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STUDY ON G+6 BUILDING WITH DIFFERENT PLAN IRREGULARITIES BY STAAD PRO SOFTWARE

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ABSTRACT

Because of their effective structural systems and use of high-strength materials, modern tall buildings are able to lower their height and become more thin, flexible, and damping-efficient. The residents of these flexible structures experience discomfort due to their extreme sensitivity to seismic load and wind stimulation. Thus, a lot of research and studies have been conducted to lessen such an excitation and enhance tall structures' resistance to earthquake and wind loads. A tall building's architectural design heavily relies on the early integration of aerodynamic shape, wind engineering considerations, and structural system choices to minimise the building's reaction to wind excitations. In order to decrease its dynamic displacement within the bounds of the criteria level for the design wind speed, a tall structure with an inappropriate form often needs a lot of steel or a unique damping system. Four different shaped buildings are generally studied for this research work: circular, rectangular, square, and triangular. It makes sense that choosing the right building shape and making architectural changes are also very important and effective design approaches to reduce wind and earthquake induced motion by altering the flow pattern around the building.

The current research employed STAAD Pro V8i software to compare the shear force, bending moment, and deflection of buildings of the following shapes: rectangular, T-shaped, H-shaped, and O-shaped.

Key words: dynamic displacement, aerodynamic shaping, architectural design, STAAD Pro V8i, shear force, bending moment, and building deflection.

I. INTRODUCTION

1.1 GENERAL

The forces acting on the structure must be described in order to build it to withstand earthquake and wind loads. It is impossible to predict the precise forces that will exist throughout the structure's lifetime. According to the boundary circumstances of each structure taken into consideration in the study to provide for life safety, the majority of National structure Codes specify certain variables. While it's necessary to have a reasonable estimate for these aspects, the project's economic feasibility and construction cost are crucial. The Egyptian Codes 1993 and 2003 place more emphasis on estimating these lateral loads and the related extra stresses that must be taken into consideration in the construction of the buildings since there are no earthquake or wind forecasting centres.

Points of weakness are where a building begins to collapse during an earthquake. This weakness results from discontinuities in the structure's mass, stiffness, and shape. Irregular structures are those that exhibit this discontinuity. A significant amount of urban infrastructure is made up of irregular structures. One of the main causes of structural collapses during earthquakes is vertical abnormalities. For instance, the most prominent constructions that fell were those with soft storeys. Thus, the impact of vertical abnormalities on a structure's seismic performance becomes crucial. These structures' dynamic properties vary from those of "regular"

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buildings due to height-wise variations in mass and stiffness. The definition of vertically irregular structures in IS 1893 is as follows: Inconsistent mass, strength, and stiffness distributions across the building's height might be the cause of the irregularities in the structures. The analysis and design of such structures become more complex when they are built in seismically active areas. There are two different kinds of irregularities. The lateral force resisting system (L.F.R.S.) is the part of the structure that withstands seismic forces. The building's L.F.R.S. might be of several kinds. Shear walls, frame-shear wall dual systems, and special moment-resisting frames are the most prevalent types of these systems in a building. The position of the structurally weak planes in the building systems is often where deterioration to a structure begins. These flaws cause further structural degradation, which ultimately results in the collapse of the structure. These flaws are often brought on by structural abnormalities in a building system's mass, stiffness, and strength. Plan and vertical irregularities are two general categories for the structural irregularity. If a structure has an uneven distribution of mass, strength, and stiffness across the building height, it may be categorised as vertically irregular. According to IS 1893:2002, a storey is considered to have mass irregularity if its mass is more than 200% that of the storey next to it. A storey is said to be "weak" if its stiffness is less than 60% of that of the storey next to it. A storey is referred described as a "soft storey" if its stiffness is 70% or less than that of the storey next to it.

In actuality, there are irregularities in a lot of existing structures, and some of them were originally intended to be irregular in order to serve various purposes, such as commercial basements made possible by the removal of central columns. Additionally, the beams and columns in the top stories are being reduced in size to meet functional needs and for additional commercial uses, such as storing large mechanical equipment. Uneven mass, stiffness, and strength distributions across the building height are the consequence of a particular floor's use differing from that of the floors next to it. Furthermore, a lot of other structures are inadvertently made irregular by a number of causes, such as variations in the materials and construction methods. Along the design, the building may also have inconsistent mass, strength, and stiffness distributions. One may say that the building has a horizontal irregularity in this situation. Figure 1.1 provides a thorough categorisation of structural irregularities, whereas Tables 1.1 and 1.2 provide code limitations. It is evident from a survey of code restrictions that most codes prescribe comparable standards for abnormalities based on size, neglecting the impractical factor of irregularity location. It is clear from the actual examples of existing irregular structures in Figures 1.2 to 1.4 that irregular buildings are chosen for both practical and aesthetic reasons. As will be covered in the following section, historical earthquake data demonstrate these constructions' poor seismic performance during earthquakes. Figures 1.5 through 1.8 show the many kinds of anomalies.

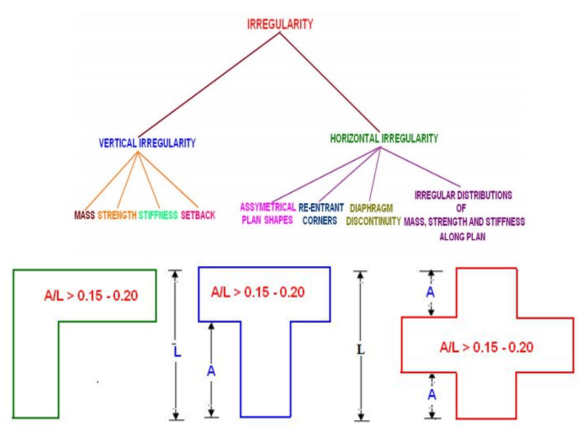

Figure 1. 1: Re-entrant corner irregularity

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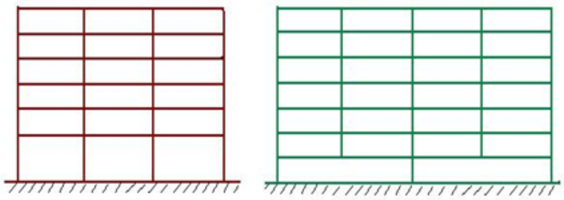

Figure 1. 2 : Irregular distribution of stiffness in the building system

1.2 STAAD PRO

The number of areas in units is steadily decreasing in the twenty-first century owing to the large population. A few years ago, when the population was less, they stayed in the horizontal structure since there was a lot of space for each individual. However, many of days favour the Vertical System (high-rise buildings because of space constraints). All the forces acting on a building, including its own weight and the soil-bearing capability, should be taken into consideration when designing high-rise structures. The building's beam, column, and reinforcement should be strong enough to effectively withstand external pressures acting on it. Additionally, the soil must be suitable for properly transferring the weight to the foundation. We preferred a deep foundation (pile) for loose soil. It will take longer and human mistake may arise if we do a lot of calculations for a high-rise project by hand. Therefore, using STAAD-PRO will make things simple. Static analysis, seismic analysis, and natural frequency are examples of common problems that STAAD-PRO can resolve. Together with IS-CODE, STAAD-PRO can fix this kind of issue. Additionally, STAAD-PRO is superior to the manual method as it produces results that are more exact and precise.

Giant STAAD-PRO was born. It is now the most widely used piece of software. In essence, it is carrying out design work. To accomplish the aim, use STAAD-PRO in four phases.

- Prepare the input file.
- Analyze the input file.
- Watch the results and verify them.
- Send the analysis result to steel design or concrete design engines for designing purpose.

1.3 FAILURE OF VARIOUS SHAPES OF BUILDINGS

In the past, several large and small earthquakes have been known to inflict damage to a variety of structures due to planar asymmetry. In the most laterally flexible areas of a structure, the non-coincident centres of mass and stiffness create plan asymmetry, which leads to torsional vibration and serious damage to structural elements. The structure in Figure 1.21 illustrates how torsion caused a three-story reinforced concrete building to collapse during the 1978 Miyagi-Ken-Oki earthquake in Japan. The centre of rigidity moved towards the direction of the wall because of its presence. As a consequence, the building twisted in relation to the centre of rigidity. This resulted from torsion caused by the eccentricity between the stiffness and mass centres. Columns in the outskirts, distant from the wall, suffered significant damage as a consequence of the torsion. The Ministry of Culture building, damaged by torsion during the 2010 Haiti earthquake, is seen on Figure 1.22. Damage to lateral load-resisting elements distant from the centre of stiffness occurred from twisting caused by the existence of a stiff core region on one side of the structure. These members' failure caused a downward strain on the whole floor, ultimately resulting in the building's complete collapse.

1.6 EARTHQUAKE

Techniques for earthquake analysis that take into account the forces that occur during an earthquake. The magnitude of the earthquake determines how strong these forces are.

Dynamic actions on buildings-wind and earthquake

Both wind and earthquakes may create dynamic motions on structures. However, there are clear differences in designing for earthquake impacts and wind forces. Force is the foundation of the

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initiative philosophy of structural design, which is congruent with wind design. In force-type loading, the exposed surface area of the structure is subjected to pressure. Displacement-type loading occurs when a building is designed to withstand earthquakes because the ground at its base moves randomly (Figure 1.1), creating inertia forces within the structure that lead to strains. This difference can also be expressed using the building's load-deformation curve, where the demands on the structure are displacement (i.e., horizontal axis) in displacement-type loading imposed by earthquake shaking and force (i.e., vertical axis) in force-type loading imposed by wind pressure.

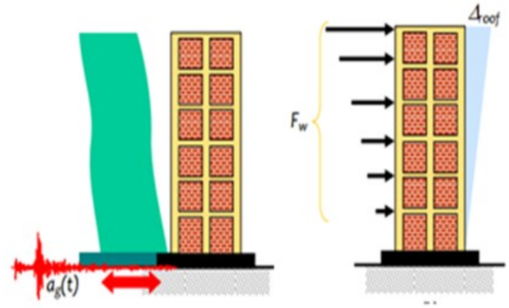

Figure 1. 3 : Disparities in how a building's design is affected by earthquake-related natural events, such as ground movement at the base and wind pressure on exposed areas

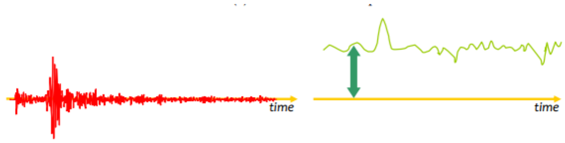

Figure 1. 4 : Characteristics of temporal changes of design actions: oscillatory, cytic and wind pressure, earthquake ground motion, and zero mean

Basic aspects of seismic design

Because earthquakes produce inertia forces proportionate to the mass of the structure, the mass of the building being constructed governs seismic design in addition to structural stiffness. The project may not be financially feasible if structures are designed to respond elastically during earthquakes without sustaining damage. As a result, the structure may need to suffer damage in order to release the energy that was applied to it during the earthquake. Consequently, standard structures must be able to withstand

1. Mild (and frequent) shaking without causing damage to structural or non-structural materials, according to the classic earthquake-resistant design philosophy;
2. Severe (and occasional) shaking with structural element damage but no collapse (to preserve life and property inside/adjoining the structure);
3. Moderate shaking with moderate structural element damage and some non-structural element damage.

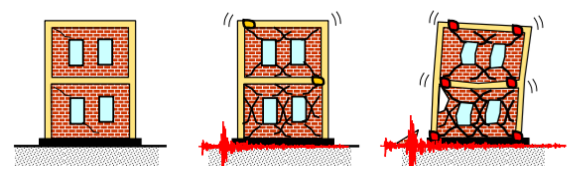

Figure 1. 5 : Earthquake-Resistant Design Philosophy for buildings

Designing to Resist Earthquakes Building philosophy is as follows: moderate shaking causes little structural damage and some non-structural damage, severe (infrequent) shaking causes structural damage but no collapse, and small (frequent) shaking causes little to no damage.

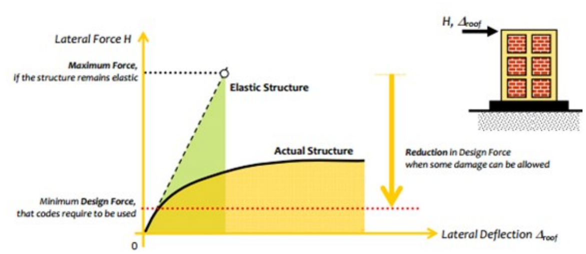

Figure 1. 6 : Basic strategy of earthquake design: Calculate maximum elastic forces and reduce by a factor to obtain design forces

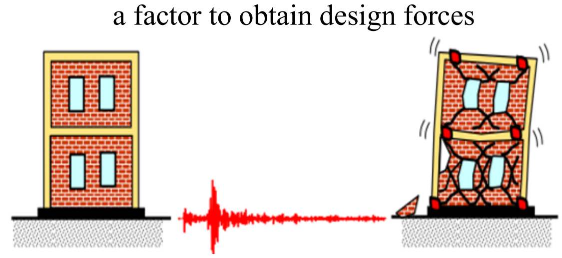

Figure 1. 7 : Earthquake-Resistant and NOT earthquake proof: Damage is expected during an earthquake in normal constructions under damaged building and damaged building.

1.7 OBJECTIVE OF THE STUDY

1. To use Staad pro V8i to compute the design lateral pressures on various multi-story building forms and compare the outcomes of various designs.
2. To investigate three structural anomalies: mass, stiffness, and vertical geometry irregularities.
3. Using Staad pro V8i, determine how structures will react to low, middle, and high frequency ground vibrations and compare the outcomes.
4. To assess the differences in design by conducting ductility-based earthquake-resistant design in accordance with IS 1893-2002, which corresponds to comparable static analysis and Staad pro V8i.

1.8 SCOPE OF THE STUDY:

1. Only RC buildings are taken into account.
2. The only abnormality examined was vertical.
3. The structures were analysed using nonlinear dynamic.
4. A column that was attached to the base was modelled.
5. The infill wall's contribution to stiffness was not taken into account. Infill wall loading was taken into consideration.
6. The interplay of soil structure is not taken into consideration.

1.9 SUMMARY

The majority of buildings nowadays are characterised by uneven vertical and plan arrangements. A detrimental coupled lateral response may result from irregularities in arrangement and a lack of symmetry, which may indicate important eccentricity between the building mass and stiffness centres (Giordano, Guadagnuolo, and Faella, 2008). Furthermore, it takes a lot of engineering and design work to design and analyse an irregular structure, but a bad designer will develop and analyse choices that are simple to understand. To put it another way, those with irregular choices suffer more harm than those with regular ones. As a result, irregular buildings need a more thorough structural study in order to function well after a catastrophic earthquake (Herrera, Gonzalez, and Soberon, 2008).

Inconsistencies in elevation and plan in the Indian Standard Code (IS 1893-2002): Both plan and vertical irregularities can be classified by five different types, such as torsional, re-entrant corner, out-of-array offset, and non-parallel systems for plan irregularities, and stiffness (soft storey), mass, vertical geometric, in-plane separation in vertical components resisting lateral force, and separation in capability (weak storey) for vertical irregularities. (Part I of IS 1893: 2002)

The irregularity of the re-entrant corners was described in IS 1893 (Part I): 2002. Every projection of the structural document serves as a template for the re-entrant corner irregularity arrangement seen in a building's lateral force-resisting system. The Journal's website offers the option to download an electronic copy. Please contact the journal publishing committee using the information provided on the journal website if you have any issues about the article guidelines. The conference website has details on submitting the final paper.

II. LITERATURE REVIEW

Tesfamariam and Rajeeva et al. (2012)

Three, five, and nine-story reinforced concrete building frames that were developed before the 1970s were used to illustrate the fragility-based seismic susceptibility of buildings while taking soft-story (SS) and quality of construction (CQ) into account. For those gravity load built buildings, a probabilistic seismic demand model (PSDM) was created using non-linear finite

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element analysis, taking into account the interactions between SS and CQ. A predictive equation for PSDM parameters as a function of SS and CQ is created using the response surface approach. The analysis's outcome demonstrates how sensitive the model parameter is to the way SS and CQ interact. A novel approach to measuring irregularity in vertically irregular building frames that takes dynamic properties (mass and stiffness) into consideration was presented by Sarkar et al. (2010). The following were the key findings: (1) The "regularity index," a measure of vertical irregularity appropriate for stepped structures, is presented. It takes into consideration the variations in mass and stiffness along the building's height. (2) To determine the basic time period of stepped buildings as a function of regularity index, an empirical formula is put forward.

The inelastic seismic response of planar steel moment-resisting frames with vertical mass irregularity is examined by Karavasilis et al. (2008). The number of stories, the ratio of beam to column strength, and the location of the heavier mass all affect the height-wise distribution and amplitude of inelastic deformation demands, according to the analysis of the generated response databank. However, the mass ratio appears to have no effect on the response.

According to Athanassiadou et al. (2008), the ductility class has little bearing on building costs, and all irregular frames that are subjected to earthquakes seem to perform just as well as regular ones, even when subjected to twice the design earthquake forces. Compared to the similar DCH frames, DCM frames were found to be less ductile and stronger. While DCH frames were discovered to dispose of greater over strength than DCM frames, the irregular frames' over strength was determined to be comparable to that of the regular ones. The reaction volumes in the top levels of the irregular frames seemed to be underestimated by pushover analysis.

Lee, Ko, and others (2007)

In order to study the seismic response characteristics of three 1:12 scale models of 17-story RC wall buildings with various irregularities at the bottom two floors, he exposed them to the same set of simulated earthquake excitations. While the second model had an infilled shear wall in the centre frame (Model 2), the third model only featured an infilled shear wall in one of the external frames (Model 3) at the bottom two floors. The first model featured a symmetrical moment-resisting frame (Model 1). Regardless of whether the infilled shear wall is present or not, the overall quantities of energy absorption by damage are comparable. Overturning caused the greatest energy absorption, which was followed by shear deformation.

He concurred with Devesh et al. (2006) that buildings with irregular mass, strength, and stiffness distributions will experience an increase in seismic demand as well as an increase in drift demand in the tower component of set-back structures. The combined stiffness and strength irregularity was determined to have the highest seismic demand. It was discovered that the kind of model has an impact on seismic behaviour.

III. METHODOLOGY

3.1 STATEMENT OF PROBLEM

Salient features

Utility of building : Residential complex
No of stories : G+6
Type of construction : R.C.C framed structure

Geometric details:

Ground floor : 3m
Floor to floor height : 3 m.
Length : 9 m.
Width : 9 m.
Height : 39 m.
Beam Size Width : 0.25 m.
Depth : 0.35 m.

Column Size Width : 0.35 m.
Depth : 0.45 m.

Materials:

Concrete grade : M30
All steel grades : Fe500 grade
Bearing capacity of soil : 300KN/M2
Seismic zone : V (Z=0.36).IS 1893(Part-1):2002
Soil type : II.
Importance factor : 1.
Response reduction factor : 4.
Damping : 5%.

3.2 CLASSIFICATION OF MULTI STOREY STRUCTURES

Buildings with many stories may be categorised as follows:

- Low-rise: a structure that is too short to qualify as a high-rise.
- Mid-rise: structures with elevators that are five to 10 stories high.
- High-rise: containing seven or more stories.
- Skyscraper: at least forty stories.
- Supertall: more than 300 meters.
- Megatall: more than 600 meters

3.3 STRUCTURAL TYPES

The fundamental kinds of multi-story buildings, which may be combined, include:

1. Framed structure

The building's structural'skeleton' is made up of a network of columns and connecting beams that support loads on the foundations.

2. Propped structure

Uses a platform or cantilever slab to support columns. It makes use of exterior propped columns and an interior core.

3. Suspended structure

Consists of an internal core and horizontal floors held up by strong steel cables suspended from above cross beams. Has an internal core that allows floors and beams to cantilever. This eliminates the need for columns.

4. Braced structure

In order for columns to be built as pure compression members, bracing is employed to provide stability. The bracing system supports the lateral loads, while the beams and columns that make up the frame support the vertical stresses. Braced frames are inexpensive, simple to construct, and provide the design freedom to produce the necessary strength and stiffness. They also reduce lateral displacement and bending moment in columns.

4. Shear wall structure

Made up of rigid braced (or shear) panels that mitigate the impacts of wind and lateral stresses. The floors transfer the stresses to the shear walls.

6. Core structure

Makes use of a rigid structural core that contains stairs, elevators, and other features. The floors transfer lateral forces and wind to the core.

7. Hull core structure

Also referred to as "tube-in-tube," it is made up of an external tube system and a core tube within the building that houses functions like utilities and elevators. As the shear and flexural elements of a wall-frame construction, the inner and outer tubes interact horizontally.

3.4. LOADS ACTING ON THE STRUCTURE

Vertical, horizontal, and longitudinal loads are the three general categories of loads that are applied to buildings and other structures. Dead loads, living loads, and impact loads make up the vertical loads. Wind and seismic loads are included in the horizontal loads. When designing bridges, gantry girders, and other structures, longitudinal loads—that is, tractive and braking forces—are taken into account.

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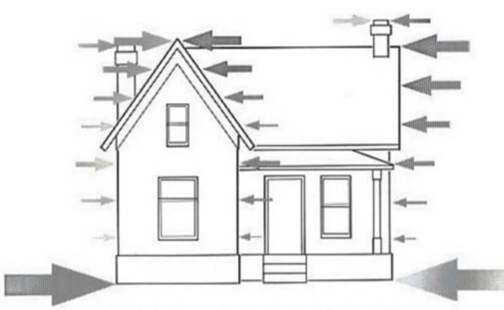
Figure 3. 1 : Different types of Loads on Building

EARTHQUAKE LOADS (EL)

Both vertical and horizontal forces acting on the structure are caused by earthquakes. Three mutually perpendicular directions—typically interpreted as vertical and two horizontal—can be distinguished from the entire vibration induced by an earthquake.

There are no appreciable forces in the superstructure as a result of vertical motions. However, while planning, the building's horizontal displacement during an earthquake must be taken into account.

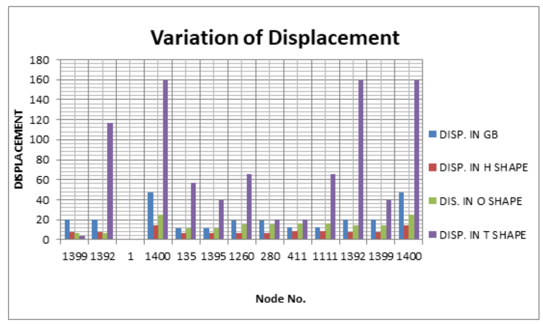


IV. RESULTS AND ANALYSIS

4.1 VARIATION OF DISPLACEMENT

Table 4. 1 : Variation of Displacement

NODE NO.	GB	H SHAPE	0 SHAPE	T SHAPE
1399	19.988	7.73	6.143	3.702
1392	19.988	7.73	6.143	116.74
1	0	0	0	0
1400	46.814	14.338	24.832	158.973
135	11.816	7.034	11.827	57.205
1395	11.816	7.034	11.827	39.472
1260	19.29	7.034	14.957	65.548
280	19.29	7.034	14.957	19.824
411	12.391	8.434	16.66	20.165
1111	12.391	8.434	16.66	65.548
1392	19.988	7.634	14.046	158.973
1399	19.988	7.634	14.046	39.916
1400	46.814	14.338	24.832	158.973



Graph 4. 1 : Variation of Displacement

4.2 VARIATION OF SHEAR FORCES IN X DIRECTION

Table 4. 2 : Variation of Shearforce in X Directon

BEAM NO.	GB	H SHAPE	0 SHAPE	T SHAPE
2350	8248.315	2465.819	4399.176	4413.15
2335	-64.524	-32.956	-30.819	-123.072
2331	-19.66	-2.733	-4.153	375.524
2323	-19.66	-2.733	-4.153	-13.112
2223	251.398	91.063	193.794	289.304
494	251.398	91.063	193.794	150.52
117	96.713	-7.224	10.361	9.736
109	96.713	-7.224	10.361	44.32
2223	206.574	61.181	148.97	234.355
494	206.574	61.181	148.97	289.304
2323	-19.66	3.216	-4.759	-13.112
2323	-19.66	-3.073	-4.153	320.575

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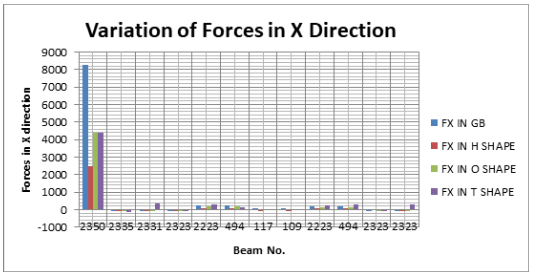
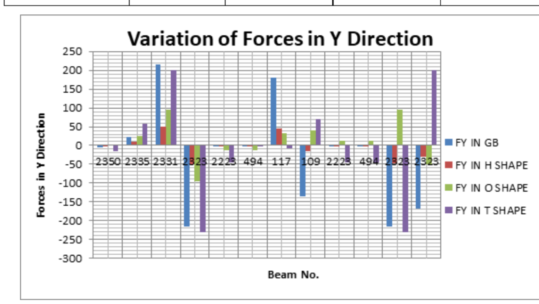


Graph 4. 2 : Variation of Shearforce in X Directon

4.3 VARIATION OF SHEAR FORCES IN Y DIRECTION

Table 4. 3 : Variation of Shearforce in Y Directon

BEAM NO.	GB	H SHAPE	0 SHAPE	T SHAPE
2350	-5.918	-0.086	0.575	-15.2
2335	23.24	9.658	24.495	58.005
2331	214.869	50.682	95.795	199.935
2323	-214.869	-50.682	-95.795	-230.439
2223	-3.007	-2.2	-11.851	-43.95
494	-3.007	-2.2	-11.851	-0.161
117	180.806	45.279	33.624	-7.29
109	-134.685	-14.532	39.497	69.49
2223	-3.007	-2.2	11.851	-43.95
494	-3.007	-2.2	11.851	-43.95
2323	-214.869	-48.612	95.671	-230.439
2323	-168.748	-29.405	-49.674	199.935

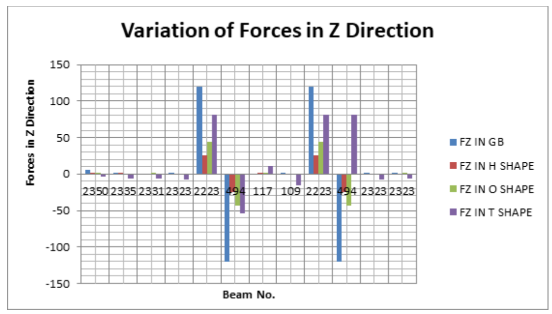


Graph 4. 3 : Variation of Shearforce in Y Directon

4.4 VARIATION OF SHEAR FORCES IN Z DIRECTION

Table 4. 4 : Variation of Shearforce in Z Directon

BEAM NO.	GB	H SHAPE	0 SHAPE	T SHAPE
2350	5.277	0.034	0.159	-3.617
2335	0.075	0.074	-0.151	-6.172
2331	-0.096	-0.026	0.262	-6.123
2323	0.096	-0.026	-0.262	-7.311
2223	119.927	25.41	43.748	81.354
494	-119.927	-25.41	-43.748	-54.099
117	-0.57	0.298	0.58	11.344
109	0.57	-0.298	-0.58	-15.06
2223	119.927	25.41	43.748	81.354
494	-119.927	-25.41	-43.748	81.354
2323	0.096	-0.018	-0.12	-7.311
2323	0.096	-0.012	0.262	-6.123



Graph 4. 4 : Variation of Shearforce in Z Directon

4.5 VARIATION OF MOMENTS IN X DIRECTION

Table 4. 5 : variation of moments in x direction

BEAM NO.	GB	H SHAPE	0 SHAPE	T SHAPE
2350	0.015	0.009	-0.004	0.371
2335	0.059	0.015	0.056	0.187
2331	-4.554	0.777	1.352	2.396
2323	4.554	0.777	-1.352	2.031
2223	-0.384	0.127	0.247	3.286
494	0.384	-0.127	-0.247	9.756
117	9.448	2.483	3.294	22.473
109	-9.448	-2.483	-3.294	-29.054
2223	-0.384	0.127	-0.247	3.286
494	0.384	-0.127	0.247	3.286
2323	4.554	1.012	1.296	2.031
2323	4.554	0.692	1.352	2.396

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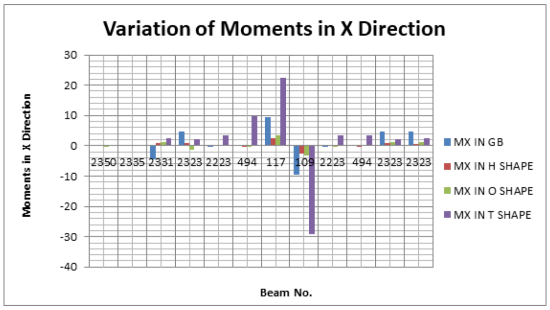
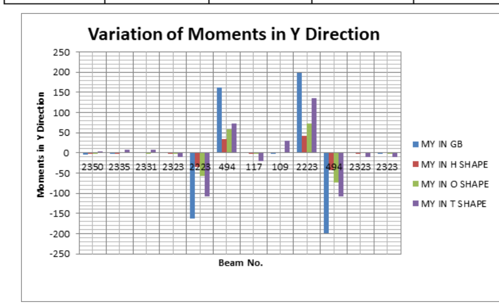


Graph 4. 5 : variation of moments in x direction

4.6 VARIATION OF MOMENTS IN Y DIRECTION

Table 4. 6 : variation of moments in Y direction

BEAM NO.	GB	H SHAPE	0 SHAPE	T SHAPE
2350	-5.183	-0.044	-0.152	3.029
2335	-0.119	-0.127	0.136	8.851
2331	0.159	0.047	-0.322	8.385
2323	0.159	-0.047	-0.322	-10.207
2223	-161.875	-34.225	-57.712	-108.586
494	161.875	34.225	57.712	73.149
117	0.895	-0.418	-0.811	-20.093
109	-0.814	0.476	0.928	30.822
2223	197.906	42.005	73.531	135.476
494	-197.906	-42.005	-73.531	-108.586
2323	0.159	-0.014	0.181	-10.207
2323	-0.13	0.007	-0.464	-9.984

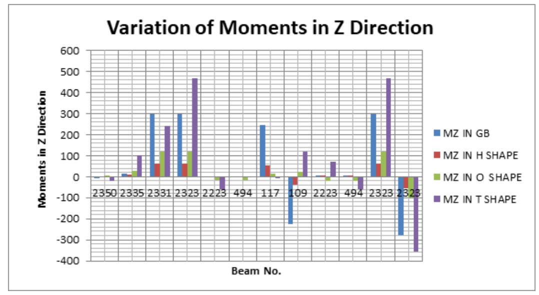


Graph 4. 6 : variation of moments in Y direction

4.7 VARIATION OF MOMENTS IN Z DIRECTION

Table 4. 7 : variation of moments in Z direction

BEAM NO.	GB	H SHAPE	0 SHAPE	T SHAPE
2350	-5.913	-0.213	0.496	-20.256
2335	13.475	10.927	28.723	101.14
2331	298.315	60.697	117.573	242.62
2323	298.315	60.697	117.573	468.788
2223	-2.797	-2.742	-14.458	-58.319
494	-2.797	-2.742	-14.458	-3.247
117	247.12	52.795	14.527	-5.093
109	-226.115	-36.922	23.337	120.898
2223	6.222	3.859	-21.096	73.531
494	6.222	3.859	-21.096	-58.319
2323	298.315	63.082	117.681	468.788
2323	-277.11	-54.464	-100.63	-357.185



Graph 4. 7 : change in seconds along the x-axis

V. CONCLUSION

The following conclusions were drawn from the findings and conversations.

1. T-shaped buildings are stable whereas H-shaped buildings are unstable from the perspective of displacement.
2. A T-shaped structure is stable and an H-shaped building is unstable when the forces acting in the X direction are taken into account.
3. A T-shaped structure is stable and an H-shaped building is unstable when the forces acting in the Y direction are taken into account.
4. A T-shaped structure is stable while an H-shaped building is unstable when the forces in the Z-direction are taken into account.
5. The T-shaped structure is stable while the H-shaped building is unstable when the moments in the X, Y, and Z directions are taken into account.
6. Based on the aforementioned findings, it was determined that T-shaped structures are more stable than H-, O-, and rectangular-shaped buildings.

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