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A COMPARATIVE STUDY ON SEISMIC ANALYSIS OF MULTISTOREY OFFICE BUILDING

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Abstract : India faces potential risks for multi-storeyed office buildings in seismically active regions, with over 65% of the country prone to moderate to high intensity earthquakes. Mega cities in these regions are designed for gravity loads only, and earthquake motion causes both horizontal and vertical ground motions. Vertical ground motion has smaller magnitudes, but can be resisted by safety factors in structure design. Structures designed for gravity loads cannot resist horizontal ground motion, which causes significant damage to the foundation by shaking the foundation. Building mass resists this motion by setting up inertia forces throughout the structure. Therefore, it is crucial to check the adequacy of structures to withstand horizontal ground motion, even if it is expensive.

The Bhuj Earthquake in 2001 sparked increased awareness of earthquakes' damaging effects in India. The need to evaluate the seismic adequacy of existing buildings has become crucial, especially after the loss of life and property. Seismic analysis is essential for determining the magnitude of lateral earthquake forces, making multi-storeyed office buildings in India a major concern. The objective of the project is to carry out the seismic analysis and comparison of a five storey, ten storey and fifteen storey office building located in zone -III for obtaining the basic parameters like time period frequency storey shears and displacements and compare the result by using the code IS 1893-2016.The analysis of frame is worked out manually and it verified by using ETABS software.

Key words: Auto cad, STAAD Pro, ETABS.

I. Introduction:

In seismically active regions like India, there is potential risk for multi-storeyed office buildings. As per the latest seismic zoning map brought out by the Bureau of Indian Standards (BIS), over 65% of the country is prone to moderate to high intensity earthquakes. Most of the mega cities in India are in seismically active zones and many structures in these cities are designed for gravity loads only. India faces potential risks for multi-storeyed office buildings in seismically active regions, with over 65% of the country prone to moderate to high intensity earthquakes. Mega cities in these regions are designed for gravity loads only, and earthquake motion causes both horizontal and vertical ground motions. Vertical ground motion has smaller magnitudes, but can be resisted by safety factors in structure design. Structures designed for gravity loads cannot resist horizontal ground motion, which causes significant damage to the foundation by shaking the foundation. Building mass resists this motion by setting up inertia forces throughout the structure. Therefore, it is crucial to check the adequacy of structures to withstand horizontal ground motion, even if it is expensive.

The Bhuj Earthquake in 2001 sparked increased awareness of earthquakes' damaging effects in India. The need to evaluate the seismic adequacy of existing buildings has become crucial, especially after the loss of life and property. Seismic analysis is essential for determining the magnitude of lateral earthquake forces, making multi-storeyed office buildings in India a major concern. India's construction industry predominantly uses low-rise buildings, often using steel and concrete due to their ease of construction and economy. However, population growth and land scarcity necessitate vertical expansion in many cities. Composite parts are being used more efficiently and cost-effective for high-rise structures. A response spectrum analysis is used to assess structural reactions to quick, nondeterministic, transient dynamic events like earthquakes and shocks/impacts. Time-dependent analysis is challenging due to the unknown load history and short duration of events, making random response strategies inappropriate. A unique type of mode superposition serves as the foundation for the response spectrum approach.

Base shear is a crucial structural property that determines the total lateral force at the base of a building during earthquake or seismic motion. Two methods are used to determine base shear: manual and software. Software is widely used for seismic analysis and multistoried building design. This study focuses on the percentage of base shear difference between manual and software methods, using linear static analysis techniques in the software method. Code books like IS875(Part-1)-1987, IS875(Part-2)-1987, and IS1893(Part-1)-2016 were consulted for this study. India is experiencing a growing demand for major construction projects to develop undeveloped towns and cities. Structural analysis and planning are crucial for determining the general shape, specific dimensions, and size of buildings to serve their purpose and withstand impacts throughout their useful life. This process requires imagination, complex calculations, and knowledge of structural engineering. Urban cities need to accommodate overpopulation and land capital, leading to the construction of multi-storey reinforced concrete structures. Due to limited land availability, vertical construction is preferred over horizontal construction. Time delay is a major barrier in economic construction methodology, so structural optimization methods are needed to economize structures and accelerate growth. This project focuses on planning, analysis, and design of multi-storey Office buildings in seismic zone III.

II.Seismotectonic

The tectonics of the shilling plateau, which experienced a magnitude 8.7 event in 1897, is distinctly different from that of regions to its north, south and west. The Hindukush and Pamir knot regions are characterized by the junction of several tectonic feathers. This plate boundary region experiences high levels of seismicity varying from shallow to intermediate depth earthquakes. The major earthquakes occurred in the Indian subcontinent are presented in table 2.The other potential tectonic feathers in the Northwest Indian region are the transverse fault systems known as the Chama fault, the Kithara and Sula imam ranges.

Table 1- Major Earthquakes Occurred in Indian Subcontinent

Year	Region	Magnitude	Death Toll
1819	Kutch	8.0	2,000
1885	Spare, J & K	7.0	2,000
1897	Shillong	8.7	1,542
1905	Assam	8.0	19,500
1918	Assam	7.6	NA
1930	Bihar-Nepal	7.1	NA
1934	Andamans	8.3	10,300
1941	Assam	8.1	NA
1943	Arunachal	7.2	NA
1950	Gujarat	8.5	1,526
1956	Konya, Aha	7.0	113
1967	Uttarkashi	6.3	1,200
1988	Latur, Aha	6.4	900
1991	Jabalpur, MP	6.6	2,000
1993	Chamoli, UP	6.3	9,748
1997	Bhuj (Gujarat)	6.0	38
1999	Chamoli, UP	6.8	100
2001	Bhuj (Gujarat)	7.9	40,000
2005	Kashmir	7.6	86,000
2008	East Nepal	7.8	87
2011	Sikkim	6.9	111
2015	Nepal	7.5	9,000
2020	Rajasthan	5.3	1
2021	Uttarakhand	6.0	2
2022	Nepal	5.6	6
2023	West Nepal	5.7	6

III.Plan

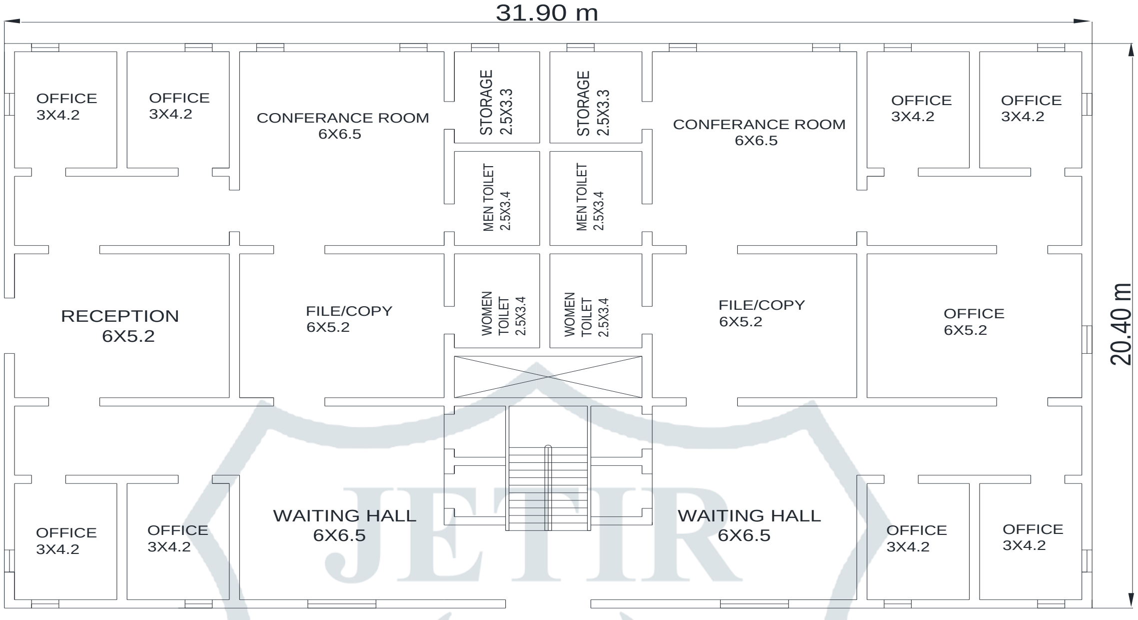
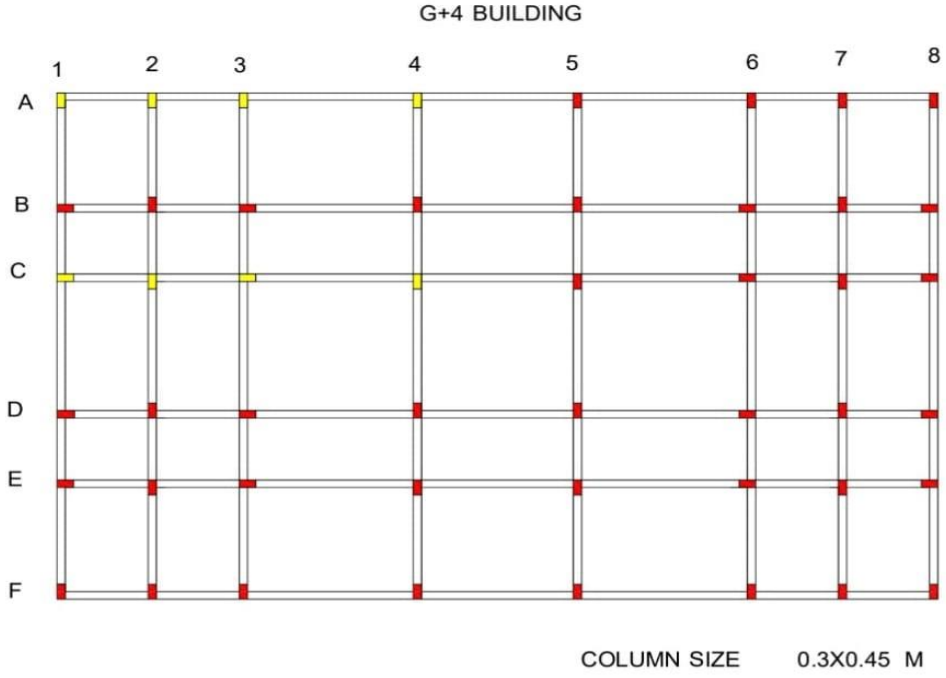
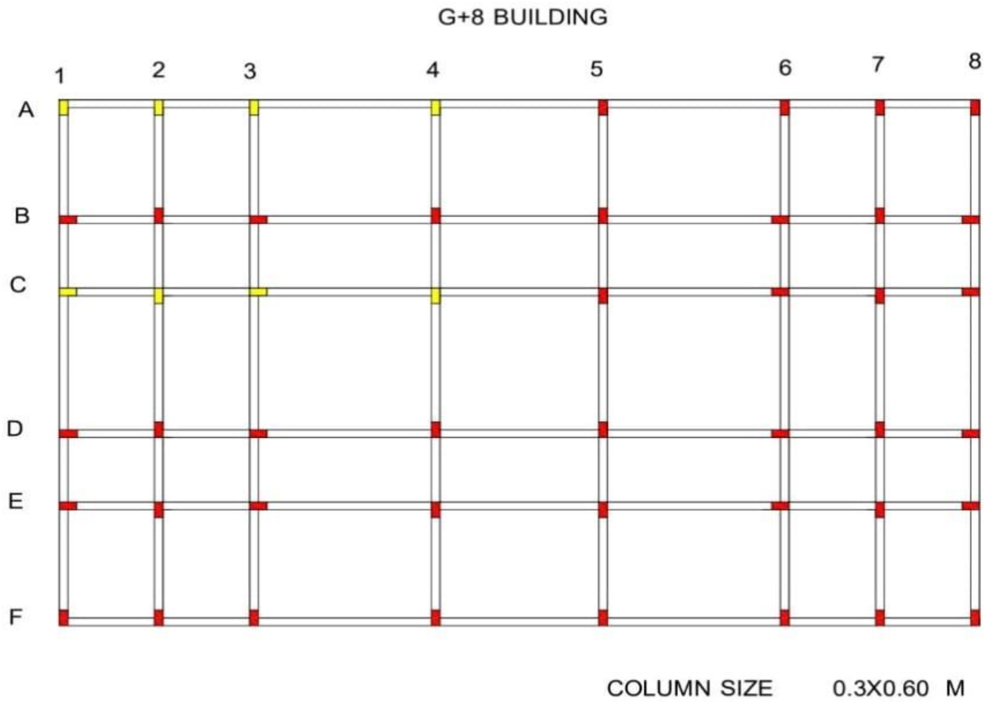


Fig 1- Plan



Critical Column

Fig 2- Beam Column layout On G+4 Building



Critical Column

Fig 3- Beam Column layout On G+8 Building

Critical Column

Fig 4-Beam Column layout On G+12 Building

Preliminary Data:

Table 2 - The Dimensions and Size of Individual Elements

PARAMETER	DIMENSIONS
Height of the Building	15m,27m,36 m
Height of the Each Storey	3 m
No. of Storeys	5,9,12
Column Size at G+4	0.3 m x 0.45 m
Column Size at G+8	0.3 m x 0.6 m
Column Size at G+12	0.3 m x 0.75 m
Beam Size Longitudinal Beam Size Transverse Beam Size	0.23 m x 0.45 m 0.23 m x 0.45 m
Slab Thickness	0.15 m
Parapet Wall Height	1 m
External Wall Thickness	0.23 m
Internal Wall Thickness	0.115 m
IS 1893 Part 1 (2016) used for Earthquake Load & IS 456 (2016) Code is Used for RCC	
Proposed Software	STAAD. Pro, ETABS

Material Properties:

Table 3 - Properties of Materials & Gravity Loads

PROPERTY OF MATERIAL	LOADS
Grade of Concrete	M25
Grade of Steel	Fe 415
Unit Weight of Concrete	25 kN/m^3
Unit Weight of Brick	19 kN/m^3
Live Load (Floor Level)	3.5 kN/m^2
Live Load (Terrace)	1.0 kN/m^2
Floor Finish Load	1.0 kN/m^2
Terrace Finish Load	1.0kN/m^2

The load calculation on G+4 building at C_2 column is presented in table 4

Table 4-Load On Critical Column C_2

ELEVATION (M)	BEAM (KN) C2 C3	BEAM (KN) C2 D2	BEAM (KN) C1 C2	BEAM (KN) C2 B2	SELF WEIGHT OF COLUMN (KN)	LOAD IN KN	CUMULATIVE LOAD (KN)
15	21.878	45.491	21.878	14.931	8.606	112.78	112.785
12	42.043	36.710	42.043	32.937	8.606	162.34	275.126
9	42.043	36.710	42.043	32.937	8.606	162.34	437.467
6	42.043	36.710	42.043	32.937	8.606	162.34	599.808
3	42.043	36.710	42.043	32.937	8.606	162.34	**762.148**
Total load on footing							**762.148**

Total Load On Column C2 = 762.1489 kN

The load calculation on G+8 building at C_2 column is presented in table 5

Table 5-Load On Critical Column C_2

ELEVATION (M)	BEAM (KN) C2 C3	BEAM (KN) C2 D2	BEAM (KN) C1 C2	BEAM (KN) C2 B2	SELF WEIGHT OF COLUMN (KN)	LOAD IN KN	CUMULATIVE LOAD (KN)
27	21.878	45.491	21.878	14.931	10.8	114.979	114.979
24	42.043	36.710	42.043	32.937	10.8	164.534	279.514
21	42.043	36.710	42.043	32.937	10.8	164.534	444.049
18	42.043	36.710	42.043	32.937	10.8	164.534	608.584
15	42.043	36.710	42.043	32.937	10.8	164.534	773.118
12	42.043	36.710	42.043	32.937	10.8	164.534	937.653
9	42.043	36.710	42.043	32.937	10.8	164.534	1102.188
6	42.043	36.710	42.043	32.937	10.8	164.534	1266.723
3	42.043	36.710	42.043	32.937	10.8	164.534	**1431.258**
Total load on footing							**1431.258**

Total Load On Column C2 = 1431.258 KN

The load calculation on G+12 building at C_2 column is presented in table 6

Table 6-Load On Critical Column C_2

ELEVATION (M)	BEAM (KN) C2 C3	BEAM (KN) C2 D2	BEAM (KN) C1 C2	BEAM (KN) C2 B2	SELF WEIGHT OF COLUMN (KN)	LOAD IN KN	CUMULATIVE LOAD (KN)
39	21.878	45.491	21.878	14.931	12.656	116.83	116.836
36	42.043	36.710	42.043	32.937	12.656	166.39	283.227
33	42.043	36.710	42.043	32.937	12.656	166.39	449.618
30	42.043	36.710	42.043	32.937	12.656	166.39	616.009
27	42.043	36.710	42.043	32.937	12.656	166.39	782.400
24	42.043	36.710	42.043	32.937	12.656	166.39	948.791
21	42.043	36.710	42.043	32.937	12.656	166.39	1115.182
18	42.043	36.710	42.043	32.937	12.656	166.39	1281.573
15	42.043	36.710	42.043	32.937	12.656	166.39	1447.964
12	42.043	36.710	42.043	32.937	12.656	166.39	1614.355
9	42.043	36.710	42.043	32.937	12.656	166.39	1780.746
6	42.043	36.710	42.043	32.937	12.656	166.39	1947.137
3	42.043	36.710	42.043	32.937	12.656	166.39	**2113.528**
Total load on footing							**2113.528**

Total Load On Column C2 = 2113.528 KN

IV. STAAD Pro Analysis:

STAAD Pro, or Structural Analysis and Designing Program, is a widely used software for structural analysis and design by Civil engineers worldwide. Developed by Research Engineers International (REL) in 1997, it supports various steel, concrete, and timber design codes. Civil engineers can design structures and share synchronized model data among the design team, ensuring on-time and budget-friendly completion of projects related to steel, concrete, timber, aluminium, and cold-formed steel. STAAD Pro automates tasks by removing tedious manual methods and allows civil engineers to analyze and design structures on virtual platforms. It is widely used by structural engineering firms, consultancies, construction companies, and government firms. Online platforms and apps offer certification for STAAD Pro, but a Civil Engineering degree is required to pursue this course. Research and reviews are recommended before enrolling in online courses.

For those pursuing a career in structural designing but lack time for traditional offline classes, online certification programs like STAAD Pro training can be beneficial. These programs offer flexibility, allowing learners to learn at their own pace and location. To fully benefit from STAAD Pro software, it is essential to choose a reputable institute, app, or online platform in India with a proven track record of producing industry-ready professionals with advanced skills and professional knowledge.

4.1. Building Modal:

Staad is powerful design software licensed by Bentley. Staad stand for structural analysis and design. Any object which is stable under a given loading can be considered as structure. So first find the outline of the structure, whereas analysis is the estimation of what are the type of loads that acts on the beam and calculation of shear force and bending moment comes under analysis stage. Design phase is designing the type of materials and its dimensions to resist the load. This we do after the analysis. To calculate SFD and BMD of a complex loading beam it takes about an hour. So when it comes into the building with several members it will take a week. Staad pro is a very powerful tool which does this job in just an hour's STAAD is a best alternative for high rise buildings. Now a days most of the high-rise buildings are designed by staad which makes a compulsion for a civil engineer to know about this software. This software can be used to carry rcc steel, bridge, truss etc according to various country codes.

G+4 Building Model:

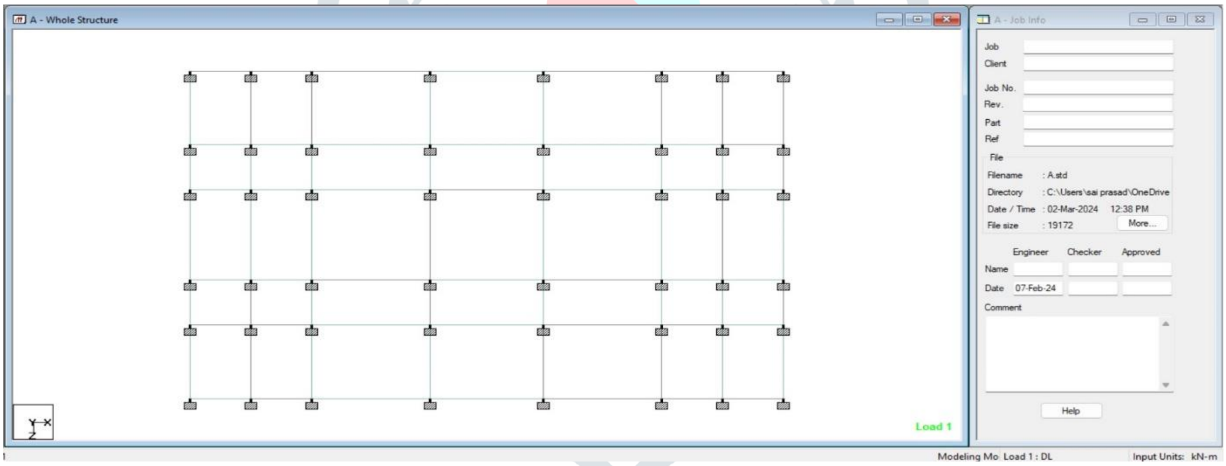


Fig.5- Plan of the G+4 Storey Building

All columns = 0.30 x 0.45 m
All beams = 0.23 x 0.45 m
All slabs = 0.150 mm

V. Response Of Seismic Analysis:

In seismically active regions like India, there is potential risk for multi- storied office buildings. As per the latest seismic zoning map brought out by the Bureau of Indian Standards (BIS), over 65% of the country is prone to moderate to high intensity earthquakes. Most of the mega cities in India are in seismically active zones and many structures in these cities are designed for gravity loads only.

In general, Earthquake motion causes both horizontal and vertical ground motions. Usually, vertical ground motion has much smaller magnitudes than that of horizontal. The vertical ground motion due to the earthquakes can be resisted by the factor of safety provided in the design of structures. The structures which are designed to carry only the gravity loads will not be able to resist the horizontal ground motion. The horizontal ground motion causes the most significant effect on the structure by shaking the foundation. The mass of building resists this motion by setting up inertia forces throughout the structure. Hence, it is necessary to check the adequacy of the structures to withstand the horizontal ground motion. A structure should be properly designed to carry these lateral forces even though it will be expensive.

5.1 Building Model:

A conventional twelve storey building is chosen for the analysis to calculate fundamental time periods, base shears and displacements of the structure considering SSI effect when similar structure rests on different soils / rock media and the results are compared with the values obtained when the structure is assumed to be fixed at the base as shown in Fig.42.

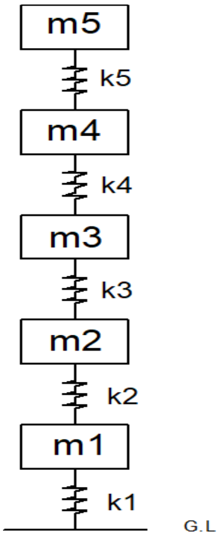


Fig.6- Building Model

5.2 Comparison Of Results Manually And Etabs software.

Table 7 - Comparison Of Results Manually And Etabs software.

Load Case /Combination		manual		software		Percentage %	
		Base Shear in KN	**Time period in sec**	**Base Shear in KN**	**Time period in sec**	**Base Shear in KN**	**Time period in sec**
Eqx	G+4	1895	0.243	2043	0.25	7.8	2.8
	G+8	3285	0.437	3497	0.47	6.4	5.43
	G+12	3709	0.63	3947	0.66	6.4	4.76

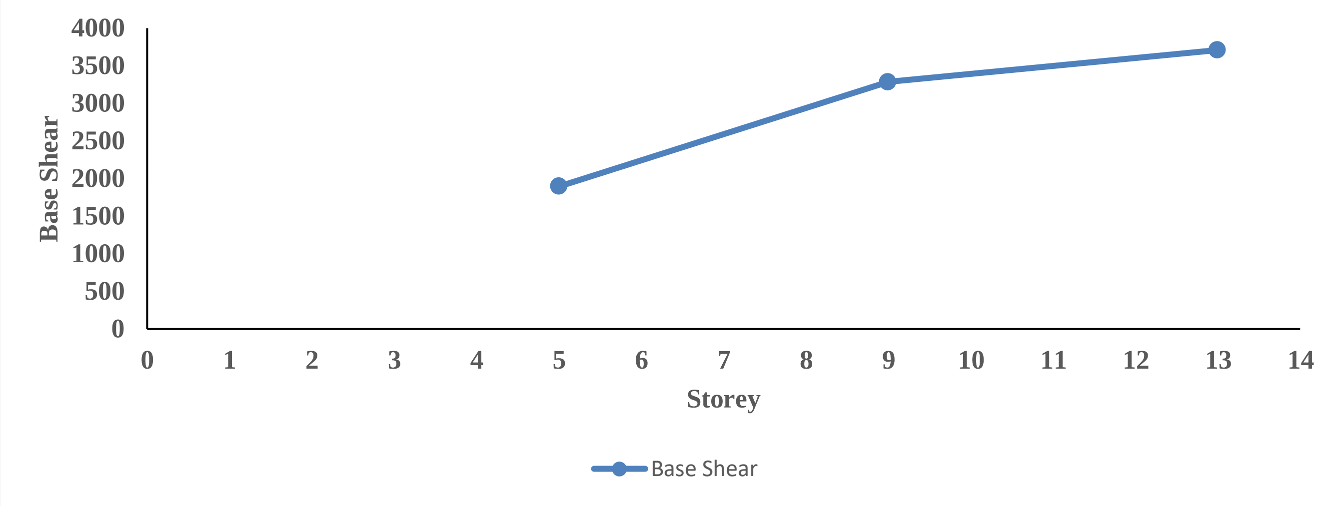


Fig.7- Graph for Base Shear and Storey

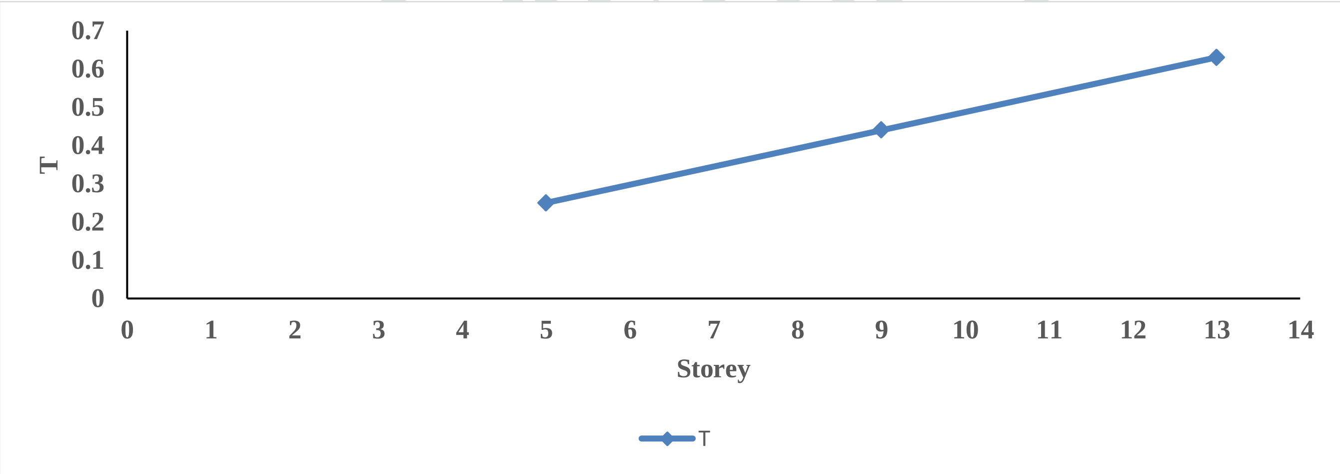


Fig.8- Graph for Time Period and Storey

VI. CONCLUSIONS:

1. a.) Total Base Shear for G+4 building is 2043 KN.
   b.) Total Base Shear for G+8 building is 3497 KN.
   c.) Total Base Shear for G+12 building is 3947 KN.
2. The percentage difference between the critical column load calculations done manually and those done with STAAD pro software is 5.03%.
3. The percentage difference between manually calculating moment in a beam and doing it using STAAD pro software is 6.81 %.
4. The percentage difference between manually calculating an area of steel in a column and doing it using STAAD pro software is 8.68%.
5. The percentage difference between manually calculating an area of steel in a beam and doing it using STAAD pro software is 10.61%.
6. The percentage difference between manually calculating an base shear and time period in a structure and doing it using Etabs software is 10%.

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