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An Autodesk Modeling of Urbanization by Vertical Multistoried Structures over Incompetent Soils

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Abstract*: *The vertical growth of multi storied buildings has become requisite considering limitations on housing area and upsurge in population growth. Cities with population density >10000 person/Km2may go for high rise buildings. Multiple cases of foundation failure have been observed around the globe due to incompetent soil, weak foundation, poor building materials, faulty workmanship, excess superimposed loading, want of geotechnical investigations, and failure analysis. The analysis and design of multistoried buildings [minimum G +3]is of demand in urban and economically sound areas. The STAAD. Pro is an efficient tool adhering to IS specifications for design of structures by limit state design to avoid erroneous computations, cumbersome and time consuming processes of manual calculation in India. The software is user interface to visualize, analyze and design structures by radical finite element technique and has dynamic analysis abilities. The present work is a 3-D RCC frame having 4 bays x5m along x-direction and 3 bays x5m in z- direction were taken where each floor has 299 beams and 40umns at different elevations in each floor subjected to dead, live , wind and seismic loads as per Indian beneath different load arrangements, considering structural safety under minimum requirements. The perception levels against vibrations and different foundations against failure (especially pile foundation) is stressed for a safe, comfortable multi storied building in Indian soil.

***Keywords*: Multistoried buildings, STAD Pro, Pile foundation, Load distribution, Wind & Seismic forces**

I. INTRODUCTION

The augmented economy, burgeoning population, fast industrialization, urbanization, Squeeze of dwelling space and advancement in construction technology, has delimited the horizontal growth in construction edges towards fag end of 20th century whereas growth of vertical cities are encouraged for potential urban sprawl. The concrete canyons in urban cluster can be associated as a part of the multistoried buildings. The edifices, like skyscrapers are the indicators of a financial fizz, and exciting building commotion and encouraged urbanization. The developing countries in China, USA, Indonesia, Canada, Europe and India, the high rise buildings (HRB's) have been encouraged and also constructed Building by Laws 2016 prescribe the maximum elevation of structure which should not exceeding>1.5 times the width of boulevard near by anterior open places as per provisions of floor area ratio (FAR).

A. Indian Urbanization

Urban population in India, was 11.4% (1901 census), 28.53% (2001 census), and was 31.16% (2011 census) and 34% as estimated in 2017 according to the World Bank. The cities having population density need high rise buildings and cities like Mumbai, Delhi, Calcutta, Pune, Navi Mumbai, Chennai and other cities whose population density is >10000 urgently need vertical expansion of township as the horizontal growth is a meager chance (Fig 1).According to CTBUH, India, 61 numbers of 150m+ buildings are completed and 62 are under construction in India whereas 300m+ HRB's are only two which are under construction. These concrete HRB's has common residential or mixed use functions http://regions .ctbuh.org/india. The skyscrapers are restricted in India due restrictions on floor space index (FSI) and incompetent soil conditions.

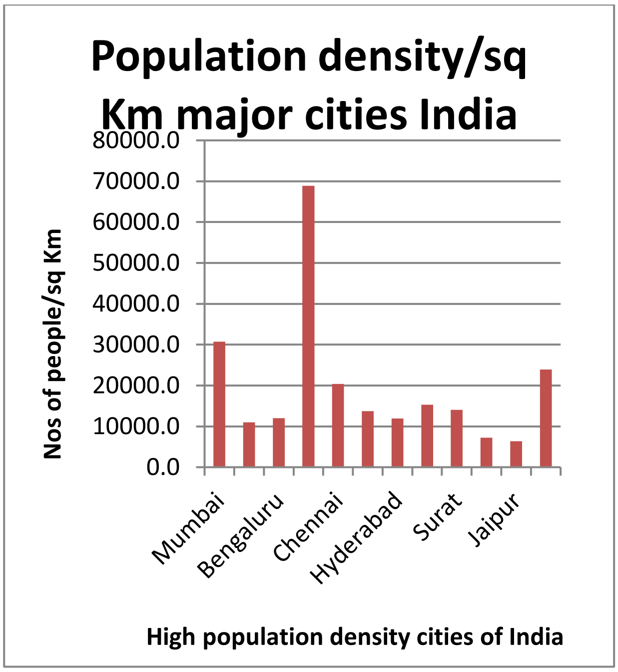

Fig 1: The major population density cosmopolitan cities (persons /Km^2) in cities (2011 census)

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B. High rise building:

A building is a high-rise one which is difficult to evacuate during fire or any hazardous situation when inaccessible to fire hose and ladders (firefighting) as per fire & building norms. The cutoff point worldwide is accepted as about seven stories and higher (≥22m). CTBUH Height Criteria of High rise buildings-2017, prescribe (HRB's) (50m+), Skyscraper (150m+), Supper tall (300m+), Mega tall (600m+) http://www.ctbuh.org /High Rise Info/Tallest Database/Criteria/tabid/446. High rise/ multistoried edifices, Sky scrapers, like the La Azteca edifice in Mexico, USA, the Burj-Khalifa mansion, (Dubai, UAE), the Incheon 151 Tower (South Korea) and Jeddah in Saudi Arabia are the buildings are super tall buildings. The numbers of sky scrapers (>300m high) in the globe has increased from 15numbers in 1995 to 116 in 2015 and likely to rise ~200 by 2020. The HRB's >150m+ are in cities like Hong Kong (355), New York (280), Shenzhen (222), and Dubai (190). The multistoried buildings such as G + 3 storied have become common all along the world, in country side, rural and urban areas. The design of the HRB's and their foundation strategies are common problem. The tall buildings are classified in various countries/ states/ cities are given below (Table 1).

Table 1: High rise buildings classes in different countries, https://www.mdpi.com/2075-5309/8/1/7/htm

#	Name of the country	Name assigned	Height in m	Reference
1	German regulation	Tall Building	≥22m	Ross, D.E., 2004[1]
2	Leicester City Council (UK)	Tall building	Predominantly high building $\geq 20m$	Al-Kodmany K., 2018[2]
3	Ireland, Cork City, 2004	Tall building	≥ 10 stories and higher	Cork City Council, UK
4	According to CTBUH:(Council on Tall Buildings and Urban Habitats)	Tall Building Sky scraper Super tall Building Mega tall Building	$\geq 50m +$ $\geq 150m +$ $\geq 300m +$ $\geq 600m +$	Al-Kodmany K., 2018[2]
5	ASHRAE:	Tall Building	≥50m+	EllisP.G.,et al.,2008[3]
6	Mumbai Municipal Corpn. (BMC)	High rise revised High rise existing	≥30m (nine floors) ≥24m (seven floors)	Kavilkar R. & Patil S., 2014[4]
7	Ministry of Urban Dev. India (http://mohua.gov.in/upload/uploadfiles/files/MBBL.pdf)	High rise building	≥15m high without stilts and ≥ 17.5m of height with stilts	Model Building Bye-Laws -2016, MOUD GOI, 2016[1(10)]

The Aires already constructed in India are in the Calcutta city (42, Kolkata, 268m, total numbers 11), Bombay city (44numbers): Imperial Tower 1, (256m), and 2 numbers in New Delhi and one is under construction and to be completed by 2020 (Supernova Spira at Noida of 300m).

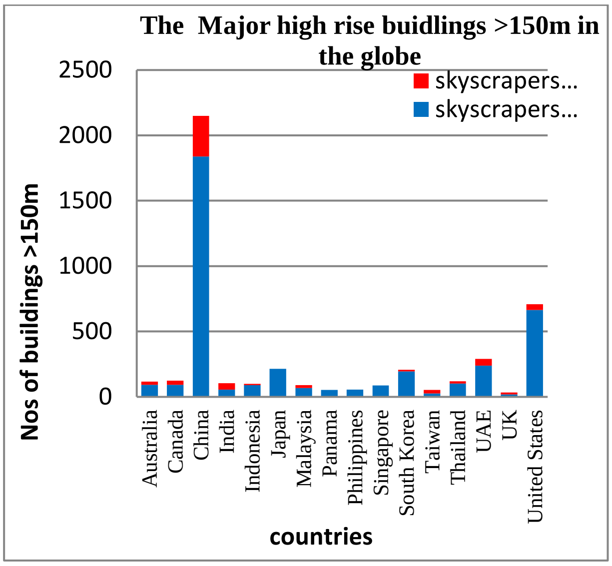

Fig 2: The major high rise buildings >150m in different countries of the globe, Source https://en.wikipedia.org/wiki/Listofcities_with_the_most_skyscrapers.

Out of 4838numbers of high rise buildings >150m has already been constructed 4196 in numbers and under construction are 642 numbers throughout the globe,. China has the highest sky scrapers existing are (1838 numbers) followed by USA (665numbers), UAE (239numbers) and Japan (214numbers). Major Aires exist in India are in thickly populated cities like Mumbai (44numbers) and Calcutta (11numbers)Poulos G. H., 2016[5] Fig -2.

C. Reasons for study:

India has 1.37 billion populations as on date according to worldpopulationreview.com. The census repositories, the good and habitable buildings are 50.3%, just livable are 44.5% and old dilapidated but people are living are 5.2%. The annual population growth 1.02% in the country and migration of people from rural to urban were 52million in 2001 census to 78millions as per 2011 census with a rise of migration by 51%. Millions of urban dwellers are either homeless or living in dilapidated buildings. India's urge for smart city mission or housing for all in las 3-4 years as per MOHUA (Min of Housing & Urban affairs, GOI). Mishra S.P. et al, 2019[6].It is only possible by constructing vertical cities rather than horizontal expansions. Under the constraints of rapid growth of vertical cities, the present study is the design of multistoried housing compartments, residential buildings and high rise tall building to the demand for dwelling houses and roofs for the homeless providing them dynamic effects of living with comforts of in occupancy in HRB's such as thermal, wind induced perceptions, motion sickness, and seismic vertigo etc.

D. *Soil of tall buildings:*

Poulos H. G., 2001[7] and 2011[8]recommended relatively stiff clays, or dense sand is ideal soil for tall buildings and uncomplimentary conditions are loose sand, soft clays, loose clays, soft compressible layers, near the surface and profiles of soil sheet undergoing consolidation, settlements and swelling compressible layers at shallow depth.

Soil properties of multistoried buildings for foundation should have high shear strength, low compressibility, low void ratio, high density/unit weight, low permeability, low atterberg limits (mostly liquid limit). The available soils in India having above properties are very stiff clay (not swelling montmorillonite causing buckling), hard rock, red soil and angular grained soils. The most disapproving soil for multistoried building foundation is Black cotton soil, sandy soil, and alluvium. The areas located for HRB's in India generally are not suitable, so either deep (piling), mat/raft foundation, piles with raft or mat foundations are provided to withstand the high rise building loads. The soilsare clays and silts (purely cohesive) or sand and gravels (purely cohesion less) orsandy clay or silty sand (partly cohesive and partly cohesion less) are the incompetent type soil.

II. REVIEW OF LITERATURE

The leaning tower of Pisa is tall built building exhibiting part foundation failure over an incompetent, soil of geotechnical inadequacy, unevenly distributed load bearing capacity and poor foundation design Buchanan A et al.,, 2011[9], Allen P T N et al, 2017[10]. The foundation failures are due to metastable soils and swelling clays in British Columbia and adjoining provinces. Marshall R.R. 1999[11]. The Pile foundations are preferred where the soils are as mound, peat, silt deposits, sediments, cohesive soils and are in flow plastic state, and when the building is subjected to heavy (dead and live), concentrated loads as in tall buildings, dams, bridges and overhead water tanks Kosiakov Egor 2018[12].The IBC (International Building Code-2000) and NFPA (the Building Construction and Safety Code, 2002), delineate high-rise buildings are buildings of 23m or higher from the nethermost level to the highest occupied top story. The building codes of India, a tall / HRB is one which is 15 meters or more vertically Kavilkar et al 2014[4]. Sancio R. B. et al., 2004[13]reported about loss of 2627 lives and 5,078 tall buildings (27% of total) stock) were failed or damaged due to vertical displacement, tilt, and lateral translation over the ground during 2004 earth quake in Turkey. The weight of a building escalate non-linearly with growing elevation, as a result the foundation has to bear the upsurge vertical load Poulos H. G. et al., 2012[14] .Sze J. W. C., 2015[15]reported that bored piles or steel H piles of large diameter are best suited for foundation high rise buildings in Hong Jong. Li Lianget al, 2016[16], reported about a 13storied building collapse in Shanghai due to excavation of a 4.6m trench near the basement garage on 27th June, 2009. Buttling S, et al., 2018[17], proposed to design the foundation and piles of a high rise building by using a combination of structural model and geotech model bearing in mind relative stiffness of soil and structural movement along each pile and the construction boom of tall building. Costela D. et al, 2009[18]reported that pressure coefficients pertaining to Wind "Cp" impacts facade detailing, building geometry, degree of exposure/sheltering, speed and direction of wind.

Issues related to HRB Foundations:

The burgeoning population growth and migration to the urban megacities need vertical extension of buildings so that the demand for roof over head is possible. HRB's need a sound and solid foundation to avoid settlement, failure and tilts. The major causes for building collapse are incompetent BC soil (expansive with least bearing capacity and strange swelling and shrinkage characteristics), loose soil, weak foundation, poor building materials, faulty workmanship, excess superimposed loading, want of failure analysis, failed to transfer loads, old existing structures like water courses, drains, trenches below foundation, and filled up water bodies, design error, excess lateral loads due to meteorological extremes like floods, drag down and heaves, lateral loads (flood, heavy rain, strong wind and earth quake tremors, land slide) and unstable slope, improper geo-tech investigation, unsymmetrical loading, high ground water fluctuation, incompetent soil and many others, Srivastav A. et al., 2012[19], Nagarajan D et al., 2014[20], Aruna et al., 2017[21], Nagarjuna K. et al., 2018[22. The overall differential settlement of the multi storied buildings urges structural design of foundation. The issues related to foundation and design are groupings of vertical, lateral/ moment loading, the harmonic movement of foundation due to wind and tremor forces. The foundation of HRB's are associated with three types of foundation depending upon the soil and structural loading like Pile foundation, Mat/raft foundation or the combinations of the two above.

III. METHODOLOGY

The present study is to analyze load calculation manually and design according to IS code (Limit State Design)for multistoried building [G +3 (3-D frame)] using STAAD Pro. . The simple analysis of 2-D frames and their accuracy were physically tested with software results. The analysis and design of a set of G + 3 storied building [2-D Frame] were done under the potential load groupings.RCC framed structures (3-D)with the orthogonal coordinates of 4 bays of 5m.along x-direction, G 3 floors along y-axis of 3 baysof5m along z-direction were considered. There were299 beams and 40 columns 40 in each floor. The ground floor is 3.5mhigh. The succeeding floors are 3.3m high. The dead, live, lateral and vibration loads or combinations are analyzed by STAAD Pro software. The variable lateral wind load values were created according to prevailing intensities of wind at various elevations (IS 875 -1987) and vibratory seismic load as per IS 1893-2000. The materials of the beams and columns were followed as per IS code under practice. The post-processing approach of STAD Pro (towards end of the design and detailing), BM/ SF values are created and reflected in diagrams. Checking of deflection of members was conducted under the assigned loading arrangements. The structural design is reliant on the adherence of minimum necessities provided in the IS Codes to have the structural safety of the Structure. The elements were designed considering Limit State Technique.

Why STAAD Pro. Software? HRB's needs rigorous, repetitive and complex calculations if designed by conventional manual methods. But STAAD GUI (graphic user interface) can analyze and design all types and individual members of the structure and give graphical interpretation as it is versatile, easy, fast, accurate, a true user interface and finally confirm to IS codes.

A 3-D frame structure (SPACE structure), with loads application along any plane, is common. Soft ware's available for design/modeling of multistoried buildings are STAD foundation, E Tab, 3DS Max, Civil 3D, AutoCAD with a civil engineering, AutoCAD (from Auto desk), CATIA (model buildings), Chief Architect, Revit. BIM, Rhino 6 and Sketch up. STAAD Pro, a multi- faceted design software that confirms IS codes and provides a profligate, effective, informal to use and accurate firm platform for analysis, design various structures (CC, RCC, Steel, timber, and aluminum) like dams, bridges, high rise buildings, docks and harbors etc. using information such as structural loads, geometry, support conditions, stability, dynamic response, nonlinearity and materials properties. Design, for the durability, erection and usage must be accounted as complete amenability with well-defined standards for ingredients, construction methods, workmanship, running maintenance and finally the service usage Saha et al 2016[23], Seva et al., 2017[24]. Setback around HRB's, India :As per NBC model by laws-2016 (MBBL-2016)[1(10),the open space is to be left as setbacks for the multistoried buildings depending upon the heights are:21m to 30m (10m), 30m to 35 (11m), 35 to 40 (12m), 40-45 (13m), 45m-50m (14m) and >50mis always ≥16m. The setback areas are to be provided with hard surface around all sides of the building and should be capable of bearing load of >45 MT/m2 , to take the loads of firefighting vehicles. The total elevation of the building shall be< 1.5 times the road width and the adjoining open space around the multi storied building. The clearance from the power line medium voltage/ service lines (1.2m to 2.50m), 11KVolts line (1.2 to 3.7m), Voltage line >11000V (2.2m to 3.70m), extra high voltage line >33KV 2.0m. adding 0.3 m. for every 33KV and part.(Model Building Bye-Law, 2016, TCPO)

Human perception levels in HRB's: The uniqueness by perception, cognizance or realization between physical and mental status is the mind-body problem. These Human problems do respond to motion of the HRB's due to wind intensity laterally encountering a building. Human body is bio dynamic and responsive to body vibration at low frequencies even within the range of 0.85m/sec2 and within frequency ranges 0.15 to 1.0Hz.The resonant freq. of RCC HRB's are within range 2.2 to 2.9Hz. It is highly essential the soil frequency must be greater than resonant frequencies. As per SEVENSK standard (SS-ISO 10137-2008): This Swedish standard prescribes the perception levels of human response of the HRB dwellers Farouk Mohamed I, 2016[25], Halle brand Erik et al., 2016[26].There is noticeable impact of displacements, speeding up, and resulting forces that restricts the comfort of residents in HRB's. There are four the effects on heel drop and walking activities such as Imperceptible, Slightly perceptible, distinctly perceptible and strongly perceptible depending upon thresholds damping ratios are as follows, Table 2:

Table 2: The acceleration rate and frequency of vibrations and human impact to access perception level on human due to lateral and vibration impact on multistoried buildings.

Acceleration (m/Sec^2)	Hor. wind vibration (freq) (1-year return period in Hz))		Human Impact	Reference
	Office	Residential		
<0.05	0.14	0.21	Imperceptible	
0.1	0.12	0.18	Slightly perceptible, limp objects swing slightly	Hallebrand Erik et al., 2016[26]
0.25	0.78	0.13	distinctly perceptible, affect small table work , produce motion sickness	Lee1 M. J et al., 2009[27]
0.4	0.06	0.09	Desk operation hard/ impossible light work still possible	Faroki M. I., 2016[22]
0.5	0.075	0.085	Distinctly perceptible, tough to tread lose balance on standing	Nhleko S. P et al, 2009[28]
0.6	0.05	0.075	The dwellers cannot stand the vibration &cannot maintain natural walking	
0.7	0.05	0.065	Motion not possible	
>0.85	0.05	0.065	Objects start falling causing trauma	

Loads structure of HRB's:

The foundation of HRB's is designed to bear and transmit all the loads, so that the structure should be safe and under the ultimate bearing capacity and against differential settlements. The different loads are dead load (self-weight), Live (Imposed) Loads), wind, and Seismic load, snow load (cold areas), and other loads. The lateral cyclic wind forces and intermittent tremors of earthquake and their resulting moments thereof are needed to be borne by foundation. The dynamic forces and moments developed by dynamic and kinematic impact due to lateral tremor of earthquake and wind forces must be resisted by the foundation without causing tilting and settling Poulos H. G. 2016[5]. The major mechanism of failure of foundations are due to ad freezing , swelling clay, fill settlement, slope stability, frost heaving and minor causes are high fluctuation in GWT and sulphate attack Marshal R. R., 1999[11].

The designers consider the combinations of loadsare 1.5(DL+LL), 1.2(DL+LL+EQ along X axis), 1.2(DL+LL+EQ along Z -axis), 1.5(DL+EQ along X-axis), , 1.5(DL+EQ along Z-axis), 1.5(DL + WL along X-axis), 1.5(DL + WL along Z axis), 0.9DL+1.5EQ along X-axis, 0.9DL+1.5EQ along Z-axis, 0.8DL +0.9 SL, (1.5 (DL + 1.2 LL+1.2 SL) and (1.2 DL + 1.2 LL +1.2 WL) where DL is dead load, LL is Live load, WL is Wind load EQX/ EQZ =Earthquake load along X-axis and Z-axis, SL = Snow load , Nagaraju V. et al 2018[22].

Dead Loads:

DL is the self-weight of the structure of the long-term components like columns, walls, beams, floor roof slabs and all permanent constructions can be generated by providing command to STAAD pro engine. Dead load remains constant during the whole lifespan of the construction. The dead load is premeditated according to the sizes of different members and the unit weights of the CC and RCC supporters and other materials used in the structure. The coarse aggregate like black HGchips, and fine aggregate, fine aggregates like river sand/ crushed stones, can be considered respectively as 24 KN/m2or 25 KN/m2...Slab's dead load is created by STAAD.Pro after stipulating the floor thicknesses.

The loads on the floors/ m2 and the IS code provisions to be followed. Estimation of the load / m2 was done as the weight of building components. The results of different dead loads were found are 14.48KN/ m2 [terrace area], 13.5 KN/ m2 [of a typical floor area], 14.37 KN/ m2 [of 1st floor], Fig -3.

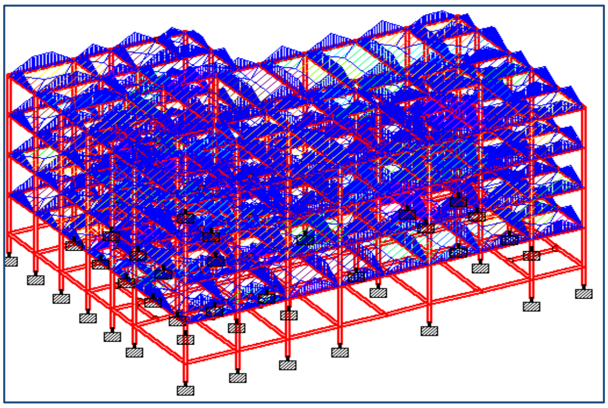

Fig 3: The structure under DL from slab

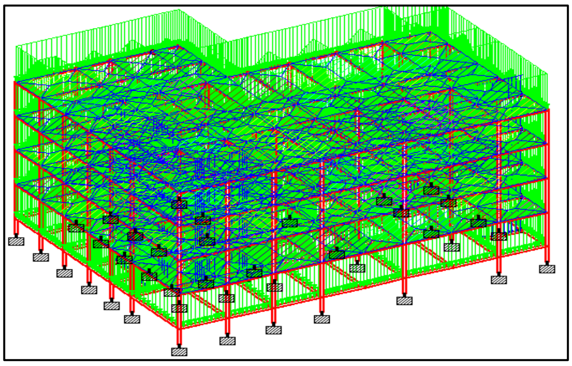

Fig 4: The structure under live load

Live loads:

The transient load that has quasi-permanent variability subjected to a structure is called imposed load. Imposed load is due to projected use or occupancy distributed including temporary partitions or temporary point loads excluding lateral loads like Aeolian, flood, seismic, snow, and thermal expansions and contractions. The imposed loads can bring, creep and shrink full/partial settlement to the structure. The accepted values of some important live loads of materials such as brick masonry as 18.8 KN/m3, stone masonry as 20.4-26.5 kN/m3 and timbers used are5-8 kN/m3.The minimum values of UDL and concentrated imposed loads for occupancy are in Table-3 and Fig-4.

Table 3: The occupancy, the minimum design imposed loads both live and concentrated loads

Occupancy	Uniformly distributed	Concentrated	Occupant load covered area (NBC), India	Source
	kN/m^2	kN	kN /100 Km^2	
Living, Bed, Wash room, toilet, Kitchen, dwelling	2	1.8	Residential: 8.00, aged, orphanages or mental hospitals:13.3 person /100Km^2	https:/theconstructor.org/structural-engg/types-of-loads-on-structure/ 1698/
Hotels, hostels, hospitals, Business buildings	2.5 - 4.0	2.7 - 4.5	Business/small trades units:10.0	IS 875 (Part-II)-1987
Mercantile,Industrial: Bank, Industries ,hospitals (OT, X-rays), class room, reading room, prayer hall, health units,	3.0 - 4.5	2.7 - 4.5	Institutional : 6.6 Mercantile: basement/street floor: 33.3 Subsequent floors: 16.6	https://theconstructor.org/structural-engg/live-loads-buildings-floors-structures/6993
Assembly: Mercantile, stores, buildings, areas, educational complexes, Libraries	4.0 - 5.0	3.6 - 4.5	Assembly: temporary sitting: 166.6 Dance/ dining no sitting floor:66.6	Model Building By-Laws-2016 (NBC)
Educational: Library store room	6m^2 till 2.2m	4.5	Educational: 25.0	
Hazardous Industrial: Boiler rooms &plant rooms, Assembly & storage buildings	7.5kN /m^2	5.0	Hazardous Industries:10.0	

Wind Load:

Surface air in motion with respect to the surface of the mother earth is called wind and is caused by rotation of the globe, meteorological events and earthly radiation. The wind usually blow parallel to the ground and vary with height and considered always horizontal at different levels. The wind speeds are evaluated by anemometers/anemographs set at the weather observatories at 10 to 30 m heights above surface. The foundation of the building should have sufficient bearing strength as the Aeolian force depends on wind velocity, topography, elevation, internal pressure of the building according to the IS 875(Part 3):1987. The risk level, roughness of the landscape, topography, the volume, size and the height of the structure are used to find the design of wind speed (V): $V = K_1 * K_2 * K_3 * V_b$ (1)

Where V_b = wind velocity designed (m/s) at height z, K_I = Risk Coeff. (Coefficient), K_2 =landscape, height and size factor of the structure and K_s = topography factor. The risk Coeff. (K_I) signifies simple wind speeds for landscape Cat. 2 as appropriate at height 10 m above GL (50 years mean return period as per IS code).The terrain factor (K_2)is selected for design at different elevations which shall vary depending upon normal direction of wind of the site given by meteorological dept. The K_s, the topography factor varies as per the geographic features like hills, cliffs, valleys and escarpments, ridges etc. Dalgliesh W. A., et al., 2019[29]

Table -4 and Fig-5, Fig 6 & Fig 7

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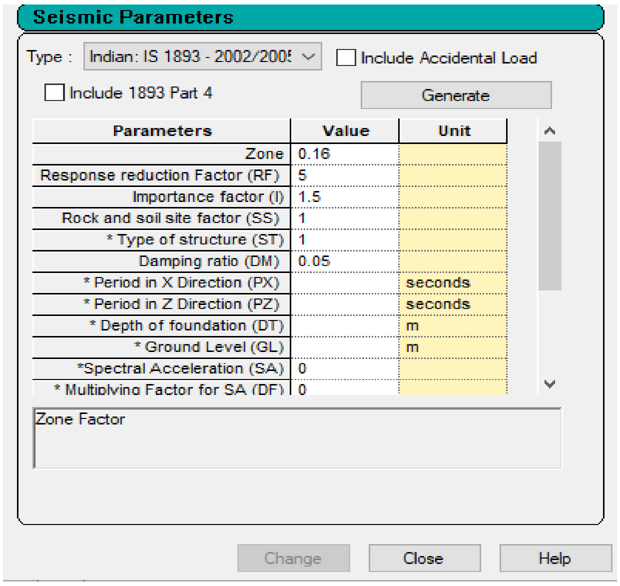

Fig 5: The lateral wind load intensities

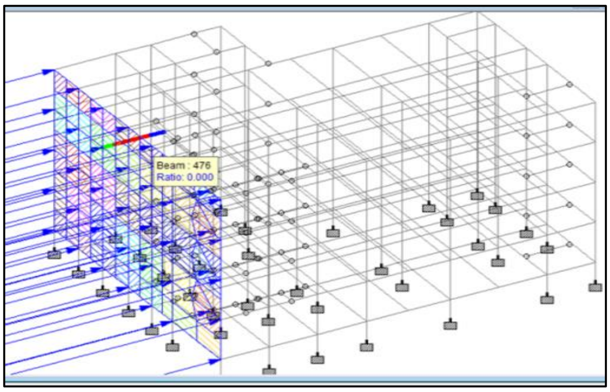

Fig 6: STAAD Pro seismic parameters

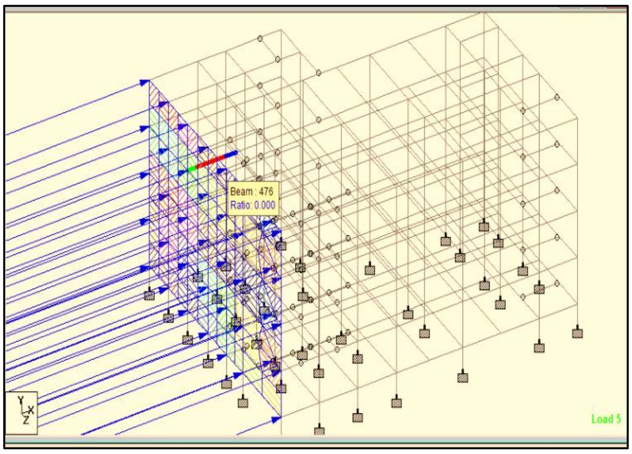

Fig 7: STAAD Pro seismic load structure with combined load distribution levels

Table 4: The wind pressure at various heights according to design for the proposed G3+ building (created by STAAD as per IS 875- Part (3), 1987.

Height [ht] in (m)	Wind speed designed [V_z] in m/s	Design pressure of wind [P_z] KN/ m^2
Up to 10	57.2	1962.62
10. -15	61.1	2239.9
15-20	63.7	2434.61
20-30	66.95	2689.38

The WL on a building is calculated either building as a whole, or part (foundation, roofs and walls) along with individual cladding units (doors, fixtures and glazing).The designed uniform wind pressure (Pz) = 0.6 ⟦V_z⟧^2, where Pz(N/m2) at elevation Z and Vz(m/sec) till height upto 30 m as above 30 m the Pw increases. The Wind Pressure Coefficients (Cp) that effect building geometry, portico listing, placing, the exposure, shielding, wind speed and wind direction. The varying pressure coefficients "F" (ratio of pressure forces to inertial forces) are given for a building is given as:

$$F = (C_{pe} - C_{pi})\, A * P_d^{\,2} \qquad (2)$$

Where Cpe = peripheral pressure coeff.,Cpi= interior pressure coeff., A = surface area of construction and Pd = designed airstream pressure considering the average values of pressure coeff. And shape of the building. The total load is to be calculated to each critical path from all quadrants (IS-875, Part 3 -1987)

Seismic Load:

The seismic design constraints are provided altered in different EQ zones (zone I to zone V), the zone factors are provided in IS: 1893 -2002 (Part I and part-2) in table-02 and table -6 in association with IS-13290 (1993) for resisting moments and the factor for reduction (R) in table -7 of IS 1893 -2002 (part I). The lateral force design is done for the building partly/whole. Later the lateral force is distributed floor wise based upon its diaphragm action.

The design seismic base shears (V_b) *It is the* total design lateral force along any X, Y and Z direction is calculated as per different tables in IS:

1893 – 2002:

$$V_b = A_h * W \qquad (3)$$

Where, A_h = accelerated horizontal spectrum

$\left(A_h = {}^{Z * I * S_a}\!/_{2 * R * g} \right)$, Where, Z = zone factor, (Table-2), I = occupancy factor (use factor) (Table 6), R=factor for response reduction which should always be >1, (Table 7) and Sa/g = Coefficient of av. response acceleration according to IS: 1893(Part 1)-2002 and W = EQ weight of all floors (IS: 875- 1987 (part III), 2002). The design for wind load calculations are not needed for a multistoried building when earthquake loads exceed the wind loads according to the same code. The tentative major vibration time of (natural), (T_a, in sec), of a building eliminating the basement devoid of bricks in the panels is empirical estimated as:

$$T_a = 0.075 h_{0.75} \text{ For buildings (RC framed)} \qquad 4(a)$$

$$T_a = 0.085 h_{0.75} \text{ For buildings (steel framed)} \qquad 4(b)$$

Where, h = height (ht.) of building in m. The accepted value of T_a (seconds) for all other buildings, is given by:

$$T_a(m) = 0.9\ {}^{h}\!/_{\sqrt{d}} \qquad (5)$$

Where, h= ht. of the building and d= dimension of the building base from plinth level, along lateral force direction. The co-efficient of the EQ zone is given "1893(Part 1)-2002 specs" and the LOAD can be obtained through the command given to DEFINE 1893. The life period of the structure (T), is calculated by the Sa/g Program and the seismic base shear (Vb).

The weight W is found from the weight (wt.) data provided by DEFINE 1893 LOAD command. The overall seismic load (lateral)is then disseminated by the database at various levels. The elevation dissemination of EQ forces at different levels are given in Tab- 5& Fig-7.

Table 5: Elevation distribution of seismic forces to different floor levels of the proposed multistoried building

Floor level	Wi (KN)	Hi(m)	Hi^2	Wi hi^2 *10^3	(Wihi^2) / ∑(Wi$_{hi}$2)	Along x direction		Along Y direction	
						Qix	Story shear	Qiy	Story shear
22	4129	73.3	5372.89	22184662.81	.123	426.309		372.15	
21	4252	70	4900	20834800	.115	398.58	824	347.95	372.1
20	4252	66.7	4448.89	18916680.28	.105	363.9	1188	317.69	720.1
19	4252	63.4	4019.56	17091169.12	.0949	328.91	1517	272.3	1037
18	4252	60.1	3612.01	15358266.52	.085	294.60	1812	257.18	1310
17	4252	56.8	3226.24	13717972.48	.076	263.41	2075	229.95	1567
16	4252	53.5	2862.25	12170287	.067	232.2	2307	202.7	1797
15	4252	50.2	2520.04	10717972.18	.059	204.48	2512	178.5	1999
14	4252	46.9	2199.61	9352741.72	.0519	179.88	2692	157.03	2178
13	4252	43.6	1900.26	8082881.92	.044	152.50	2844	133.12	2335
12	4252	40.3	1624.09	6905630.68	.0383	132.74	2977	115.88	2468
11	4252	37	1369	5820988	.032	110.90	3110	96.82	2584
10	4252	33.7	1135.69	4828953.88	.0268	92.80	3221	81.08	2665
9	4252	30.4	924.16	3929528.32	.021	72.78	3314	63.53	2729
8	4252	27.1	734.41	3122711.32	.017	58.92	3386	51.43	2780
7	4252	23.8	566.41	2408502.88	.013	45.05	3445	39.33	2831
6	4252	20.5	420.25	1786903	.0099	34.31	3490	29.95	2871
5	4252	17.2	295.84	1257911.68	.0069	23.91	3525	20.87	2901
4	4252	13.9	193.21	821528.92	.0045	15.59	3549	13.61	2922
3	4252	10.6	112.36	477754.72	.0026	9.01	3564	7.866	2935
2	4252	7.3	53.29	226589.08	.00125	4.33	3573	3.782	2943
1	4505	4	16	72080	.0004	1.38	3577	1.210	2947
Total							3579		2948

Dissemination of the Design Force

The $V_{B,}$ (planned base shear) is disseminated along different floors of the structure as per the expression: $Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$ (6)

Where Q_i = lateral force at the floori (designed), W_i = EQ wt. of ith floor, h_i = floors from the base of the ith floor and, n = the number of floors. The total V_B along any horizontal plane is disseminated to the vertical components of lateral force resisting system, assuming the floors as infinitely rigid along X- plane. If not infinitely rigid then the lateral shear along every floor is disseminated among vertical components opposing the lateral forces.

Dynamic Analysis:

Dynamic analysis is required for the design EQ force. The EQ forces are disseminated at various building elevations and the resisting elements to various lateral loads used for the Regular buildings (of ht. > 40m) in EQ zone IV and EQ zone V. Tall buildings> 90m height can be erected in seismic Zones II and III. For all buildings not with plan irregularities (unplanned framed structures of height> 12m in EQ Zones IV and EQ zone V and those > 40m in height in Zones II and III must undergo dynamic analysis. For irregular buildings, <40 m high in Zones II and III, the dynamic analysis is not mandatory, but recommended by two methods (a) Time History Method or (b) Response Spectrum Method.

STAAD.Pro Operations:

, or fixed. A pinned support considers all forces but shall not resist any moments. Fixed supports have limitations in all moving directions. The spring constant for translational and rotational forces are to be provided by the user of STAAD programmer. A translational and rotational spring constants are also to be commanded in **Fig 9.**

Fig 9: Multistoried Buildings in flexure, shear and both

Load Configuration:

Different loads of Structures are classified as member, joint, temperature and fixed end member loads. STAAD.Pro software generates the structural self-weight (dead load), and transform to uniformly distributed loads (UDL)during analysis dividing the self-weight along the desired direction. Joint loads (both forces and moments) are applied to free joints (along X, Y and Z axis) of a structure. The Positive (+ve) forces act in the +ve directions of the coordinate and vice versa. Different Loads acting along any joint are always additive. The 3-types of member loads are UDL, conc (concentrated) loads, and linearly variable loads (even trapezoidal**)**. UDL act full length or part length of a member. conc. loads act at a point. The linearly variable loads act over the full length.. Linear Trapezoidal varying loads are later converted to UDL and act over the full or part length.

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A floor (X-Z plane) may be subjected to UDL whose calculation is complex and time consuming as individual load. Hence floor load is provided as command. The unit load/ unit square area is always provided in one-way direction, or loading in 2-way direction..

Fixed end loads are given by the coordinate system (member wise) and are in the opposite directions to the actual load. Axial; shear y; shear z; torsion; moment y, and moment z. are the six forces provided in the each fixed end.

Design Parameters:

The HRB's are designed as per IS 13920-2016 and IS: 456-2000. Default parameter values (changed when needed) have been selected such that they are frequently used for conventional design requirements by declaring length (mm) and force (Newton) before concrete design. The column members in a structure may be square circular or rectangular whereas the beams are can have square or rectangular or of T in shape.

Beam and columns Design:

Beams are designed for flexure, shear and torsion to know the effect of the axial forces. All Beams are loaded as per IS: 13920-2016(restrictions: the member> 200mm and preferably width/ depth ratio >0.3).However provisions shall be made as per beam design length exceeding 4mis unsupported, the minimum column size > 300 mm..

Columns are intended for pivotal or shear powers and biaxial minutes which might be furnished with longitudinal and transverse fortification according to IS 456:2000 and IS 13920-2016 when structured by STAAD. The proportion of the most brief CS territory to the ⊥lr measurement will ideally be > 0. 5. The support is provided over a given length L_0 from every joint face, to the mid-range, on each side of any area to avoid occurrence of flexural yielding. The length (L) should be >large horizontal member in case of yielding (keeping 1/6th of clear range of the part, and size should be 450 mm. The dispersing of loops are utilized as unique limiting support which will not surpass ¼th of least part measurement and < 75 mm or in excess of 100 mm.

Design for Flexure:

Design is done in HRB's adhering to IS 456-2000. The M20 concrete and Fe 415 steel are used as per 13920-2016. The most extreme steel proportion $\rho_{max} < 0.025$ where on any face, at any segment the base pressure steel proportion is given by

$$\rho_{min} = (0.24) * \sqrt{f_{ck}}/f_y \tag{7}$$

The +ve steel proportion at any joint face should be equal to the negative steel at that face. The steel to be provided at the top and base, at any segment should be equal to ¼ th of the most extreme -ve steel.

Design for Shear forces and torsion:

The shear force should oppose by vertical bands and the torsion calculations should follow IS 13920:1993.

Failure constraints:

The 2 major failures are failure due to overstress and failure by considering stability. The failure depends upon soil – structure orientation has to be considered depending upon modulus of elasticity lower sub grade soil when earthquake intensity is high, Pavan Kumar M et al., 2015[30]. The procedures adopted while designing are ULS (Ultimate Limit Stress) to risk foundation failure, SLS (serviceability Limit stress) to avoid risky differential settlement, and for safety and stability the combinations of ULS and SLS is adopted. The allowable stresses being calculated using stability criteria, Members are well-adjusted to resist the design loads which should not be > allowable stresses. Selection of the most economic section is done basing upon criterion of least weight.. The code checking (IS: 800, 1984)) part of the program check the stability and strength requirements and reporting of the critical loading condition is done as per IS-800, 1984. The detailing necessitates like provision of stiffeners, and local effects checks such as the buckling of flange and crippling of webs) are checked,. The permissible stresses should be chosen as per IS: 800- (1984) and IS: 800-2007 to obtain a stable structure from geotechnical aspect. In multiple analyses the STAAD allows change of member properties during a run which indicate versatility of the engine making some commands active or inactive Fig -9.

Stability Requirements:

Slenderness ratios, the column length to the least radius of gyration of its CS, (λ) are calculated and checked for all members by optimized appropriate values. IS: 800 (2007)gives the maximum λ-value of the member which need to be checked against a value of 180 as maximum and tension members has value of 400 as maximum.

Deflection Check:

The deflection is checked under the code check and selection processes of members as per IS code provisions The plan and the elevation of the G+3 proposed building is shown in fig. 10 and Fig. 11.

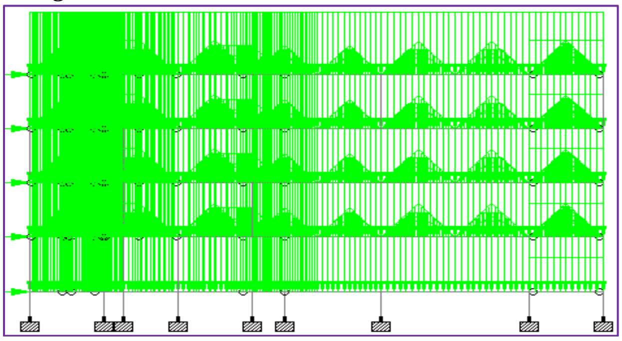

Fig 10: Under combination with wind load

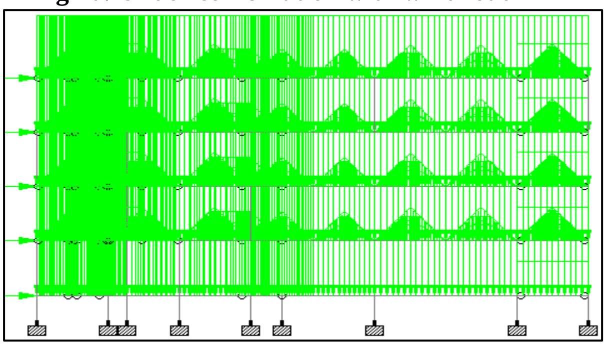

Fig 11: Under combination with seismic load

IV. ANALYSIS OF RESULTS

The results obtained after analysis and design of the G + 3 RCC framed building made up of M-30 RCC and Fe 415 steel using STAAD.Pro are as follows:

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Considerations: Length:
4bays x 5m =20m, Width = 3bays x 5m =15m, Height 4m + (3stories x 3.3m) = 13.3m., live load (floor @ 2kN/m^2 and roof load @ 0.75kN/m^2, All columns = 0.50m x 0.50 m (after ground floor) Columns at the ground floor: 0.8m x 0.8 m, All beams = 0.3 m x 0.5 m, All slabs = 0.20 m thickness, Terrace = 0.2 m thickness (average). Parapet = 0.10 m thick (RCC). Fig 3 (a) shows the plan and Fig 3(b) give the elevation of the designed G+3 storied building.

Load combination:
The structure is analyzed for load blends considering about all the past burdens in proper proportion. In the primary case a mix of self-weight, dead load, live burden and wind force is considered. The combination of wind load and seismic load is shown in Fig 10(a) and Fig 10(b). The structure was proposed to be constructed by cement as per IS 12269-2013 code. The parameters, for example, clear cover, (Fy, Fc, etc) were determined as mentioned.

The member property:
Member property is generated by using STAAD. **Fig -4,** with section of beams as (0.5mx 0.3 m) and the columns 0.8 m x 0.8 m at the ground floor and 0.5m x 0.5 m at over top. The base supports of the structure were assigned as fixed. The supports were generated using the STAAD support generator **Fig 12.**

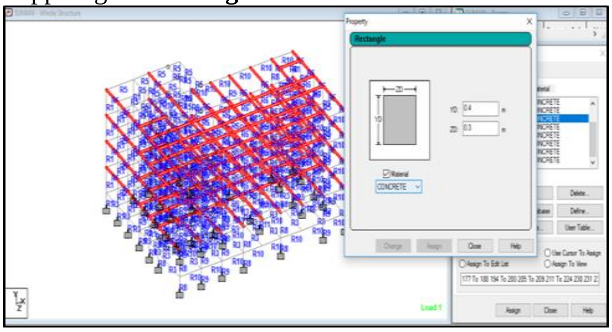

Fig 12: The generation of member property designed

Pile design and arrangement:
For designing piles the different dimensional values taken are: Columns: Shap: (rectangular), length along X (Plane):(0.4 m), width–along Z plane (PW) : 0.3 m,with Pedestals and Geometrical Data:, Pile Caps: length (PCL) = 2.500 m; width (PCW) = 1.0 m; Initial Thickness PTI = 0.300 m,

Pile Geometrical Data:
Spacing (Ps) = 1.500m; Edge distance = 0.500m and diameter (dp) = 0.500 m, and the Pile Capacities: Axial Capacity (PP)= 550.0 kN; (For pile cap parallel to X-direction, Mx=0,Fz=0. and for pile cap parallel to Z, Mz = 0,Fx=0).Pile Lateral Capacity: PL = 100.0kN; Uplift Capacity PU = 300.0 kN, Material Properties; Concrete: f'c = 25000 kN/m2;steel (fy) = 550000 kN/m2;Cover: Clear Bottom Cover (CCB) = 0.05m;Clear Side Cover (CCS) = 0.05m; Pile in Pile Cap PCP = 0.075 m., Pile Cap:height (H) = 2.50m, Pile Cap size (in investigated ⊥lr direction) B = 1.0m

Pile cap design calculation:
Pile Reactions: Total number (piles): N = 2, Reaction Pile Arrangement No. X (m) Y (m) Axial (kN) Lateral (kN) Uplift (kN) are 1 -0.750, 0 -389.499, 10.869, 0.000, 2, 0.750, 0.000 -370.591, 10.869, 0.00 respectively. Pile Cap Thickness Check: Calculated Thickness (t) = 0.619 m, Check for Moment: Critical Load Case: Moment inX1-X1(kNm) ;Moment alongX2-X2 (kNm) 1 -214.221, 0.000 -203.821 respectively. Effective Depth = 0.486m Principal moment (Mu) = -214.221 kNm, (K ≤ 0.156... hence, safe). Selection of Reinforcement: Check for One Way Shear; Shear Force in X1-X1(kNm) ; Moment along X2-X2 (kNm) are -244.605 0.000, 0.000 -232.731 and Total -244.605 -232.731 and Design One-Way Shear action lengthwise , SOL = 244.6kN ; V= 503.3 kN/m2,VC1= 380.395 kN/m2 but it is observed Vc1> V so safe. (Fig 13, Fig 14 and Fig 15.

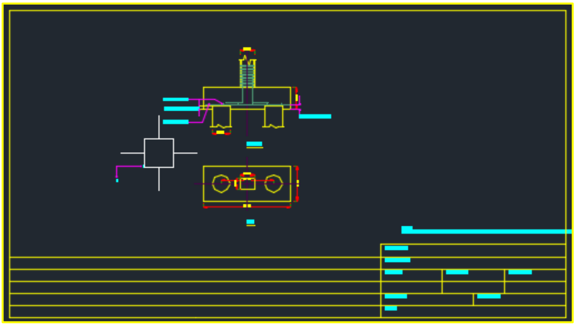

Fig 13: The positioning of piles

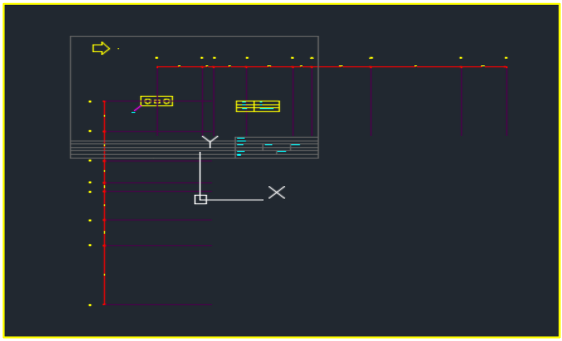

Fig 14: Design Pile Cap P63

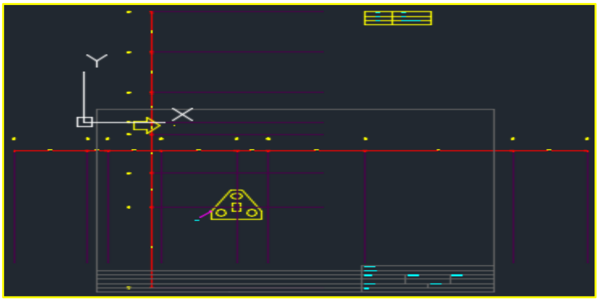

Fig15: Design of Pile Cap- 102

Maximum size of steel bars:
The maximum steel bar diameter is 10mm are (db) = 28.651 mm. IS 456 (2000),provide the required length is 1.53m but actual length = 1.000 m so redesigned to have length >1.53m

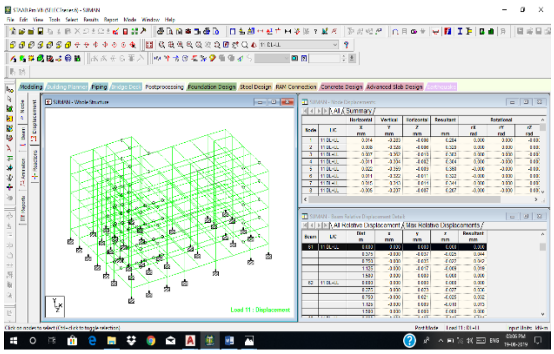

Fig 16: The post processing mode in STAAD.Pro

Critical Load Case-102:

Principal moment (M_{tl}) = -214.221kNm; d_β = 0.85, if fc ≤ 4000, then d_β = 0.65, if 4000 < fc ≤ 8000 then d_β = 0.85 and if fc > 8000 then redesign. In the present case the calculated reinforcement (R) = 985.427 mm^2as the R-value<R_{max}, R is accepted. Minimum spacing allowed (S_{min}) = 1.5 + db = 56.0mm.So selected spacing (S) = 221.0mm, gives S_{min}≤ S and bar size < selected maximum bar size (reinforcement accepted).

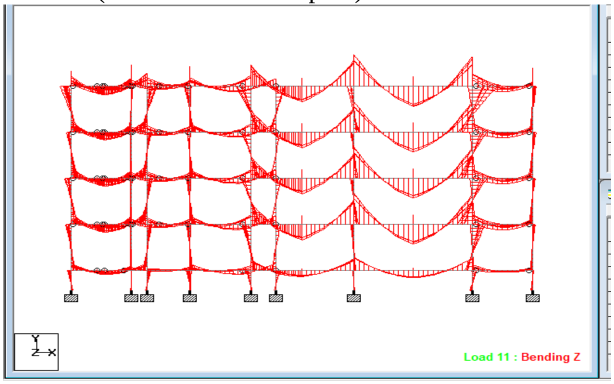

Fig 17: The bending moment diagram at various members of the structure

The figure shown in the diagram is the graph for SF and BM for a beam of the structure for member beam 1196.

Post processing mode:

The final design of the structure is in the post processing mode and is in **Fig 16, Fig 17, Fig. 18 and Fig. 19**

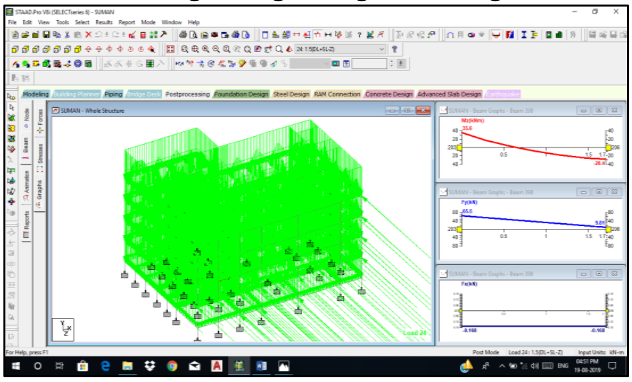

Fig 18: The graph for SF, shear force

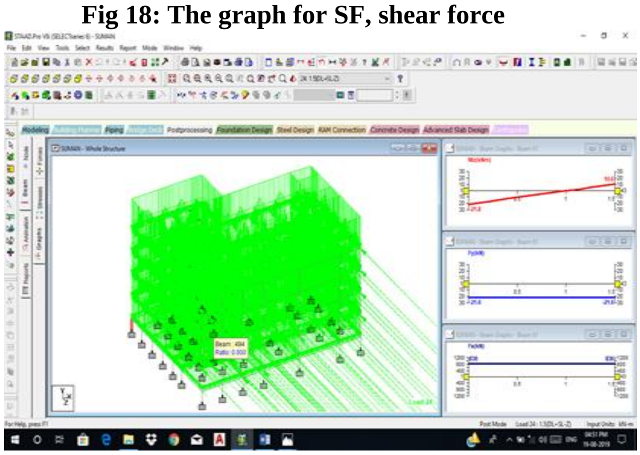

Fig.19:Bending moment (BM) for a beam of the structure

India is lagging for Skyscrapers:

The construction cost of multistoried buildings such as condominiums, apartments, skyscrapers is too high.For HRB's, requirement should have higher floor area (FAR). The constricted roads cannot accommodate heavy traffic/vehicles to the tall buildings. India is presently financially sound and has technical expertise to have super tall buildings. The risk for HRB construction is of very high cost and risk of loss to the constructor if the building is deficient by 3P's [*people* (the societal utility), *profit* (financial vitality) and *planet* (the environmental sustainability)]. More over land norms, government F.A.R regulation, high seismic activity in some populous areas, loose soil and groundwater conditions are pulling legs for high rise buildings. Lack of proper urban planning, wide streets, adequate transport facilities and adequate technology, are also causes for India has less numbers of high rise buildings in comparison to other developing and populous countries like China, USA,UAE, South Korea and Japan etc. No specific laws, adequate funding, risk involvement, technology advancement in construction sector and specific IS codes for mega tall buildings are the bottlenecks for Aires structure in India.

V. CONCLUSION

The structure weight along with the upright load to be bolstered by the building members can be significant. HRB's or multi storied structures are regularly delimited by slums/ squat height constructions. Those are exposed to fewer loadings. There creates differential settlements between the high-and low height structures which should be regulated. The lateral forces of strong and gusty wind enhances the amount of the establishment, mainly on the external exposed members in the framework to which the design should consider these wind induced cyclic vertical and parallel loads. Seismic tremors will instigate extra horizontal loading to the structure and initiate lateral movements in the foundation. Inertial forces and moments are formed in the horizontal/vibrational structural excitation. The ground developments are necessary to these kinematic powers.

The breeze initiated and seismically instigated lateral forces are dynamic and their capability to offer ascent to boom the structure inside which should be evaluated. The danger of dynamic reverberation relies upon various components, including the unmatched time of the dynamic stacking, the normal structural life and the monolithic property, and damping of HRB's. The dynamism of the multistoried structures represents some fascinating basic and establishment configuration challenges for clumsy soils, sidelong powers and time of vibration (10 s or more, Richter's scale > 6 or more). The regular powerful stacking sources, like flooding, wind action, and tremors have a short lived impact and have no uniform actions and energization of the structure through the basic method of vibration. A comparatively long period of tremors can cause damage to the buildings constructed over incompetent soils without proper design procedures, construction technologies and mostly on a through geo-tech investigation.

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