y	LinStatic	0	0.013	0	9254.4612	17.141	539886.75
Story19	EQ Y	LinStatic	0	0.012	0	9405.216	17.543	536119.235
Story18	EQ Y	LinStatic	0	0.004	0	9540.4608	17.785	536419.668
Story17	EQ Y	LinStatic	0	0.003	0	9660.8345	17.991	536980.513
Story16	EQ Y	LinStatic	0	0.003	0	9767.463	18.158	537916.674
Story15	EQ Y	LinStatic	0	0.003	0	9861.1795	18.289	539192.08
Story14	EQ Y	LinStatic	0	0.002	0	9942.817	18.386	540788.846
Story13	EQ Y	LinStatic	0	0.002	0	10013.2085	18.451	542696.357
Story12	EQ Y	LinStatic	0	0.002	0	10073.187	18.486	544910.489
Story11	EQ Y	LinStatic	0	0.002	0	10123.5857	18.493	547432.743
Story10	EQ Y	LinStatic	0	0.002	0	10165.2374	18.473	550269.667
Story9	EQ Y	LinStatic	0	0.002	0	10198.9754	18.429	553432.51
Story8	EQ Y	LinStatic	0	0.002	0	10225.6325	18.36	556937.059
Story7	EQ Y	LinStatic	0	0.002	0	10246.0419	18.27	560803.647
Story6	EQ Y	LinStatic	0	0.002	0	10261.0365	18.159	565057.326
Story5	EQ Y	LinStatic	0	0.002	0	10271.4495	18.029	569728.211
Story4	EQ Y	LinStatic	0	0.002	0	10278.1138	17.88	574851.717
Story3	EQ Y	LinStatic	0	0.002	0	10281.8624	17.713	580479.878
Story2	EQ Y	LinStatic	0	0.002	0	10283.5285	17.521	586939.252
Story1	EQ Y	LinStatic	0	0.001	0	10283.945	16.212	634338.787

Appendix C: Story forces from ETABS output

Table 27: Story Forces

Story	Output Case	Case Type	Location	P	VX	VY	T	MX	MY
Story55	EQ X	LinStatic	Top	0	-356.2077	0	9546.2556	0	0
Story55	EQ X	LinStatic	Bottom	0	-356.2077	0	9546.2556	0	-1317.9685
Story55	EQ Y	LinStatic	Top	0	0	-356.2077	-9617.6081	0	0
Story55	EQ Y	LinStatic	Bottom	0	0	-356.2077	-9617.6081	1317.9685	0
Story55	W x	LinStatic	Top	0	-130.2187	0	3515.906	0	0
Story55	W x	LinStatic	Bottom	0	-130.2187	0	3515.906	0	-481.8093
Story54	EQ X	LinStatic	Top	0	-716.0557	0	19193.3707	0	-1317.9685
Story54	EQ X	LinStatic	Bottom	0	-716.0557	0	19193.3707	0	-3967.3747
Story54	EQ Y	LinStatic	Top	0	0	-716.0557	-19333.5047	1317.9685	0
Story54	EQ Y	LinStatic	Bottom	0	0	-716.0557	-19333.5047	3967.3747	0
Story54	W x	LinStatic	Top	0	-390.0954	0	10532.5768	0	-481.8093
Story54	W x	LinStatic	Bottom	0	-390.0954	0	10532.5768	0	-1925.1625
Story53	EQ X	LinStatic	Top	0	-1062.6994	0	28486.4936	0	-3967.3747
Story53	EQ X	LinStatic	Bottom	0	-1062.6994	0	28486.4936	0	-7899.3627
Story53	EQ Y	LinStatic	Top	0	0	-1062.6995	-28692.8852	3967.3747	0
Story53	EQ Y	LinStatic	Bottom	0	0	-1062.6995	-28692.8852	7899.3627	0
Story53	W x	LinStatic	Top	0	-649.122	0	17526.2942	0	-1925.1625
Story53	W x	LinStatic	Bottom	0	-649.122	0	17526.2942	0	-4326.9139
Story52	EQ X	LinStatic	Top	0	-1396.3857	0	37432.2409	0	-7899.3627
Story52	EQ X	LinStatic	Bottom	0	-1396.3857	0	37432.2409	0	-13065.9897
Story52	EQ Y	LinStatic	Top	0	0	-1396.3857	-37702.4134	7899.3627	0
Story52	EQ Y	LinStatic	Bottom	0	0	-1396.3857	-37702.4134	13065.9897	0
Story52	W x	LinStatic	Top	0	-907.2869	0	24496.7464	0	-4326.9139
Story52	W x	LinStatic	Bottom	0	-907.2869	0	24496.7464	0	-7683.8754
Story51	EQ X	LinStatic	Top	0	-1717.3612	0	46037.2294	0	-13065.9897
Story51	EQ X	LinStatic	Bottom	0	-1717.3612	0	46037.2294	0	-19420.2262
Story51	EQ Y	LinStatic	Top	0	0	-1717.3612	-46368.7533	13065.9897	0
Story51	EQ Y	LinStatic	Bottom	0	0	-1717.3612	-46368.7533	19420.2263	0
Story51	W x	LinStatic	Top	0	-1164.5782	0	31443.6119	0	-7683.8754
Story51	W x	LinStatic	Bottom	0	-1164.5782	0	31443.6119	0	-11992.8148
Story50	EQ X	LinStatic	Top	0	-2025.8729	0	54308.0756	0	-19420.2262
Story50	EQ X	LinStatic	Bottom	0	-2025.8729	0	54308.0756	0	-26915.9559
Story50	EQ Y	LinStatic	Top	0	0	-2025.8729	-54698.5686	19420.2263	0
Story50	EQ Y	LinStatic	Bottom	0	0	-2025.8729	-54698.5686	26915.956	0
Story50	W x	LinStatic	Top	0	-1420.9836	0	38366.5577	0	-11992.8148
Story50	W x	LinStatic	Bottom	0	-1420.9836	0	38366.5577	0	-17250.4542
Story49	EQ X	LinStatic	Top	0	-2322.1675	0	62251.3964	0	-26915.9559

Story49	EQ X	LinStatic	Bottom	0	-2322.1675	0	62251.3964	0	-35507.9758
Story49	EQ Y	LinStatic	Top	0	0	-2322.1675	-62698.5232	26915.956	0
Story49	EQ Y	LinStatic	Bottom	0	0	-2322.1675	-62698.5232	35507.9759	0
Story49	W x	LinStatic	Top	0	-1676.4904	0	45265.2397	0	-17250.4542
Story49	W x	LinStatic	Bottom	0	-1676.4904	0	45265.2397	0	-23453.4686
Story48	EQ X	LinStatic	Top	0	-2606.4919	0	69873.8083	0	-35507.9758
Story48	EQ X	LinStatic	Bottom	0	-2606.4919	0	69873.8083	0	-45151.9957
Story48	EQ Y	LinStatic	Top	0	0	-2606.4919	-70375.281	35507.9759	0
Story48	EQ Y	LinStatic	Bottom	0	0	-2606.4919	-70375.281	45151.9959	0
Story48	W x	LinStatic	Top	0	-1931.0852	0	52139.3015	0	-23453.4686
Story48	W x	LinStatic	Bottom	0	-1931.0852	0	52139.3015	0	-30598.484
Story47	EQ X	LinStatic	Top	0	-2879.0928	0	77181.9281	0	-45151.9957
Story47	EQ X	LinStatic	Bottom	0	-2879.0928	0	77181.9281	0	-55804.6391
Story47	EQ Y	LinStatic	Top	0	0	-2879.0928	-77735.5058	45151.9959	0
Story47	EQ Y	LinStatic	Bottom	0	0	-2879.0928	-77735.5058	55804.6393	0
Story47	W x	LinStatic	Top	0	-2184.7546	0	58988.3739	0	-30598.484
Story47	W x	LinStatic	Bottom	0	-2184.7546	0	58988.3739	0	-38682.0759
Story46	EQ X	LinStatic	Top	0	-3140.2171	0	84182.3724	0	-55804.6391
Story46	EQ X	LinStatic	Bottom	0	-3140.2171	0	84182.3724	0	-67423.4423
Story46	EQ Y	LinStatic	Top	0	0	-3140.2171	-84785.8615	55804.6393	0
Story46	EQ Y	LinStatic	Bottom	0	0	-3140.2171	-84785.8615	67423.4425	0
Story46	W x	LinStatic	Top	0	-2437.4842	0	65812.0742	0	-38682.0759
Story46	W x	LinStatic	Bottom	0	-2437.4842	0	65812.0742	0	-47700.7676
Story45	EQ X	LinStatic	Top	0	-3390.1115	0	90881.7579	0	-67423.4423
Story45	EQ X	LinStatic	Bottom	0	-3390.1115	0	90881.7579	0	-79966.855
Story45	EQ Y	LinStatic	Top	0	0	-3390.1116	-91533.0119	67423.4425	0
Story45	EQ Y	LinStatic	Bottom	0	0	-3390.1116	-91533.0119	79966.8553	0
Story45	W x	LinStatic	Top	0	-2689.2594	0	72610.0051	0	-47700.7676
Story45	W x	LinStatic	Bottom	0	-2689.2594	0	72610.0051	0	-57651.0276
Story44	EQ X	LinStatic	Top	0	-3629.023	0	97286.7013	0	-79966.855
Story44	EQ X	LinStatic	Bottom	0	-3629.023	0	97286.7013	0	-93394.24
Story44	EQ Y	LinStatic	Top	0	0	-3629.023	-97983.6209	79966.8553	0
Story44	EQ Y	LinStatic	Bottom	0	0	-3629.023	-97983.6209	93394.2403	0
Story44	W x	LinStatic	Top	0	-2940.065	0	79381.7544	0	-57651.0276
Story44	W x	LinStatic	Bottom	0	-2940.065	0	79381.7544	0	-68529.268
Story43	EQ X	LinStatic	Top	0	-3857.1982	0	103403.8192	0	-93394.24
Story43	EQ X	LinStatic	Bottom	0	-3857.1982	0	103403.8192	0	-
Story43	EQ Y	LinStatic	Top	0	0	-3857.1982	-	93394.2403	0
Story43	EQ Y	LinStatic	Bottom	0	0	-3857.1982	-	107665.8738	0
Story43	W x	LinStatic	Top	0	-3189.8849	0	86126.8933	0	-68529.268
Story43	W x	LinStatic	Bottom	0	-3189.8849	0	86126.8933	0	-80331.8422

Story42	EQ X	LinStatic	Top	0	-4074.8841	0	109239.7283	0	- 107665.8734
Story42	EQ X	LinStatic	Bottom	0	-4074.8841	0	109239.7283	0	- 122742.9444
Story42	EQ Y	LinStatic	Top	0	0	-4074.8841	-110021.87	107665.8738	0
Story42	EQ Y	LinStatic	Bottom	0	0	-4074.8841	-110021.87	122742.9449	0
Story42	W x	LinStatic	Top	0	-3438.7028	0	92844.976	0	-80331.8422
Story42	W x	LinStatic	Bottom	0	-3438.7028	0	92844.976	0	-93055.0426
Story41	EQ X	LinStatic	Top	0	-4282.3273	0	114801.0453	0	- 122742.9444
Story41	EQ X	LinStatic	Bottom	0	-4282.3273	0	114801.0453	0	- 138587.5555
Story41	EQ Y	LinStatic	Top	0	0	-4282.3273	- 115622.8378	122742.9449	0
Story41	EQ Y	LinStatic	Bottom	0	0	-4282.3273	- 115622.8378	138587.556	0
Story41	W x	LinStatic	Top	0	-3686.5014	0	99535.5384	0	-93055.0426
Story41	W x	LinStatic	Bottom	0	-3686.5014	0	99535.5384	0	- 106695.0979
Story40	EQ X	LinStatic	Top	0	-4675.0374	0	125376.9711	0	- 138587.5555
Story40	EQ X	LinStatic	Bottom	0	-4675.0374	0	125376.9711	0	- 155885.1938
Story40	EQ Y	LinStatic	Top	0	0	-4675.0374	- 126231.2569	138587.556	0
Story40	EQ Y	LinStatic	Bottom	0	0	-4675.0374	- 126231.2569	155885.1944	0
Story40	W x	LinStatic	Top	0	-4031.9674	0	108863.1198	0	- 106695.0979
Story40	W x	LinStatic	Bottom	0	-4031.9674	0	108863.1198	0	- 121613.3773
Story39	EQ X	LinStatic	Top	0	-5055.0414	0	135611.179	0	- 155885.1938
Story39	EQ X	LinStatic	Bottom	0	-5055.0414	0	135611.179	0	- 174588.8471
Story39	EQ Y	LinStatic	Top	0	0	-5055.0414	- 136496.3537	155885.1944	0
Story39	EQ Y	LinStatic	Bottom	0	0	-5055.0414	- 136496.3537	174588.8477	0
Story39	W x	LinStatic	Top	0	-4375.9551	0	118150.7887	0	- 121613.3773
Story39	W x	LinStatic	Bottom	0	-4375.9551	0	118150.7887	0	- 137804.4113
Story38	EQ X	LinStatic	Top	0	-5415.8079	0	145327.2843	0	-

									174588.8471
Story38	EQ X	LinStatic	Bottom	0	-5415.8079	0	145327.2843	0	- 194627.3363
Story38	EQ Y	LinStatic	Top	0	0	-5415.8079	- 146241.7842	174588.8477	0
Story38	EQ Y	LinStatic	Bottom	0	0	-5415.8079	- 146241.7842	194627.3371	0
Story38	W x	LinStatic	Top	0	-4718.4373	0	127397.8072	0	- 137804.4113
Story38	W x	LinStatic	Bottom	0	-4718.4373	0	127397.8072	0	- 155262.6293
Story37	EQ X	LinStatic	Top	0	-5757.8365	0	154538.7442	0	- 194627.3363
Story37	EQ X	LinStatic	Bottom	0	-5757.8365	0	154538.7442	0	- 215931.3315
Story37	EQ Y	LinStatic	Top	0	0	-5757.8365	- 155481.0463	194627.3371	0
Story37	EQ Y	LinStatic	Bottom	0	0	-5757.8365	- 155481.0463	215931.3323	0
Story37	W x	LinStatic	Top	0	-5059.3853	0	136603.4037	0	- 155262.6293
Story37	W x	LinStatic	Bottom	0	-5059.3853	0	136603.4037	0	-173982.355
Story36	EQ X	LinStatic	Top	0	-6081.6269	0	163259.016	0	- 215931.3315
Story36	EQ X	LinStatic	Bottom	0	-6081.6269	0	163259.016	0	- 238433.3512
Story36	EQ Y	LinStatic	Top	0	0	-6081.627	- 164227.6377	215931.3323	0
Story36	EQ Y	LinStatic	Bottom	0	0	-6081.627	- 164227.6377	238433.3521	0
Story36	W x	LinStatic	Top	0	-5398.7693	0	145766.7703	0	-173982.355
Story36	W x	LinStatic	Bottom	0	-5398.7693	0	145766.7703	0	- 193957.8013
Story35	EQ X	LinStatic	Top	0	-6387.6788	0	171501.5569	0	- 238433.3512
Story35	EQ X	LinStatic	Bottom	0	-6387.6788	0	171501.5569	0	- 262067.7629
Story35	EQ Y	LinStatic	Top	0	0	-6387.6789	- 172495.0562	238433.3521	0
Story35	EQ Y	LinStatic	Bottom	0	0	-6387.6789	- 172495.0562	262067.7639	0
Story35	W x	LinStatic	Top	0	-5736.5578	0	154887.0605	0	- 193957.8013
Story35	W x	LinStatic	Bottom	0	-5736.5578	0	154887.0605	0	-

									215183.0652
Story34	EQ X	LinStatic	Top	0	-6676.4919	0	179279.8241	0	- 262067.7629
Story34	EQ X	LinStatic	Bottom	0	-6676.4919	0	179279.8241	0	- 286770.7829
Story34	EQ Y	LinStatic	Top	0	0	-6676.4919	- 180296.7998	262067.7639	0
Story34	EQ Y	LinStatic	Bottom	0	0	-6676.4919	- 180296.7998	286770.7841	0
Story34	W x	LinStatic	Top	0	-6072.718	0	163963.3858	0	- 215183.0652
Story34	W x	LinStatic	Bottom	0	-6072.718	0	163963.3858	0	- 237652.1217
Story33	EQ X	LinStatic	Top	0	-6948.5658	0	186607.2747	0	- 286770.7829
Story33	EQ X	LinStatic	Bottom	0	-6948.5658	0	186607.2747	0	- 312480.4764
Story33	EQ Y	LinStatic	Top	0	0	-6948.5658	- 187646.3662	286770.7841	0
Story33	EQ Y	LinStatic	Bottom	0	0	-6948.5658	- 187646.3662	312480.4776	0
Story33	W x	LinStatic	Top	0	-6407.2153	0	172994.8124	0	- 237652.1217
Story33	W x	LinStatic	Bottom	0	-6407.2153	0	172994.8124	0	- 261358.8183
Story32	EQ X	LinStatic	Top	0	-7204.4002	0	193497.366	0	- 312480.4764
Story32	EQ X	LinStatic	Bottom	0	-7204.4002	0	193497.366	0	- 339136.7572
Story32	EQ Y	LinStatic	Top	0	0	-7204.4002	- 194557.2532	312480.4776	0
Story32	EQ Y	LinStatic	Bottom	0	0	-7204.4002	- 194557.2532	339136.7585	0
Story32	W x	LinStatic	Top	0	-6740.0132	0	181980.3574	0	- 261358.8183
Story32	W x	LinStatic	Bottom	0	-6740.0132	0	181980.3574	0	- 286296.8672
Story31	EQ X	LinStatic	Top	0	-7444.4948	0	199963.5552	0	- 339136.7572
Story31	EQ X	LinStatic	Bottom	0	-7444.4948	0	199963.5552	0	- 366681.3879
Story31	EQ Y	LinStatic	Top	0	0	-7444.4948	- 201042.9587	339136.7585	0
Story31	EQ Y	LinStatic	Bottom	0	0	-7444.4948	-	366681.3894	0

							201042.9587		
Story31	W x	LinStatic	Top	0	-7071.0735	0	190918.9845	0	- 286296.8672
Story31	W x	LinStatic	Bottom	0	-7071.0735	0	190918.9845	0	- 312459.8392
Story30	EQ X	LinStatic	Top	0	-7669.3493	0	206019.2995	0	- 366681.3879
Story30	EQ X	LinStatic	Bottom	0	-7669.3493	0	206019.2995	0	- 395057.9802
Story30	EQ Y	LinStatic	Top	0	0	-7669.3493	- 207116.9805	366681.3894	0
Story30	EQ Y	LinStatic	Bottom	0	0	-7669.3493	- 207116.9805	395057.9818	-5.314E-07
Story30	W x	LinStatic	Top	0	-7400.3555	0	199809.5996	0	- 312459.8392
Story30	W x	LinStatic	Bottom	0	-7400.3555	0	199809.5996	0	- 339841.1547
Story29	EQ X	LinStatic	Top	0	-7879.4633	0	211678.0561	0	- 395057.9802
Story29	EQ X	LinStatic	Bottom	0	-7879.4633	0	211678.0561	0	- 424211.9943
Story29	EQ Y	LinStatic	Top	0	0	-7879.4633	- 212792.8164	395057.9818	-5.311E-07
Story29	EQ Y	LinStatic	Bottom	0	0	-7879.4633	- 212792.8164	424211.996	-5.944E-07
Story29	W x	LinStatic	Top	0	-7727.8165	0	208651.0452	0	- 339841.1547
Story29	W x	LinStatic	Bottom	0	-7727.8165	0	208651.0452	0	- 368434.0757
Story28	EQ X	LinStatic	Top	0	-8075.3365	0	216953.2823	0	- 424211.9943
Story28	EQ X	LinStatic	Bottom	0	-8075.3365	0	216953.2823	0	- 454090.7392
Story28	EQ Y	LinStatic	Top	0	0	-8075.3365	- 218083.9643	424211.996	- 0.000000596
Story28	EQ Y	LinStatic	Bottom	0	0	-8075.3365	- 218083.9643	454090.7411	-6.614E-07
Story28	W x	LinStatic	Top	0	-8053.4109	0	217442.0944	0	- 368434.0757
Story28	W x	LinStatic	Bottom	0	-8053.4109	0	217442.0944	0	-398231.696
Story27	EQ X	LinStatic	Top	0	-8257.4686	0	221858.4352	0	- 454090.7392
Story27	EQ X	LinStatic	Bottom	0	-8257.4686	0	221858.4352	0	-484643.373
Story27	EQ Y	LinStatic	Top	0	0	-8257.4686	-223003.922	454090.7411	-6.638E-07

Story27	EQ Y	LinStatic	Bottom	0	0	-8257.4686	-223003.922	484643.375	-7.322E-07
Story27	W x	LinStatic	Top	0	-8377.0905	0	226181.4441	0	-398231.696
Story27	W x	LinStatic	Bottom	0	-8377.0905	0	226181.4441	0	-429226.931
Story26	EQ X	LinStatic	Top	0	-8426.3593	0	226406.972	0	-484643.373
Story26	EQ X	LinStatic	Bottom	0	-8426.3593	0	226406.972	0	- 515820.9023
Story26	EQ Y	LinStatic	Top	0	0	-8426.3593	- 227566.1873	484643.375	-7.318E-07
Story26	EQ Y	LinStatic	Bottom	0	0	-8426.3593	- 227566.1873	515820.9044	-8.027E-07
Story26	W x	LinStatic	Top	0	-8698.804	0	234867.7075	0	-429226.931
Story26	W x	LinStatic	Bottom	0	-8698.804	0	234867.7075	0	- 461412.5057
Story25	EQ X	LinStatic	Top	0	-8582.5082	0	230612.35	0	- 515820.9023
Story25	EQ X	LinStatic	Bottom	0	-8582.5082	0	230612.35	5.349E-07	- 547576.1826
Story25	EQ Y	LinStatic	Top	0	0	-8582.5082	-231784.258	515820.9044	-8.037E-07
Story25	EQ Y	LinStatic	Bottom	0	0	-8582.5082	-231784.258	547576.1849	-8.786E-07
Story25	W x	LinStatic	Top	0	-9018.4965	0	243499.4047	0	- 461412.5057
Story25	W x	LinStatic	Bottom	0	-9018.4965	0	243499.4047	0	- 494780.9426
Story24	EQ X	LinStatic	Top	0	-8726.4151	0	234488.0263	5.336E-07	- 547576.1826
Story24	EQ X	LinStatic	Bottom	0	-8726.4151	0	234488.0263	5.755E-07	- 579863.9183
Story24	EQ Y	LinStatic	Top	0	0	-8726.4151	- 235671.6319	547576.1849	-8.791E-07
Story24	EQ Y	LinStatic	Bottom	0	0	-8726.4151	- 235671.6319	579863.9208	-9.556E-07
Story24	W x	LinStatic	Top	0	-9336.1094	0	252074.9529	0	- 494780.9426
Story24	W x	LinStatic	Bottom	0	-9336.1094	0	252074.9529	0	- 529324.5473
Story23	EQ X	LinStatic	Top	0	-8858.5795	0	238047.4583	5.722E-07	- 579863.9183
Story23	EQ X	LinStatic	Bottom	0	-8858.5795	0	238047.4583	0.000000615	- 612640.6625
Story23	EQ Y	LinStatic	Top	0	0	-8858.5795	-239241.807	579863.9208	-9.585E-07
Story23	EQ Y	LinStatic	Bottom	0	0	-8858.5795	-239241.807	612640.6651	- 0.000001038
Story23	W x	LinStatic	Top	0	-9651.5798	0	260592.6544	0	- 529324.5473

Story23	W x	LinStatic	Bottom	0	-9651.5798	0	260592.6544	0	- 565035.3925
Story22	EQ X	LinStatic	Top	0	-8979.5012	0	241304.103	6.123E-07	- 612640.6625
Story22	EQ X	LinStatic	Bottom	0	-8979.5012	0	241304.103	6.559E-07	- 645864.8171
Story22	EQ Y	LinStatic	Top	0	0	-8979.5013	- 242508.2809	612640.6651	- 0.000001035
Story22	EQ Y	LinStatic	Bottom	0	0	-8979.5013	- 242508.2809	645864.8199	- 0.000001118
Story22	W x	LinStatic	Top	0	-9964.8401	0	269050.6827	0	- 565035.3925
Story22	W x	LinStatic	Bottom	0	-9964.8401	0	269050.6827	0	- 601905.3009
Story21	EQ X	LinStatic	Top	0	-9089.6799	0	244271.4177	6.531E-07	- 645864.8171
Story21	EQ X	LinStatic	Bottom	0	-9089.6799	0	244271.4177	0.000000698	- 679496.6328
Story21	EQ Y	LinStatic	Top	0	0	-9089.68	- 245484.5516	645864.8199	- 0.000001119
Story21	EQ Y	LinStatic	Bottom	0	0	-9089.68	- 245484.5516	679496.6357	- 0.000001204
Story21	W x	LinStatic	Top	0	- 10275.8173	0	277447.0664	0	- 601905.3009
Story21	W x	LinStatic	Bottom	0	- 10275.8173	0	277447.0664	0	- 639925.8248
Story20	EQ X	LinStatic	Top	0	-9254.4612	0	248703.9081	0.000000697	- 679496.6328
Story20	EQ X	LinStatic	Bottom	0	-9254.4612	0	248703.9081	7.435E-07	- 713738.1392
Story20	EQ Y	LinStatic	Top	0	0	-9254.4612	- 249950.6252	679496.6357	- 0.000001207
Story20	EQ Y	LinStatic	Bottom	0	0	-9254.4612	- 249950.6252	713738.1423	- 0.000001296
Story20	W x	LinStatic	Top	0	- 10672.6079	0	288160.4141	0	- 639925.8248
Story20	W x	LinStatic	Bottom	0	- 10672.6079	0	288160.4141	0	- 679414.4742
Story19	EQ X	LinStatic	Top	0	-9405.216	0	252759.3018	7.417E-07	- 713738.1392
Story19	EQ X	LinStatic	Bottom	0	-9405.216	0	252759.3018	7.895E-07	- 748537.4382
Story19	EQ Y	LinStatic	Top	0	0	-9405.216	- 254036.3277	713738.1423	- 0.000001298

Story19	EQ Y	LinStatic	Bottom	0	0	-9405.216	- 254036.3277	748537.4415	- 0.000001391
Story19	W x	LinStatic	Top	0	- 11066.2509	0	298788.7735	0	- 679414.4742
Story19	W x	LinStatic	Bottom	0	- 11066.2509	0	298788.7735	0	- 720359.6024
Story18	EQ X	LinStatic	Top	0	-9540.4608	0	256398.3423	7.873E-07	- 748537.4382
Story18	EQ X	LinStatic	Bottom	0	-9540.4608	0	256398.3423	8.367E-07	- 783837.1431
Story18	EQ Y	LinStatic	Top	0	0	-9540.4608	- 257700.2846	748537.4415	- 0.000001392
Story18	EQ Y	LinStatic	Bottom	0	0	-9540.4608	- 257700.2846	783837.1466	- 0.000001488
Story18	W x	LinStatic	Top	0	- 11456.6253	0	309328.8842	0	- 720359.6024
Story18	W x	LinStatic	Bottom	0	- 11456.6253	0	309328.8842	0	- 762749.1161
Story17	EQ X	LinStatic	Top	0	-9660.8344	0	259641.1396	8.351E-07	- 783837.1431
Story17	EQ X	LinStatic	Bottom	0	-9660.8344	0	259641.1396	8.859E-07	- 819582.2304
Story17	EQ Y	LinStatic	Top	0	0	-9660.8345	- 260955.1112	783837.1466	-0.00000149
Story17	EQ Y	LinStatic	Bottom	0	0	-9660.8345	- 260955.1112	819582.2341	- 0.000001589
Story17	W x	LinStatic	Top	0	- 11843.5988	0	319777.1678	0	- 762749.1161
Story17	W x	LinStatic	Bottom	0	- 11843.5988	0	319777.1678	5.245E-07	- 806570.4317
Story16	EQ X	LinStatic	Top	0	-9767.463	0	262513.652	8.855E-07	- 819582.2304
Story16	EQ X	LinStatic	Bottom	0	-9767.463	0	262513.652	9.362E-07	- 855721.8434
Story16	EQ Y	LinStatic	Top	0	0	-9767.463	- 263838.2793	819582.2341	- 0.000001589
Story16	EQ Y	LinStatic	Bottom	0	0	-9767.463	- 263838.2793	855721.8472	-0.00000169
Story16	W x	LinStatic	Top	0	- 12227.0251	0	330129.6769	5.225E-07	- 806570.4317
Story16	W x	LinStatic	Bottom	0	- 12227.0251	0	330129.6769	5.602E-07	- 851810.4245
Story15	EQ X	LinStatic	Top	0	-9861.1794	0	265038.3211	9.352E-07	- 855721.8434

Story15	EQ X	LinStatic	Bottom	0	-9861.1794	0	265038.3211	9.872E-07	- 892208.2073
Story15	EQ Y	LinStatic	Top	0	0	-9861.1795	- 266372.3139	855721.8472	- 0.000001691
Story15	EQ Y	LinStatic	Bottom	0	0	-9861.1795	- 266372.3139	892208.2113	- 0.000001796
Story15	W x	LinStatic	Top	0	- 12606.7418	0	340382.0298	5.594E-07	- 851810.4245
Story15	W x	LinStatic	Bottom	0	- 12606.7418	0	340382.0298	5.986E-07	- 898455.3693
Story14	EQ X	LinStatic	Top	0	-9942.8169	0	267237.5884	9.859E-07	- 892208.2073
Story14	EQ X	LinStatic	Bottom	0	-9942.8169	0	267237.5884	0.000001039	- 928996.6299
Story14	EQ Y	LinStatic	Top	0	0	-9942.817	- 268579.7395	892208.2113	- 0.000001797
Story14	EQ Y	LinStatic	Bottom	0	0	-9942.817	- 268579.7395	928996.6341	- 0.000001906
Story14	W x	LinStatic	Top	0	- 12982.5678	0	350529.3304	5.967E-07	- 898455.3693
Story14	W x	LinStatic	Bottom	0	- 12982.5678	0	350529.3304	6.373E-07	- 946490.8701
Story13	EQ X	LinStatic	Top	0	- 10013.2084	0	269133.8955	0.000001036	- 928996.6299
Story13	EQ X	LinStatic	Bottom	0	- 10013.2084	0	269133.8955	0.00000109	-966045.501
Story13	EQ Y	LinStatic	Top	0	0	- 10013.2085	-270483.081	928996.6341	- 0.000001904
Story13	EQ Y	LinStatic	Bottom	0	0	- 10013.2085	-270483.081	966045.5055	- 0.000002015
Story13	W x	LinStatic	Top	0	- 13354.2987	0	360566.065	6.347E-07	- 946490.8701
Story13	W x	LinStatic	Bottom	0	- 13354.2987	0	360566.065	6.761E-07	- 995901.7754
Story12	EQ X	LinStatic	Top	0	-10073.187	0	270749.6837	0.000001089	-966045.501
Story12	EQ X	LinStatic	Bottom	0	-10073.187	0	270749.6837	0.000001143	-1003316
Story12	EQ Y	LinStatic	Top	0	0	-10073.187	- 272104.8631	966045.5055	- 0.000002017
Story12	EQ Y	LinStatic	Bottom	0	0	-10073.187	- 272104.8631	1003316.298	- 0.000002129
Story12	W x	LinStatic	Top	0	- 13721.7026	0	370485.9689	6.753E-07	- 995901.7754
Story12	W x	LinStatic	Bottom	0	- 13721.7026	0	370485.9689	7.175E-07	-1046672

Story11	EQ X	LinStatic	Top	0	- 10123.5856	0	272107.3947	0.000001141	-1003316
Story11	EQ X	LinStatic	Bottom	0	- 10123.5856	0	272107.3947	0.000001196	-1040774
Story11	EQ Y	LinStatic	Top	0	0	- 10123.5857	- 273467.6105	1003316.298	- 0.000002127
Story11	EQ Y	LinStatic	Bottom	0	0	- 10123.5857	- 273467.6105	1040773.565	- 0.000002243
Story11	W x	LinStatic	Top	0	-14084.513	0	380281.8503	7.153E-07	-1046672
Story11	W x	LinStatic	Bottom	0	-14084.513	0	380281.8503	7.586E-07	-1098785
Story10	EQ X	LinStatic	Top	0	- 10165.2374	0	273229.4698	0.000001195	-1040774
Story10	EQ X	LinStatic	Bottom	0	- 10165.2374	0	273229.4698	0.000001251	-1078385
Story10	EQ Y	LinStatic	Top	0	0	- 10165.2374	- 274593.8481	1040773.565	- 0.000002243
Story10	EQ Y	LinStatic	Bottom	0	0	- 10165.2374	- 274593.8481	1078384.943	- 0.000002361
Story10	W x	LinStatic	Top	0	- 14442.4204	0	389945.3518	7.577E-07	-1098785
Story10	W x	LinStatic	Bottom	0	- 14442.4204	0	389945.3518	0.000000802	-1152222
Story9	EQ X	LinStatic	Top	0	- 10198.9753	0	274138.3507	0.000001251	-1078385
Story9	EQ X	LinStatic	Bottom	0	- 10198.9753	0	274138.3507	0.000001307	-1116121
Story9	EQ Y	LinStatic	Top	0	0	- 10198.9754	- 275506.1005	1078384.943	- 0.000002362
Story9	EQ Y	LinStatic	Bottom	0	0	- 10198.9754	- 275506.1005	1116121.152	- 0.000002483
Story9	W x	LinStatic	Top	0	-14795.06	0	399466.6191	8.001E-07	-1152222
Story9	W x	LinStatic	Bottom	0	-14795.06	0	399466.6191	8.453E-07	-1206963
Story8	EQ X	LinStatic	Top	0	- 10225.6325	0	274856.4788	0.000001305	-1116121
Story8	EQ X	LinStatic	Bottom	0	- 10225.6325	0	274856.4788	0.000001363	-1153956
Story8	EQ Y	LinStatic	Top	0	0	- 10225.6325	- 276226.8926	1116121.152	- 0.000002482
Story8	EQ Y	LinStatic	Bottom	0	0	- 10225.6325	- 276226.8926	1153955.992	- 0.000002606
Story8	W x	LinStatic	Top	0	- 15141.9935	0	408833.8252	8.424E-07	-1206963
Story8	W x	LinStatic	Bottom	0	- 15141.9935	0	408833.8252	8.886E-07	-1262989

Story7	EQ X	LinStatic	Top	0	- 10246.0418	0	275406.2956	0.000001362	-1153956
Story7	EQ X	LinStatic	Bottom	0	- 10246.0418	0	275406.2956	0.00000142	-1191866
Story7	EQ Y	LinStatic	Top	0	0	- 10246.0419	-276778.749	1153955.992	- 0.000002606
Story7	EQ Y	LinStatic	Bottom	0	0	- 10246.0419	-276778.749	1191866.347	- 0.000002731
Story7	W x	LinStatic	Top	0	- 15482.6837	0	418032.4591	8.891E-07	-1262989
Story7	W x	LinStatic	Bottom	0	- 15482.6837	0	418032.4591	9.361E-07	-1320275
Story6	EQ X	LinStatic	Top	0	- 10261.0365	0	275810.2427	0.00000142	-1191866
Story6	EQ X	LinStatic	Bottom	0	- 10261.0365	0	275810.2427	0.000001478	-1229832
Story6	EQ Y	LinStatic	Top	0	0	- 10261.0365	- 277184.1945	1191866.347	- 0.000002732
Story6	EQ Y	LinStatic	Bottom	0	0	- 10261.0365	- 277184.1945	1229832.182	- 0.000002858
Story6	W x	LinStatic	Top	0	- 15816.4521	0	427044.2069	9.354E-07	-1320275
Story6	W x	LinStatic	Bottom	0	- 15816.4521	0	427044.2069	9.824E-07	-1378796
Story5	EQ X	LinStatic	Top	0	- 10271.4494	0	276090.7615	0.000001478	-1229832
Story5	EQ X	LinStatic	Bottom	0	- 10271.4494	0	276090.7615	0.000001537	-1267837
Story5	EQ Y	LinStatic	Top	0	0	- 10271.4495	- 277465.7539	1229832.182	- 0.000002859
Story5	EQ Y	LinStatic	Bottom	0	0	- 10271.4495	- 277465.7539	1267836.546	- 0.000002986
Story5	W x	LinStatic	Top	0	- 16142.4101	0	435845.0719	9.812E-07	-1378796
Story5	W x	LinStatic	Bottom	0	- 16142.4101	0	435845.0719	0.000001029	-1438523
Story4	EQ X	LinStatic	Top	0	- 10278.1137	0	276270.2935	0.000001537	-1267837
Story4	EQ X	LinStatic	Bottom	0	- 10278.1137	0	276270.2935	0.000001596	-1305866
Story4	EQ Y	LinStatic	Top	0	0	- 10278.1138	- 277645.9519	1267836.546	- 0.000002986
Story4	EQ Y	LinStatic	Bottom	0	0	- 10278.1138	- 277645.9519	1305865.566	- 0.000003114

Story4	W x	LinStatic	Top	0	- 16459.3303	0	444401.9191	0.000001029	-1438523
Story4	W x	LinStatic	Bottom	0	- 16459.3303	0	444401.9191	0.000001077	-1499422
Story3	EQ X	LinStatic	Top	0	- 10281.8624	0	276371.2803	0.000001596	-1305866
Story3	EQ X	LinStatic	Bottom	0	- 10281.8624	0	276371.2803	0.000001656	-1343908
Story3	EQ Y	LinStatic	Top	0	0	- 10281.8624	- 277747.3133	1305865.566	- 0.000003115
Story3	EQ Y	LinStatic	Bottom	0	0	- 10281.8624	- 277747.3133	1343908.457	- 0.000003244
Story3	W x	LinStatic	Top	0	- 16765.3786	0	452665.2235	0.000001077	-1499422
Story3	W x	LinStatic	Bottom	0	- 16765.3786	0	452665.2235	0.000001125	-1561454
Story2	EQ X	LinStatic	Top	0	- 10283.5284	0	276416.1633	0.000001656	-1343908
Story2	EQ X	LinStatic	Bottom	0	- 10283.5284	0	276416.1633	0.000001715	-1381958
Story2	EQ Y	LinStatic	Top	0	0	- 10283.5285	- 277792.3628	1343908.457	- 0.000003244
Story2	EQ Y	LinStatic	Bottom	0	0	- 10283.5285	- 277792.3628	1381957.513	- 0.000003373
Story2	W x	LinStatic	Top	0	- 17057.4633	0	460551.51	0.000001125	-1561454
Story2	W x	LinStatic	Bottom	0	- 17057.4633	0	460551.51	0.000001173	-1624567
Story1	EQ X	LinStatic	Top	0	- 10283.9449	0	276427.384	0.000001715	-1381958
Story1	EQ X	LinStatic	Bottom	0	- 10283.9449	0	276427.384	0.000001774	-1420008
Story1	EQ Y	LinStatic	Top	0	0	-10283.945	- 277803.6252	1381957.513	- 0.000003373
Story1	EQ Y	LinStatic	Bottom	0	0	-10283.945	- 277803.6252	1420008.109	- 0.000003502
Story1	W x	LinStatic	Top	0	-17337.12	0	468102.2403	0.000001173	-1624567
Story1	W x	LinStatic	Bottom	0	-17337.12	0	468102.2403	0.000001221	-1688714

Appendix D: Centers of Mass and Rigidity for the steel structure:

Table 28: Centers of Mass and Rigidity

Story	Diaphragm	Mass X	Mass Y	XCM	YCM	Cum Mass	Cum Mass	XCCM	YCCM
	m	kg	kg	m	m	X	Y		
Story55	D1	335978.59	335978.59	27	26.7997	335978.59	335978.59	27	26.7997
Story54	D1	352099.39	352099.39	27	26.8089	688077.97	688077.97	27	26.8044
Story53	D1	352099.39	352099.39	27	26.8089	1040177.36	1040177.36	27	26.8059
Story52	D1	352099.39	352099.39	27	26.8089	1392276.75	1392276.75	27	26.8066
Story51	D1	352099.39	352099.39	27	26.8089	1744376.13	1744376.13	27	26.8071
Story50	D1	352099.39	352099.39	27	26.8089	2096475.52	2096475.52	27	26.8074
Story49	D1	352099.39	352099.39	27	26.8089	2448574.9	2448574.9	27	26.8076
Story48	D1	352099.39	352099.39	27	26.8089	2800674.29	2800674.29	27	26.8078
Story47	D1	352099.39	352099.39	27	26.8089	3152773.67	3152773.67	27	26.8079
Story46	D1	352099.39	352099.39	27	26.8089	3504873.06	3504873.06	27	26.808
Story45	D1	352099.39	352099.39	27	26.8089	3856972.44	3856972.44	27	26.8081
Story44	D1	352099.39	352099.39	27	26.8089	4209071.83	4209071.83	27	26.8081
Story43	D1	352099.39	352099.39	27	26.8089	4561171.22	4561171.22	27	26.8082
Story42	D1	352099.39	352099.39	27	26.8089	4913270.6	4913270.6	27	26.8082
Story41	D1	352099.39	352099.39	27	26.8089	5265369.99	5265369.99	27	26.8083
Story40	D1	700302.59	700302.59	27.0134	26.9306	5965672.58	5965672.58	27.0016	26.8226
Story39	D1	712840.99	712840.99	27.0131	26.9318	6678513.56	6678513.56	27.0028	26.8343
Story38	D1	712840.99	712840.99	27.0131	26.9318	7391354.55	7391354.55	27.0038	26.8437
Story37	D1	712840.99	712840.99	27.0131	26.9318	8104195.54	8104195.54	27.0046	26.8515

Story36	D1	712840.99	712840.99	27.013 1	26.931 8	8817036.52	8817036.52	27.005 3	26.858
Story35	D1	712840.99	712840.99	27.013 1	26.931 8	9529877.51	9529877.51	27.005 9	26.8635
Story34	D1	712840.99	712840.99	27.013 1	26.931 8	10242718.5	10242718.5	27.006 4	26.8682
Story33	D1	712840.99	712840.99	27.013 1	26.931 8	10955559.4 9	10955559.4 9	27.006 8	26.8724
Story32	D1	712840.99	712840.99	27.013 1	26.931 8	11668400.4 7	11668400.4 7	27.007 2	26.876
Story31	D1	712840.99	712840.99	27.013 1	26.931 8	12381241.4 6	12381241.4 6	27.007 6	26.8792
Story30	D1	712840.99	712840.99	27.013 1	26.931 8	13094082.4 5	13094082.4 5	27.007 9	26.8821
Story29	D1	712840.99	712840.99	27.013 1	26.931 8	13806923.4 4	13806923.4 4	27.008 1	26.8847
Story28	D1	712840.99	712840.99	27.013 1	26.931 8	14519764.4 2	14519764.4 2	27.008 4	26.887
Story27	D1	712840.99	712840.99	27.013 1	26.931 8	15232605.4 1	15232605.4 1	27.008 6	26.8891
Story26	D1	712840.99	712840.99	27.013 1	26.931 8	15945446.4	15945446.4	27.008 8	26.891
Story25	D1	712840.99	712840.99	27.013 1	26.931 8	16658287.3 8	16658287.3 8	27.009	26.8927
Story24	D1	712840.99	712840.99	27.013 1	26.931 8	17371128.3 7	17371128.3 7	27.009 2	26.8943
Story23	D1	712840.99	712840.99	27.013 1	26.931 8	18083969.3 6	18083969.3 6	27.009 3	26.8958
Story22	D1	712840.99	712840.99	27.013 1	26.931 8	18796810.3 5	18796810.3 5	27.009 5	26.8972
Story21	D1	712840.99	712840.99	27.013 1	26.931 8	19509651.3 3	19509651.3 3	27.009 6	26.8984
Story20	D1	1175388.7 2	1175388.7 2	27.103	26.899 2	20685040.0 5	20685040.0 5	27.014 9	26.8985
Story19	D1	1191509.5 2	1191509.5 2	27.101 6	26.900 6	21876549.5 7	21876549.5 7	27.019 6	26.8986
Story18	D1	1190993.3 3	1190993.3 3	27.091 3	26.907 1	23067542.8 9	23067542.8 9	27.023 3	26.899
Story17	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	24255955.2 8	24255955.2 8	27.024 1	26.901
Story16	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	25444367.6 7	25444367.6 7	27.024 8	26.9028
Story15	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	26632780.0 6	26632780.0 6	27.025 5	26.9045

Story14	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	27821192.4 5	27821192.4 5	27.026 1	26.9059
Story13	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	29009604.8 4	29009604.8 4	27.026 6	26.9073
Story12	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	30198017.2 2	30198017.2 2	27.027 1	26.9086
Story11	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	31386429.6 1	31386429.6 1	27.027 6	26.9097
Story10	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	32574842	32574842	27.028	26.9108
Story9	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	33763254.3 9	33763254.3 9	27.028 4	26.9118
Story8	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	34951666.7 8	34951666.7 8	27.028 8	26.9128
Story7	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	36140079.1 7	36140079.1 7	27.029 1	26.9137
Story6	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	37328491.5 5	37328491.5 5	27.029 5	26.9145
Story5	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	38516903.9 4	38516903.9 4	27.029 8	26.9152
Story4	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	39705316.3 3	39705316.3 3	27.03	26.916
Story3	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	40893728.7 2	40893728.7 2	27.030 3	26.9166
Story2	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	42082141.1 1	42082141.1 1	27.030 6	26.9173
Story1	D1	1188412.3 9	1188412.3 9	27.039 4	26.939 4	43270553.5	43270553.5	27.030 8	26.9179

Appendix E – shear and drift

Table 29: Shear and drift

Story	Output Case	Case Type	Step Type	Shear X kN	Drift X mm	Stiff X kN/m	Shear Y kN
Story55	EQ X	LinStatic	Step By Step	19689.1615	1.18	16687466.874	73.3268
Story54	EQ X	LinStatic	Step By Step	18292.9203	1.941	9424911.787	73.3268
Story53	EQ X	LinStatic	Step By Step	16947.9129	1.993	8504355.325	73.3268
Story52	EQ X	LinStatic	Step By Step	15653.1817	2.019	7751799.14	73.3268
Story51	EQ X	LinStatic	Step By Step	14407.769	2.021	7128275.811	73.3268
Story50	EQ X	LinStatic	Step By Step	13210.7173	1.976	6684869.084	73.3268
Story49	EQ X	LinStatic	Step By Step	12061.0687	1.9	6347073.61	73.3268
Story48	EQ X	LinStatic	Step By Step	10957.8658	1.799	6091071.063	73.3268
Story47	EQ X	LinStatic	Step By Step	9900.1509	1.679	5897150.922	73.3268
Story46	EQ X	LinStatic	Step By Step	8886.9662	1.544	5756753.977	73.3268
Story45	EQ X	LinStatic	Step By Step	7917.3543	1.396	5669554.053	73.3268
Story44	EQ X	LinStatic	Step By Step	6990.3574	1.239	5640499.774	73.3268
Story43	EQ X	LinStatic	Step By Step	6105.0179	1.075	5676527.126	73.3268
Story42	EQ X	LinStatic	Step By Step	5260.3782	0.901	5839357.716	73.3268
Story41	EQ X	LinStatic	Step By Step	4455.4806	0.649	6865096.516	73.3268
Story40	EQ X	LinStatic	Step By Step	3149.9204	0.223	14145297.186	73.3268
Story39	EQ X	LinStatic	Step By Step	1813.7211	0.176	10289465.208	73.3268
Story38	EQ X	LinStatic	Step By Step	545.1664	0.106	5161803.921	73.3268
Story37	EQ X	LinStatic	Step By Step	657.5008	0.053	12465785.631	73.3268
Story36	EQ X	LinStatic	Step By Step	1796.0375	0.091	19754593.987	73.3268
Story35	EQ X	LinStatic	Step By Step	2872.2006	0.178	16137472.715	73.3268
Story34	EQ X	LinStatic	Step By Step	3887.7472	0.26	14969454.923	73.3268
Story33	EQ X	LinStatic	Step By Step	4844.4342	0.336	14401440.261	73.3268
Story32	EQ X	LinStatic	Step By Step	5744.0187	0.408	14064464.702	73.3268
Story31	EQ X	LinStatic	Step By Step	6588.2577	0.478	13788841.679	73.3268
Story30	EQ X	LinStatic	Step By Step	7378.9082	0.544	13558006.439	73.3268
Story29	EQ X	LinStatic	Step By Step	8117.7271	0.607	13376107.069	73.3268
Story28	EQ X	LinStatic	Step By Step	8806.4715	0.665	13239675.574	73.3268
Story27	EQ X	LinStatic	Step By Step	9446.8984	0.714	13229993.325	73.3268
Story26	EQ X	LinStatic	Step By Step	10040.7647	0.757	13258292.257	73.3268
Story25	EQ X	LinStatic	Step By Step	10589.8275	0.796	13298626.317	73.3268
Story24	EQ X	LinStatic	Step By Step	11095.8438	0.831	13344613.382	73.3268
Story23	EQ X	LinStatic	Step By Step	11560.5706	0.866	13344613.191	73.3268
Story22	EQ X	LinStatic	Step By Step	11985.7649	0.897	13367990.183	73.3268
Story21	EQ X	LinStatic	Step By Step	12373.1836	0.913	13550830.806	73.3268

Story20	EQ X	LinStatic	Step By Step	12900.627	7.937	1625309.662	73.3268
Story19	EQ X	LinStatic	Step By Step	13403.6494	0.89	15065766.433	73.3268
Story18	EQ X	LinStatic	Step By Step	13855.1154	0.959	14443851.201	73.3268
Story17	EQ X	LinStatic	Step By Step	14257.812	0.977	14600262.35	73.3268
Story16	EQ X	LinStatic	Step By Step	14614.5259	0.988	14796027.997	73.3268
Story15	EQ X	LinStatic	Step By Step	14928.044	0.994	15023979.932	73.3268
Story14	EQ X	LinStatic	Step By Step	15201.1531	0.995	15283780.991	73.3268
Story13	EQ X	LinStatic	Step By Step	15436.64	0.991	15578801.392	73.3268
Story12	EQ X	LinStatic	Step By Step	15637.2916	0.982	15915963.84	73.3268
Story11	EQ X	LinStatic	Step By Step	15805.8947	0.969	16305952.268	73.3268
Story10	EQ X	LinStatic	Step By Step	15945.2361	0.951	16764395.216	73.3268
Story9	EQ X	LinStatic	Step By Step	16058.1026	0.927	17319362.502	73.3268
Story8	EQ X	LinStatic	Step By Step	16147.281	0.894	18056154.56	73.3268
Story7	EQ X	LinStatic	Step By Step	16215.5583	0.853	19003581.205	73.3268
Story6	EQ X	LinStatic	Step By Step	16265.7212	0.802	20285886.044	73.3268
Story5	EQ X	LinStatic	Step By Step	16300.5566	0.739	22043756.251	73.3268
Story4	EQ X	LinStatic	Step By Step	16322.8512	0.662	24651618.006	73.3268
Story3	EQ X	LinStatic	Step By Step	16335.3919	0.559	29239109.252	73.3268
Story2	EQ X	LinStatic	Step By Step	16340.9656	0.402	40600767.992	73.3268
Story1	EQ X	LinStatic	Step By Step	16342.359	0.222	73724550.81	73.3268
Story55	EQ Y	LinStatic	Step By Step	65.2287	0.137	0	19735.2129
Story54	EQ Y	LinStatic	Step By Step	65.2287	0.034	0	18338.9718
Story53	EQ Y	LinStatic	Step By Step	65.2287	0.037	0	16993.9644
Story52	EQ Y	LinStatic	Step By Step	65.2287	0.032	0	15699.2332
Story51	EQ Y	LinStatic	Step By Step	65.2287	0.023	0	14453.8205
Story50	EQ Y	LinStatic	Step By Step	65.2287	0.013	0	13256.7687
Story49	EQ Y	LinStatic	Step By Step	65.2287	0.006	0	12107.1202
Story48	EQ Y	LinStatic	Step By Step	65.2287	0.004	0	11003.9173
Story47	EQ Y	LinStatic	Step By Step	65.2287	0.004	0	9946.2023
Story46	EQ Y	LinStatic	Step By Step	65.2287	0.005	0	8933.0177
Story45	EQ Y	LinStatic	Step By Step	65.2287	0.005	0	7963.4058
Story44	EQ Y	LinStatic	Step By Step	65.2287	0.006	0	7036.4089
Story43	EQ Y	LinStatic	Step By Step	65.2287	0.007	0	6151.0694
Story42	EQ Y	LinStatic	Step By Step	65.2287	0.015	0	5306.4297
Story41	EQ Y	LinStatic	Step By Step	65.2287	0.014	0	4501.532
Story40	EQ Y	LinStatic	Step By Step	65.2287	0.044	0	3195.9719
Story39	EQ Y	LinStatic	Step By Step	65.2287	0.01	0	1859.7726
Story38	EQ Y	LinStatic	Step By Step	65.2287	0.006	11628658.198	591.2179
Story37	EQ Y	LinStatic	Step By Step	65.2287	0.007	9775232.43	611.4493
Story36	EQ Y	LinStatic	Step By Step	65.2287	0.007	0	1749.986
Story35	EQ Y	LinStatic	Step By Step	65.2287	0.007	0	2826.1491
Story34	EQ Y	LinStatic	Step By Step	65.2287	0.006	0	3841.6957
Story33	EQ Y	LinStatic	Step By Step	65.2287	0.006	0	4798.3828

Story32	EQ Y	LinStatic	Step By Step	65.2287	0.006	0	5697.9673
Story31	EQ Y	LinStatic	Step By Step	65.2287	0.005	0	6542.2063
Story30	EQ Y	LinStatic	Step By Step	65.2287	0.005	0	7332.8567
Story29	EQ Y	LinStatic	Step By Step	65.2287	0.005	0	8071.6756
Story28	EQ Y	LinStatic	Step By Step	65.2287	0.005	0	8760.42
Story27	EQ Y	LinStatic	Step By Step	65.2287	0.005	0	9400.8469
Story26	EQ Y	LinStatic	Step By Step	65.2287	0.004	0	9994.7133
Story25	EQ Y	LinStatic	Step By Step	65.2287	0.004	0	10543.7761
Story24	EQ Y	LinStatic	Step By Step	65.2287	0.004	0	11049.7924
Story23	EQ Y	LinStatic	Step By Step	65.2287	0.004	0	11514.5191
Story22	EQ Y	LinStatic	Step By Step	65.2287	0.006	0	11939.7134
Story21	EQ Y	LinStatic	Step By Step	65.2287	0.006	0	12327.1321
Story20	EQ Y	LinStatic	Step By Step	65.2287	0.02	0	12854.5755
Story19	EQ Y	LinStatic	Step By Step	65.2287	0.017	0	13357.5979
Story18	EQ Y	LinStatic	Step By Step	65.2287	0.002	0	13809.064
Story17	EQ Y	LinStatic	Step By Step	65.2287	0.002	0	14211.7605
Story16	EQ Y	LinStatic	Step By Step	65.2287	0.002	0	14568.4744
Story15	EQ Y	LinStatic	Step By Step	65.2287	0.002	0	14881.9925
Story14	EQ Y	LinStatic	Step By Step	65.2287	0.002	0	15155.1016
Story13	EQ Y	LinStatic	Step By Step	65.2287	0.002	0	15390.5886
Story12	EQ Y	LinStatic	Step By Step	65.2287	0.002	0	15591.2401
Story11	EQ Y	LinStatic	Step By Step	65.2287	0.002	0	15759.8432
Story10	EQ Y	LinStatic	Step By Step	65.2287	0.002	0	15899.1846
Story9	EQ Y	LinStatic	Step By Step	65.2287	0.002	0	16012.0511
Story8	EQ Y	LinStatic	Step By Step	65.2287	0.001	0	16101.2296
Story7	EQ Y	LinStatic	Step By Step	65.2287	0.001	0	16169.5068
Story6	EQ Y	LinStatic	Step By Step	65.2287	0.001	0	16219.6697
Story5	EQ Y	LinStatic	Step By Step	65.2287	0.002	0	16254.5051
Story4	EQ Y	LinStatic	Step By Step	65.2287	0.002	0	16276.7997
Story3	EQ Y	LinStatic	Step By Step	65.2287	0.004	0	16289.3404
Story2	EQ Y	LinStatic	Step By Step	65.2287	0.01	0	16294.9141
Story1	EQ Y	LinStatic	Step By Step	65.2287	0.001	0	16296.3075

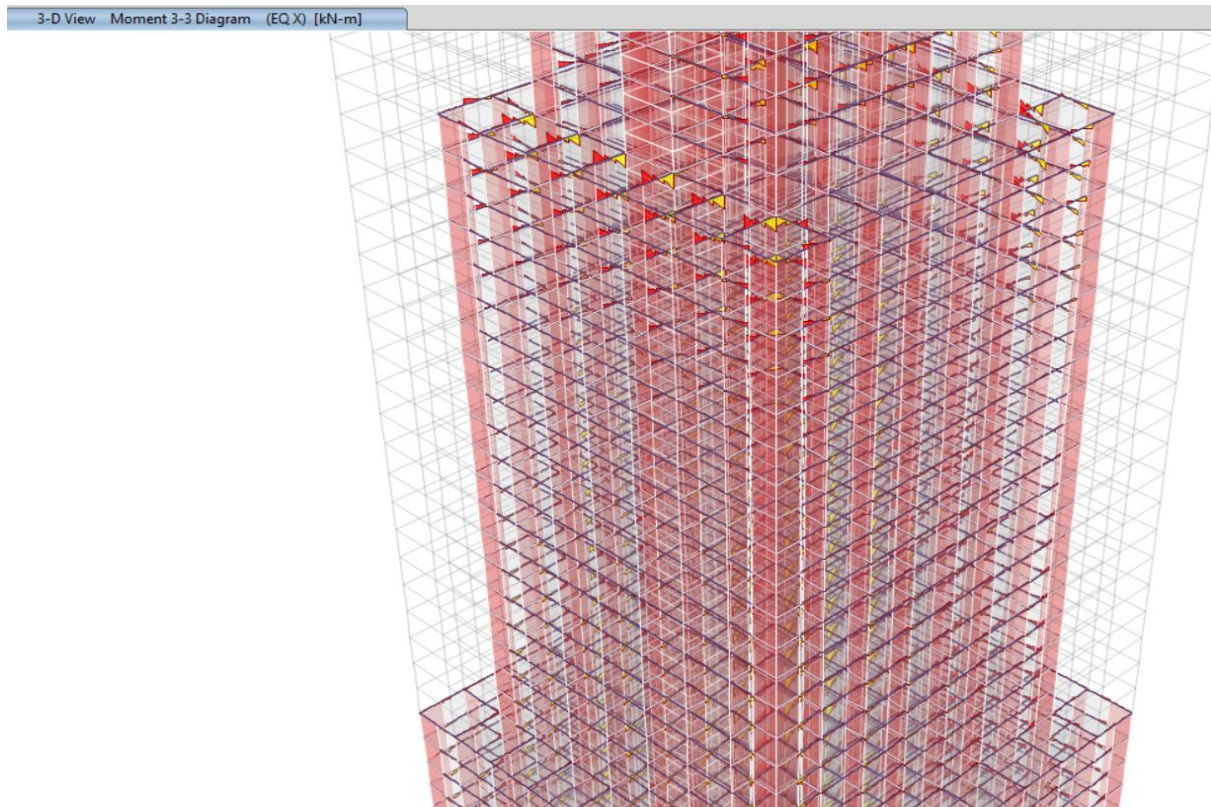


Figure 36: Sample of Moment diagram- due to Seismic load in X direction

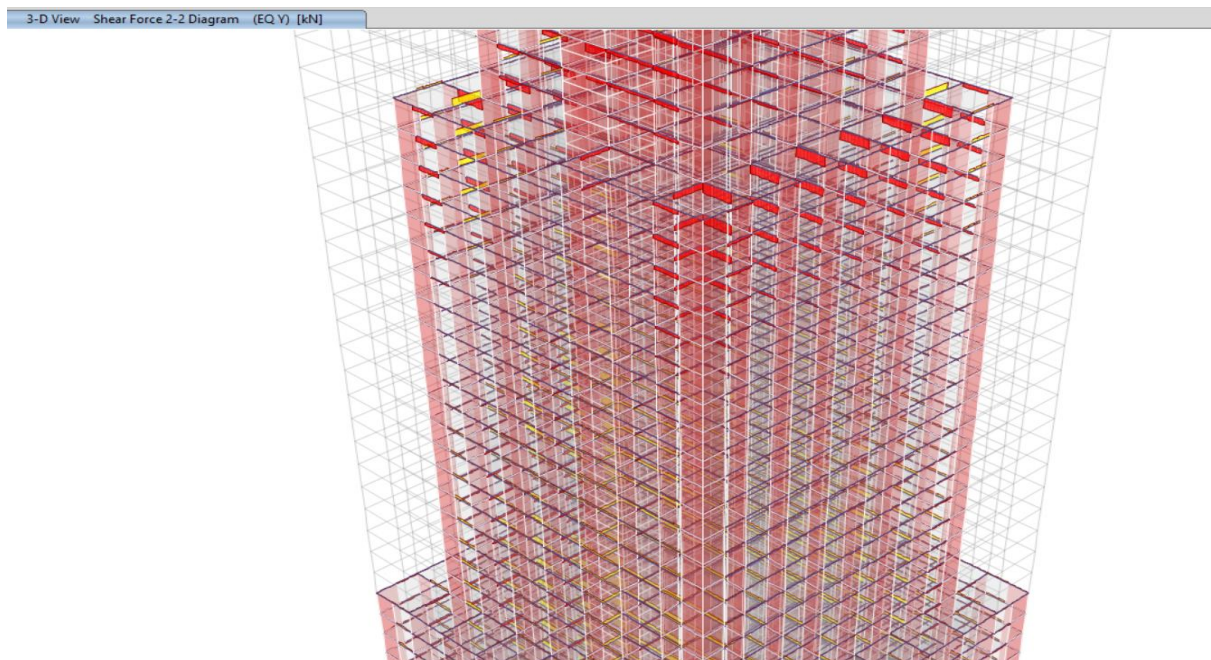


Figure 37: Sample of shear force diagram- due to Seismic load in Y direction

Appendix F: Verification of steel skyscraper design and some sections of the members:

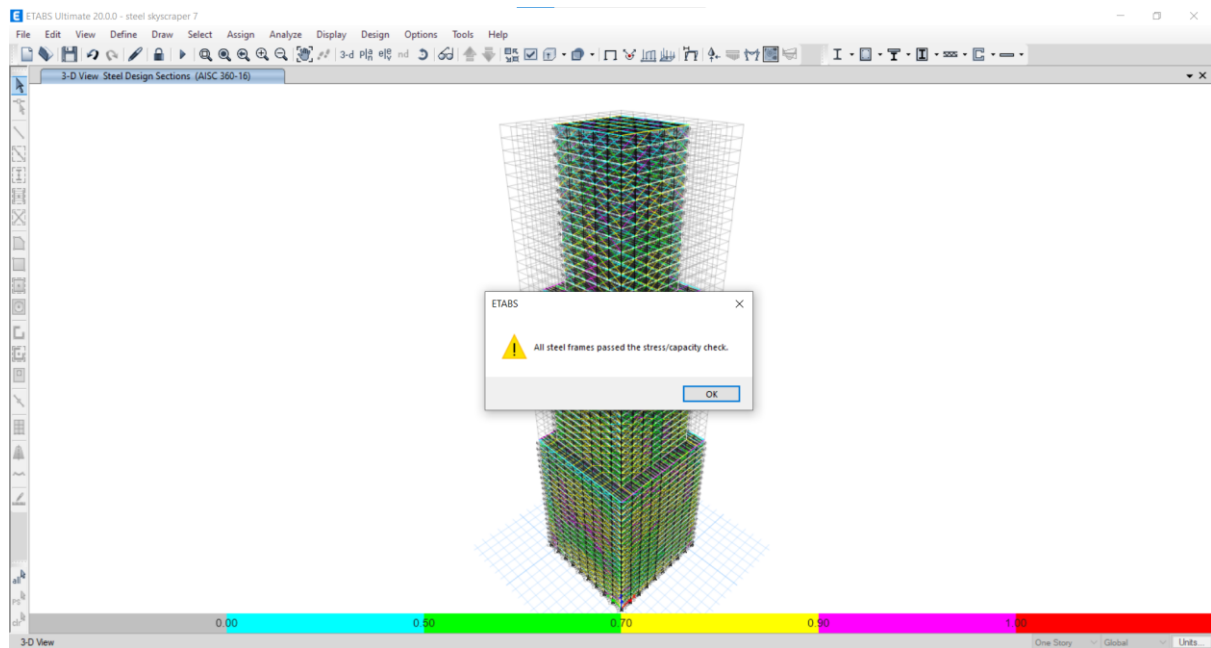


Figure 38: Checking of the stress capacity of steel frame.

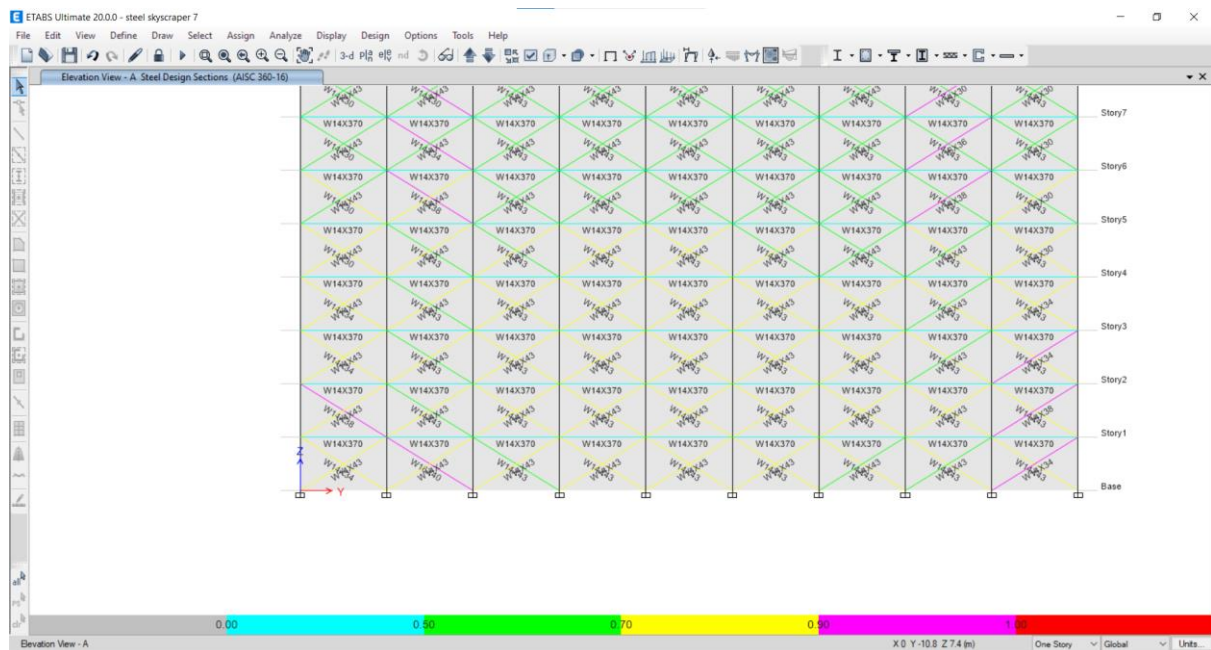


Figure 39: Sample of Bracing and external main beams sections

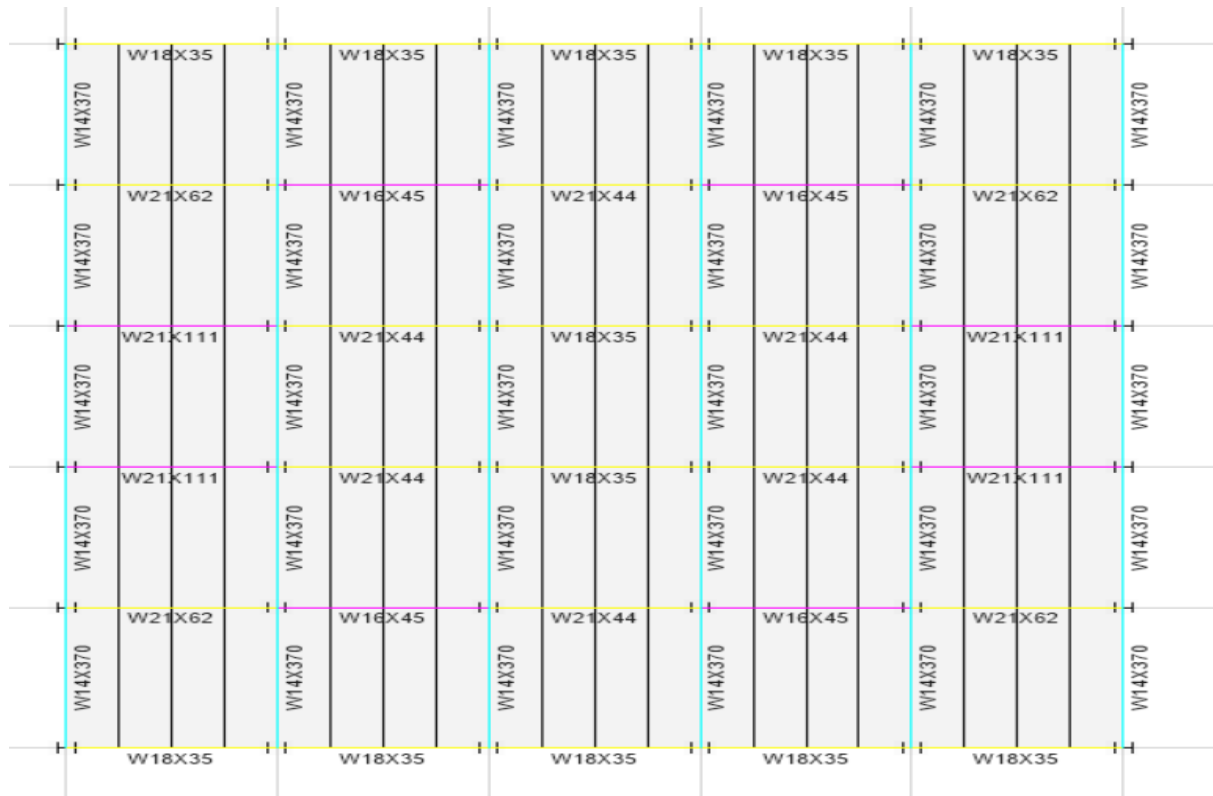


Figure 40: Sample of Selected sections of Main steel beams

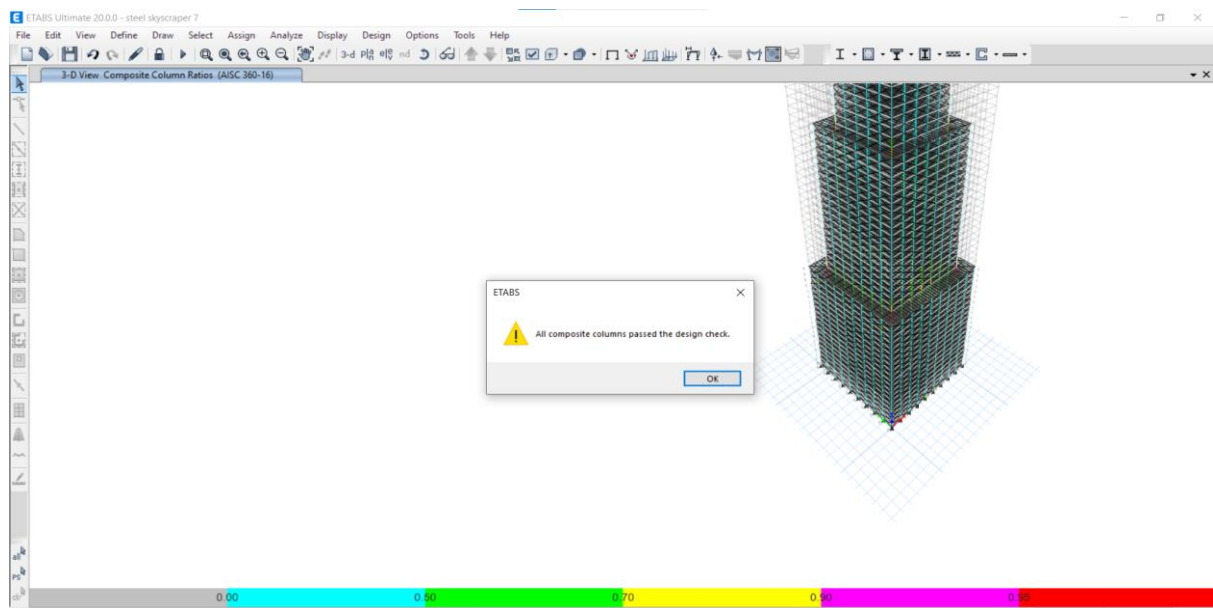


Figure 41: composite columns design check

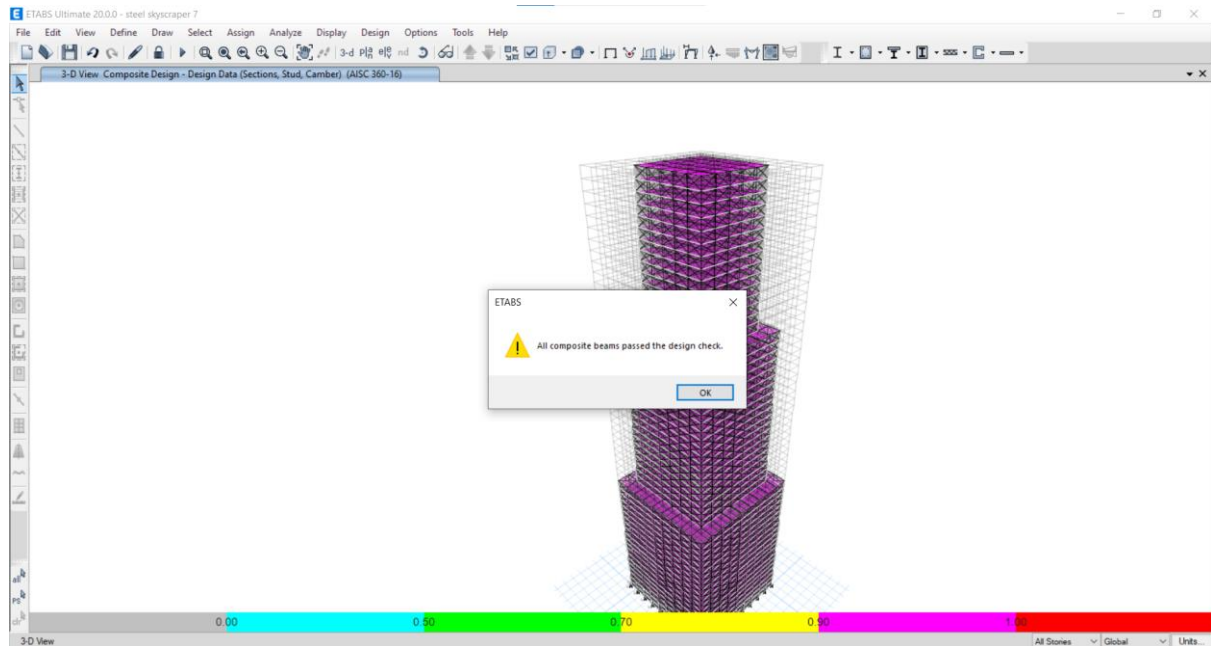


Figure 42: composite beams design check

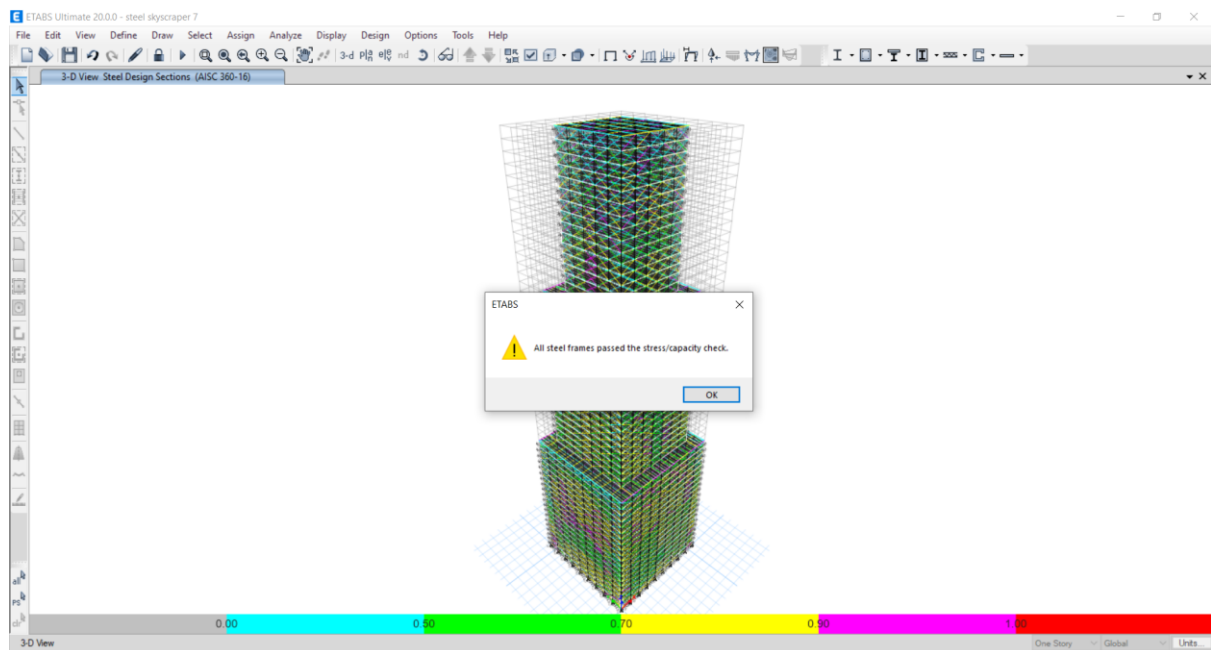


Figure 43: steel frames stress capacity check

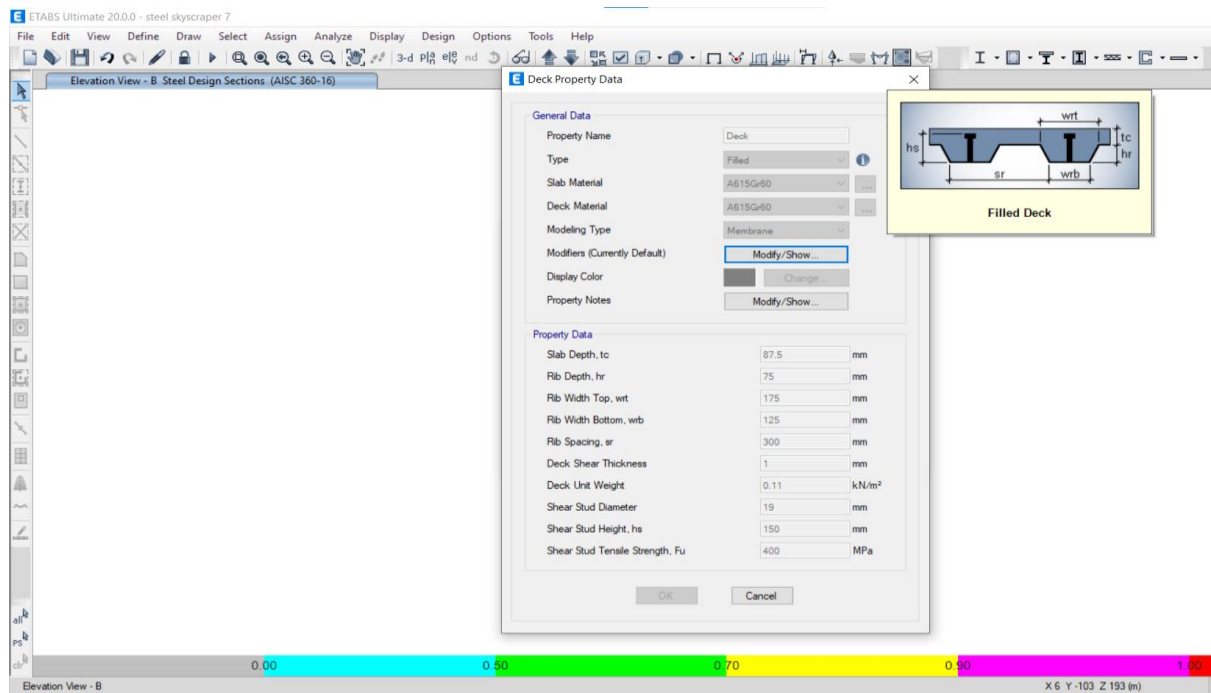


Figure 44: Deck slab property data

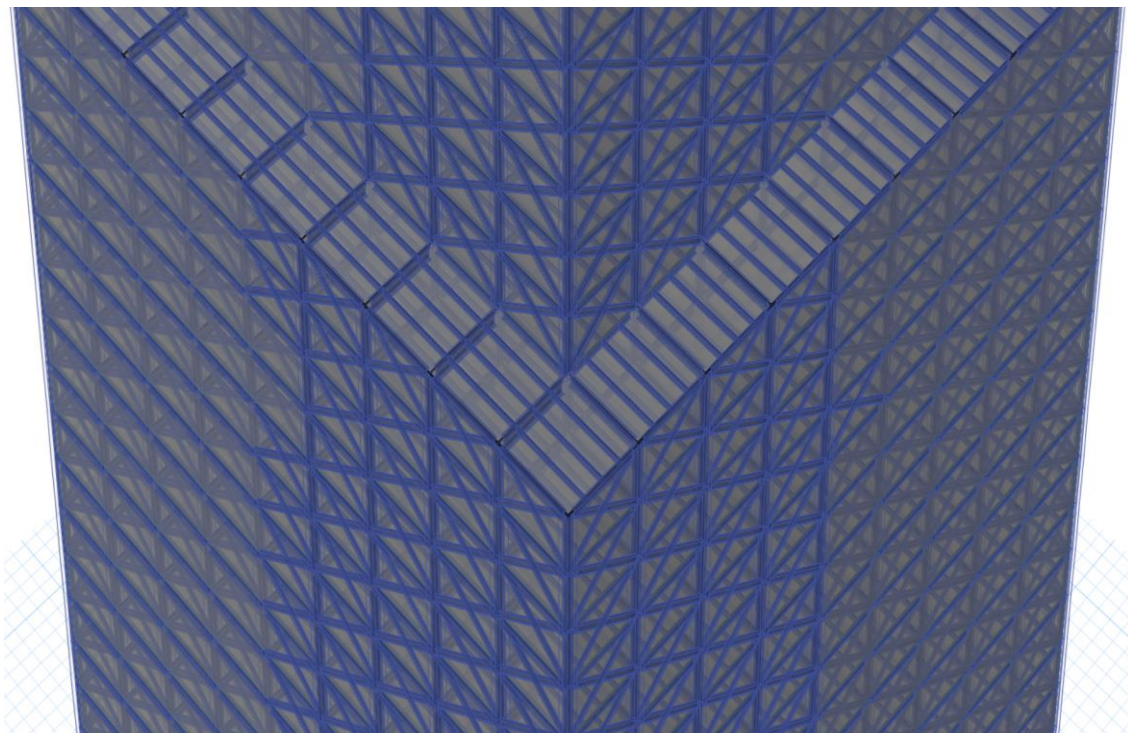


Figure 45: Partial Zoom in view of the of steel building showing the external steel columns, beams and bracings



Figure 46: Erection of Steel column



Figure 47: Connection of steel column and beams



Figure 48: Shape of Deck slab reinforcement and concrete