Computer Aided Static and Dynamic Analysis and Design of RCC Apartment with Floating and Non- Floating Columns

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Abstract— The column which are supported on a beam instead of rigid foundation are called as floating columns. Many of the buildings in india are constructed with floating columns. This is primarily beam adopted to accommodate parking or reception lobbies in the first storey. The earthquake force generated at different floor level of the building need to be carried out to the foundation by the shortest possible way which may not be the case when floating columns are provided. Providing floating columns may satisfy some of the functional requirements but structural behavior changes abruptly due provisions of floating columns. The flexural and shear demand of the beams which supports floating columns are much higher than surrounding beams, this leads to stiffness irregularities at a particular joint. Columns are main lateral load resisting elements in moment resisting frame and play a vital role in seismic performance of building. The stiffness of the storey below the floating column is usually lower than the storey above and below it. In this thesis the seismic performance of building with and without floating columns are presented in terms of various parameters such as displacement, storey drift, maximum column forces, time period of vibration etc. The building having various locations of floating columns i.e floating columns starting from different stories are considered for the study. In recent times, multi-storey buildings in urban cities are required to have column free space due to shortage of space, population and also for aesthetic and functional requirements. For this buildings are provided with floating columns at one or more storey. These floating columns are highly disadvantageous in a building built in seismically active areas. The earthquake forces that are developed at different floor levels in a building need to be carried down along the height to the ground by the shortest path. Deviation or discontinuity in this load transfer path results in poor performance of the building. The main aim is to evaluate the seismic response of (G+11 RCC APARTMENT) building with floating columns and compare it with the normal building.

Keywords: Floating and Non Floating Column, Storey Drift, Storey Displacement, Soft and Stiff Storey, Base shear, Storey shear Factor, STAAD.Pro V8i

I. Introduction

Structural engineering is a field of engineering dealing with the analysis and design of structures that support or resist loads. Structural engineering theory is based upon physical laws and empirical knowledge of the structural performance of different materials and geometries.

Structural Engineering depends upon a detailed knowledge of applied mechanics, materials science and applied mathematics to understand and predict how structures support and resist self-weight and imposed loads. To apply the knowledge successfully a Structural engineering generally requires detailed knowledge of relevant empirical and theoretical design codes, the techniques of structural analysis, as well as some knowledge of the corrosion resistance of the materials and structures, especially when those structures are exposed to the external environment. Since the 1990s, specialist software has become available to aid in the design of structures, with the functionality to assist in the drawing, analyzing and designing of structures with maximum precision; examples include AutoCAD, StaadPro, ETABS, Prokon, Revit Structure etc. Such software may also take into consideration environmental loads, such as from earthquakes and winds.

II. Commercial Buildings Constructions

Commercial building construction involves building projects that can be leased or sold in the private sector. These spaces can be anything from offices and manufacturing plants to medical centers and retail shopping centers. Each commercial construction project varies in size and effort and is unique in its own way. The designs and layouts of a structure are decided entirely by the client. Each client is unique so projects will be different. In commercial construction, a project can be separated into 3 sizes: small-scale, medium-scale, and large-scale.

A. Small-Scale:

Commercial construction, on a smaller scale, usually involves projects that center around rebranding or changing the look of a structure. Many projects that are small-scale can be seen as projects that focus on interior renovations of a building.

B. Medium-scale:

Medium-scale projects are when clients that want to remodel, expand with an addition, or restructure their building. Medium-scale projects take more time, work, and effort than small-scale projects.

C. Large-scale:

Large-scale commercial construction projects are their own task.Unlike other commercial construction projects, large-scale projects have no previous structure to work with. High-scale jobs need to be done extremely carefully to be successful.

Large-scale projects are structures such as high-rise buildings, dams, and warehouses. Large-scale projects take the words “from the ground up” literally. Only experts in the commercial construction business should really take on a complex project like this.

D. Column –

Column is a structural elements which plays an importants role in any construction project. It is an element which largely resist the lateral forces and transferred all the super structure load to the surrounding soil.

A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground is called as non floating column. The term floating column is also a vertical element which (due to architectural design/ site situation) at its lower level (termination Level) rests on a beam which is a horizontal member. The beams in turn transfer the load to other columns below it. RCC buildings are more vulnerable to the lateral forces such as wind forces and seismic or earthquake forces, the effect of wind forces and seismic or earthquake forces is high with the increase in the height of the structures. As per IS: 1893-2002 seismic resistant design code book entire India is divided into four seismic zones namely zone II,III,IV and V where as zone II is the lowest intensity seismic zone and zone V is the highest seismic intensity zone. Wind pressures on a building or structure depends on the wind velocity in a location as per IS: 875-part- 3 entire India is divided into different wind zones based on wind velocities 33m/s, 39m/s, 43m/s, 47m/s,50m/s,55m/s and also velocity of wind increases with heightof the structure. The seismic behaviour of the irregular structures had shown failure modes in past earthquake affected regions/locations. Load path irregularity is in situations where large column free area is necessary for parking's, garages, commercial and architecture importance. The Load path irregularity is common in buildings such as multi functional structures were some storeys are used for commercial and residential purposes. The columns which start from the foundation are called as non floating columns and the columns start from the elevated leveland are supported on beams called as floating columns shown in given Fig.

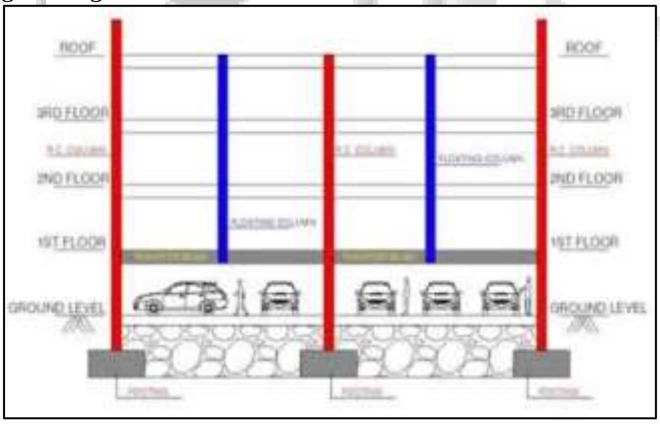

Fig. 1:

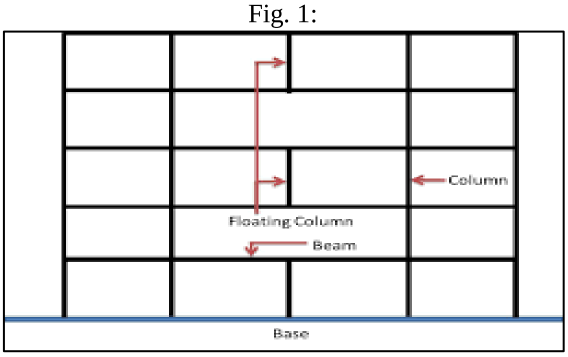

Fig. 2:

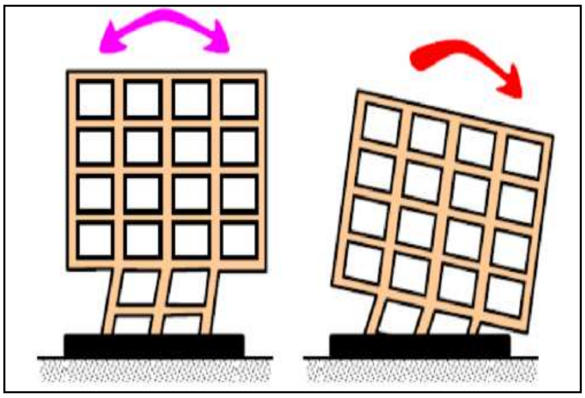

Fig. 3:

III. METHODOLOGY

The building considered in the present study is G+11 storied R.C framed buildingof symmetrical rectangular plan with configuration of buildings having a plan area of 30m x 24m with a storey height 3.5 m each and total height of chosen building including depth of foundation is 43.5m. Complete analysis is carried out for dead load, live load, wind and seismic load using STAAD PRO.

A. Design of RCC Structures (i.e. Methods of Structural Design)

It is done by using IS 456-2002 code book by adopting (Limit State Method)anyone of them;

1) Working stress method
2) Ultimate load method
3) Limit state method

IV. LIMIT STATE METHOD

The philosophy of the limit state method of design represents a definite advancement over the traditional design philosophies.

Unlike WSM which based calculations on service load conditions alone, and unlike ULM, which based calculations on ultimate load conditions alone, LSM aims for a comprehensive and rational solution to the design problem, by considering safety at ultimate loads and serviceability at working loads.

The LSM philosophy uses a multiple safety factor format which attempts to provide adequate safety at ultimate loads as well as adequate serviceability at service loads, by considering all possible 'Limit State'.

1) Limit State - A limit state is a state of impending failure, beyond which a structure ceases to perform its intended function satisfactorily,in terms of either safety of serviceability i.e. it either collapses or becomes unserviceable. There are two types of limit states:
   – Ultimate limit states (limit states of collapse):- which deal withstrength, overturning, sliding, buckling, fatigue fracture etc.
   – Serviceability limit states: – which deals with discomfort to occupancy and/ or malfunction, caused by excessive deflection, crackwidth, vibration leakage etc., and also loss of durability etc.

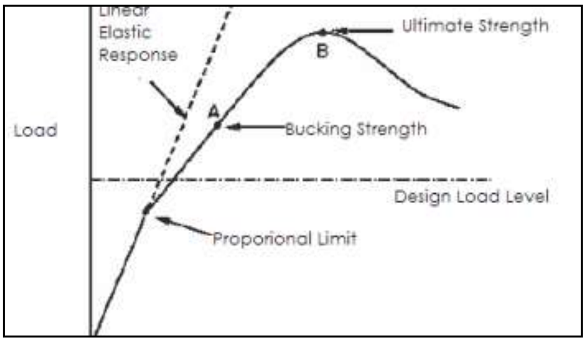

Fig. 4:

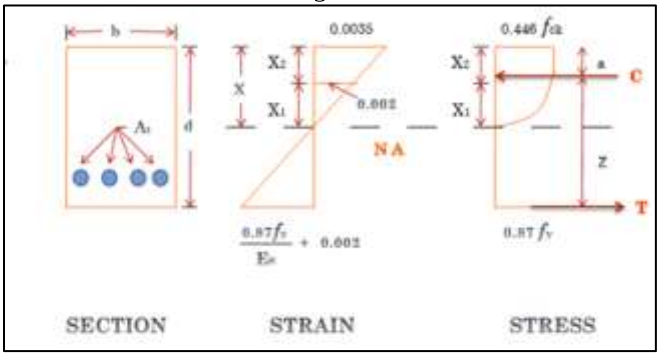

Fig. 5:

- The limit state method is a balanced combination of the working stress method and the ultimate load design method.
- It is also known as load and resistance factor design in structural engineering.
- The limit state method helps us to know the capacity load or working load of the structure.
- The motive of using the limit state method is to construct a safe and comfortable structure.
- This method gives an idea about the serviceability requirement of limiting deflection and cracking.
- To make a safe structure limit state method obey two criteria, one is the ultimate limit state ana another one is the serviceability limit state.
- A limit state design makes structure more safe, durable, and fit for human uses.
- It gives the idea that the structure ongoing to build can carry the acting loads like dead loads, live loads, wind loads, and earth quick loads are not.

A. Assumptions:

The first Assumptions in Limit State Method is, Plane sections normal to the axis remain plane even after bending.It means the strain distribution across the depth of the cross-section is linear as shown in fig.5.

At Limiting state, the maximum strain in concrete, which occurs at outermost compression fibre is 0.0035.

The stress-strain curve for concrete is having parabolic shape up to 0.002 strain and the constant up to limit state of 0.0035.However, IS Code does not prevent using other shapes like rectangle and trapezoidal

The tensile strength of concrete is ignored

The stress in reinforcement is derived from the representative stress-strain curve for the type of steel used.For design purpose a partial safety factor of 1.15 is used Hence maximum stress in steel is limited to,

$$fy/1.15= 0.87 * fy$$

The maximum strain in steel at failure shall not be less than

$$fy/1.15Es + 0.002 fy$$

Where,

f_y = Characteristic strength of steel
E_s= Modulus of elasticity of steel

V. Seismic Analysis

It is a subset of structural analysis and is the calculation of the response of abuilding (or non building) structure to earthquakes. It is part of the processof structural design earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent.

A. Static Analysis

In this method equal magnitude of excitation forces acting over equal time interval. the static analysis is generally used to access the capacity of structural system in terms of deformation and actions. The static analysis may be viewed as a special case of dynamic analysis when damping and inertia effect is zero or almost negligible. it is further divided in two types as linear static analysis and non linear static analysis.

- Linear static analysis- In this analysis structure behave as elastic corresponding to static types of excitation force and can be used to regular structure having limited height. In elastic analysis, stiffness characteristics of structure is assumed to be constant during whole duration of earthquake. the linear static analysis is of different methods such as equivalent lateral force method or equivalent static analysis or seismic coefficient method.
- Non-Linear static analysis- In this analysis structure allows non elastic behavior corresponding to static type of excitation force and this analysis can be used for any class of structure. in non elastic analysis the stiffness of structure is assumed to be constant over a small incremental time. The non linear static analysis carried out with push over analysis method which is simple method to implement and to provide information on strength, deformation and ductility of structure as well as demand distribution.

B. Dynamic analysis

In this method excitation force is not the function of the time therefore it vary with the time. the dynamic analysis is most natural approach towards evaluation of earthquake responses. it is significantly more demanding than static analysis in terms of computational efforts and interception of results. It is further divided into two types as linear dynamic analysis and non linear dynamic analysis.

- Linear dynamic analysis- in this analysis structure behaves as elastic or allowed upto elastic behavior corresponding to time varying excitation force. in elastic analysis the stiffness characteristics of structure are assumed to be constant for whole duration of earthquake. the linear dynamic analysis can perform using various methods such as response spectrum method or mode superposition method and elastic time history method.

- Non-linear dynamic analysis- in this analysis structure behaves beyond elastic behavior that is allowed under inelastic behavior corresponding to time varying excitation force in case of non elastic analysis the stiffness of structure is assumed to be constant over a small incremental time the non linear dynamic analysis can perform with inelastic time history method in which actual behavior of structure can be responded during an earthquake.

From the above analysis methods the most refined and reliable method for seismically excited structure is the Time History Analysis method because this method is applicable to both type of linear and non linear dynamic analysis. the time history analysis is the most sophisticated and accurate method of dynamic analysis.

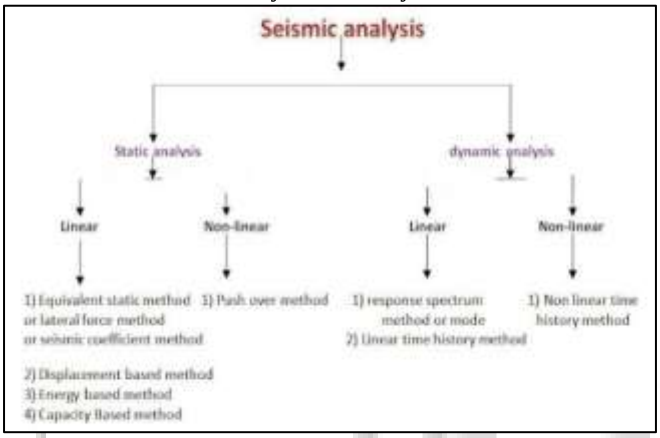

Fig. 6:

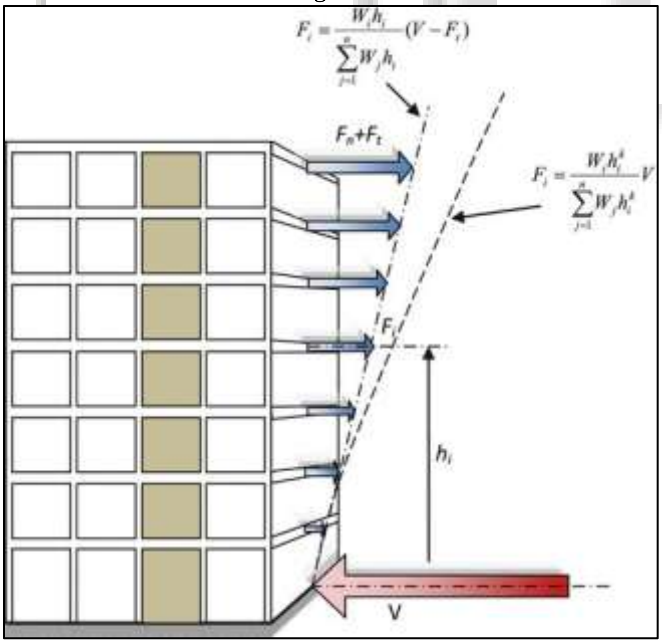

Fig. 8: static analysis of structure subjected to seismic analysis

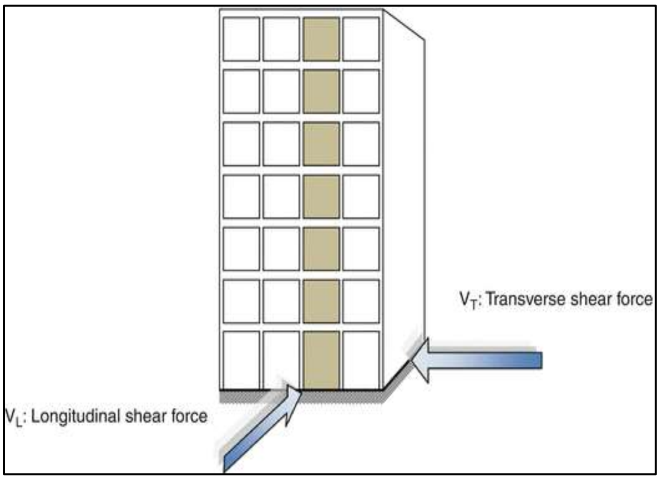

Fig. 7: Fig. (d) Equivalent shear force along two orthogonal axis.

Where,

F_i = horizontal equivalent static design force at each level i

V = horizontal equivalent static earthquake shear force

W_i = seismic weight at each i^{th} level in killo newtons

h = height of i level above the base of the structure in meters

F_n = horizontal equivalent static Force at n^{th} level

VI. DESCRIPTIONS OF APARTMENT

STRUCTURE	DESCRIPTIONS
No. of stories	G + 11
Typical height of one storey	3.5m
Soil type	Black cotton
Plinth height	1.5m
Grade of concrete	M20
Grade of steel	Fe-415
Slab thickness	0.2m
Dead load	6kn/m
Live load	5kn/m^2
Floor Finish	1kn/m^2
External wall	0.23m
Internal wall	0.1m

VII. OBJECTIVES

- To creates the geometry of the structures as per standard norms.
- To assess different load cases and combination of loads as per IS Codes 875 – 1987 (part 1 – 5) provisions .
- To evaluate statics and dynamics analysis of the structural by different methodologies Using STAAD.Pro software.
- To design all structural components using IS codes specification like IS 456 – 2000 , SP – 16, components IS 1893-2002.
- To draw the detailing of all structural components as per codal provisions such as SP34-1989.

VIII. PLAN

A. Basement

Fig. 9: Basement plan 30x24m

B. Ground floor

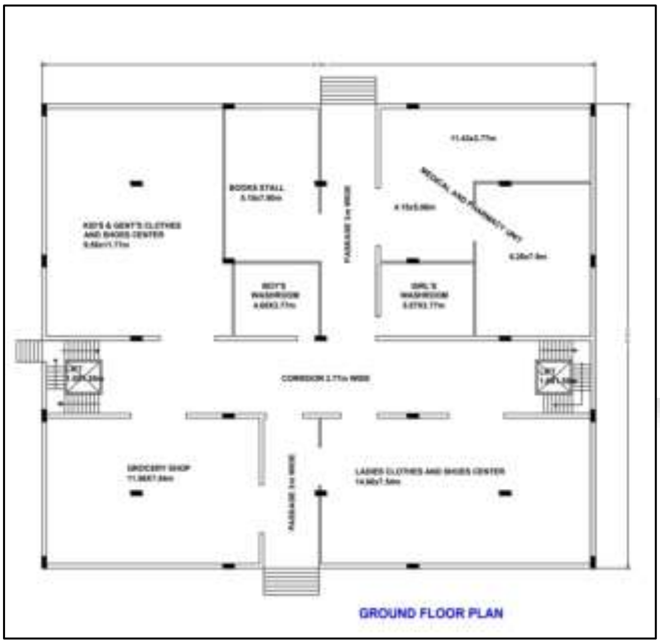

Fig. 10: Ground Floor plan

C. Typical floor plan

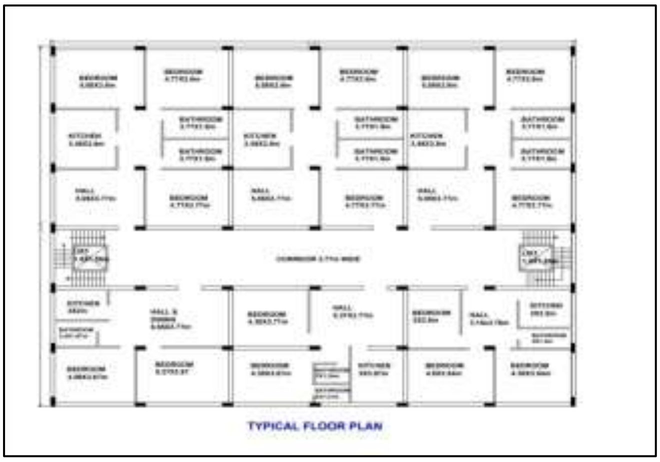

Fig. 11:

IX. MODELLING, ANALYSIS, DESIGN, DETAILING AND RESULTS

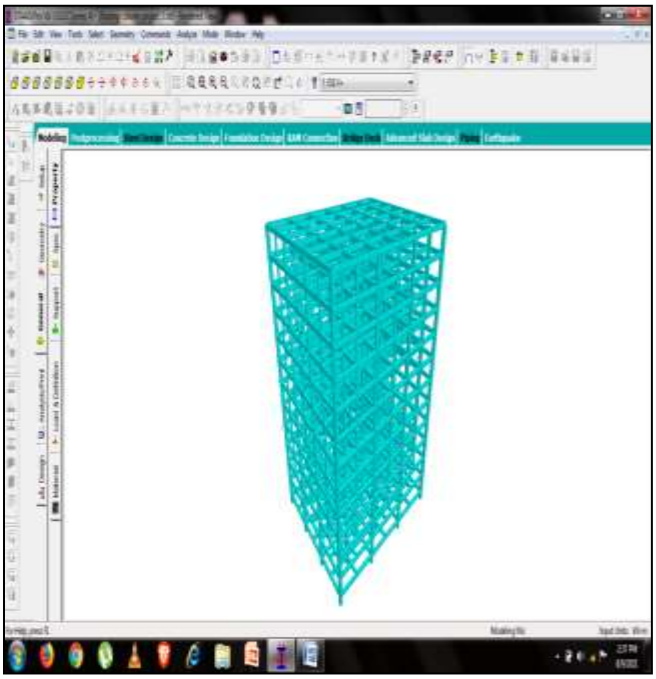

Fig. 12: 3D view of the structure

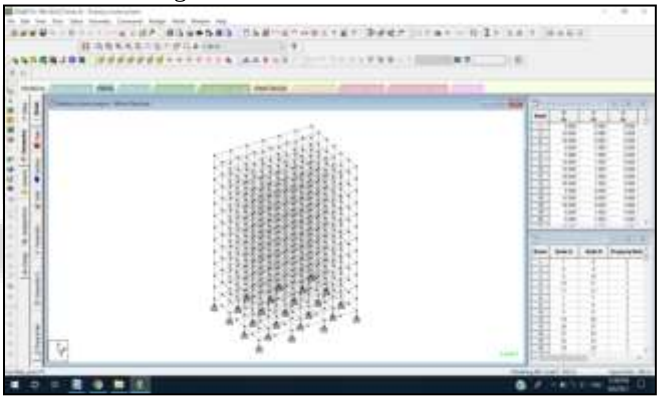

Fig. 13: generation of structure through GUI

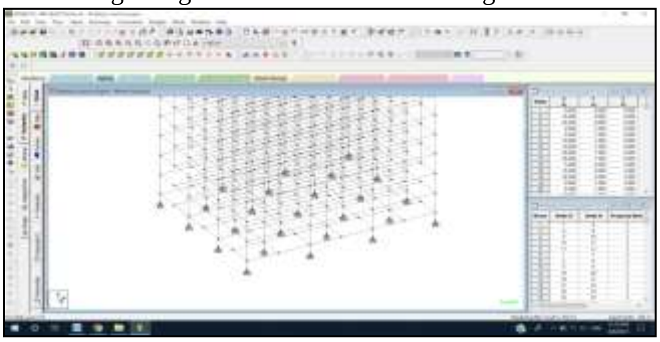

Fig. 14: supports assigned

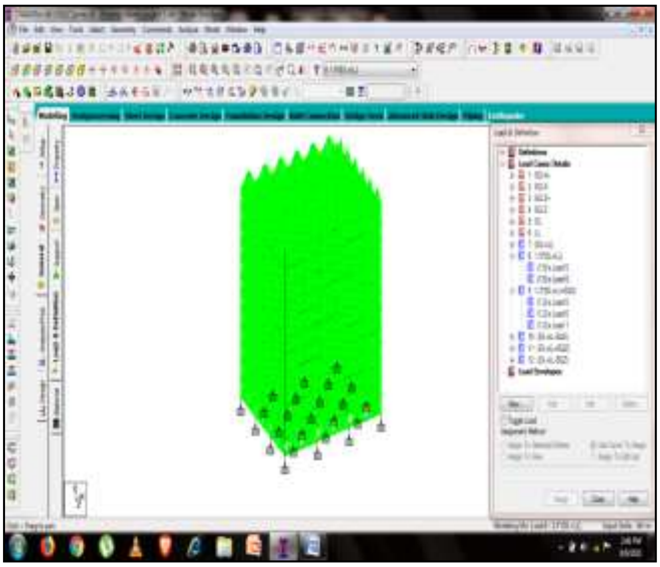

Fig. 15: combination of loads (1.5(DL+LL))

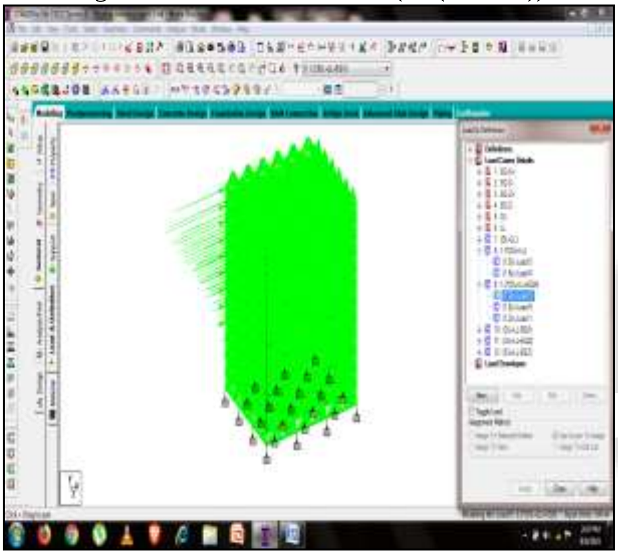

Fig. 16: combination of loads (1.2 (DL+LL+EQX))

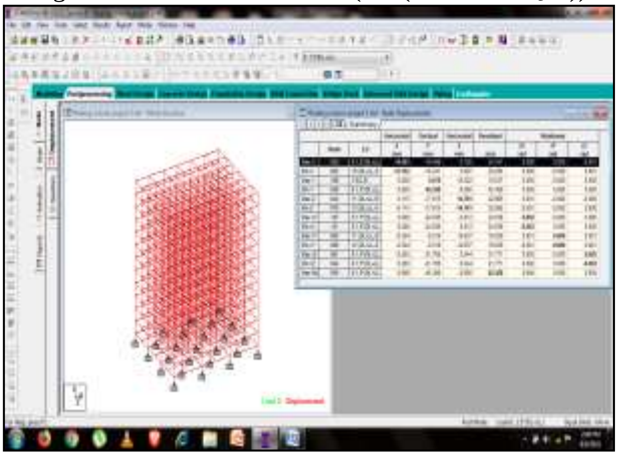

Fig. 17: Node displacement diagram

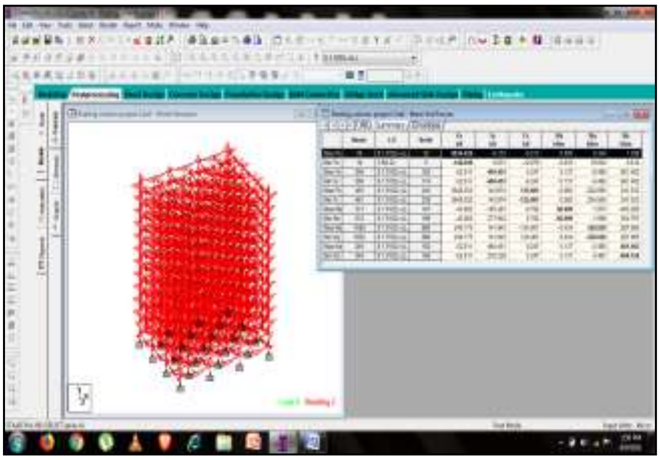

Fig. 18: Bending moment diagram

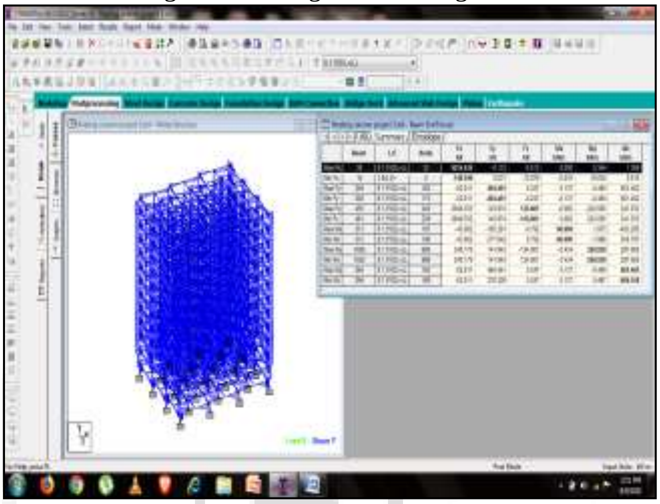

Fig. 19: Shear Force Diagram

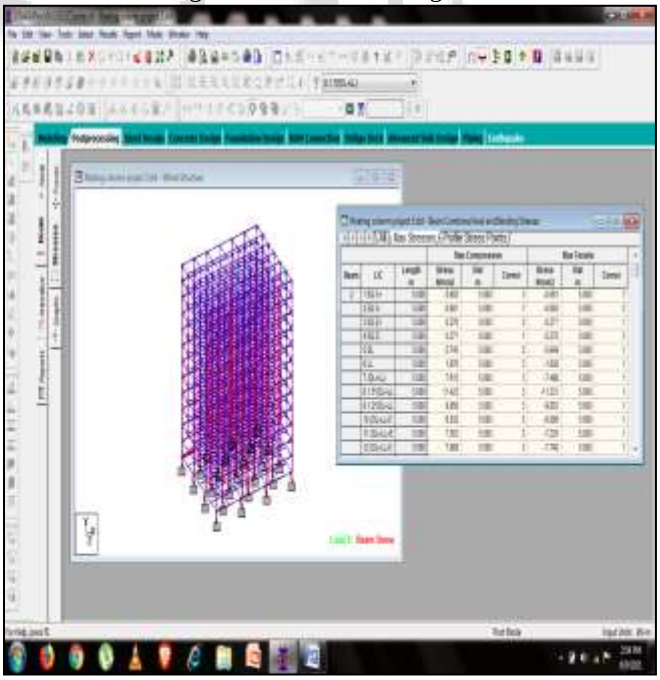

Fig. 20: Beam Stress Diagram

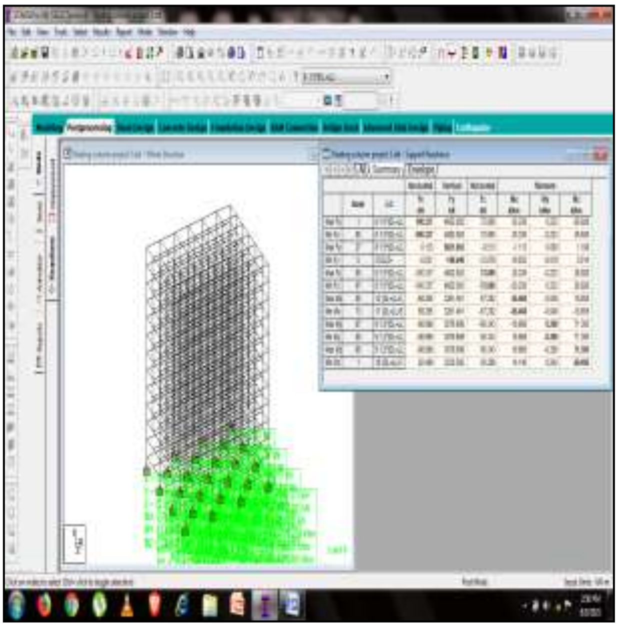

Fig. 21: Supports Reaction at Footing Level

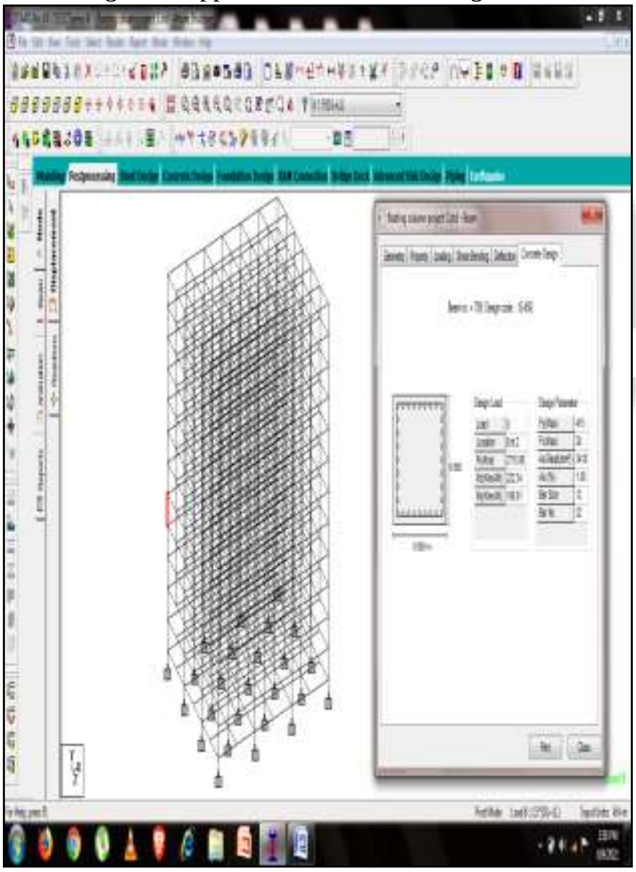

Fig. 22: (a) Cross – Section Reinforcement Details in RCC column no. 709

Fig. 22: (b) Reinforcement Details in RCC column no. 709

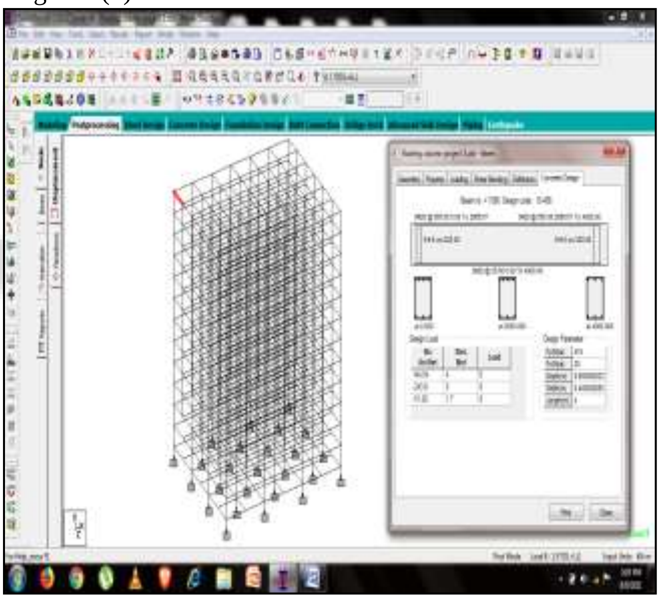

Fig. 23: (a) Cross-Section & Longitudinal Reinforcement Details in RCC Beam no. 1586

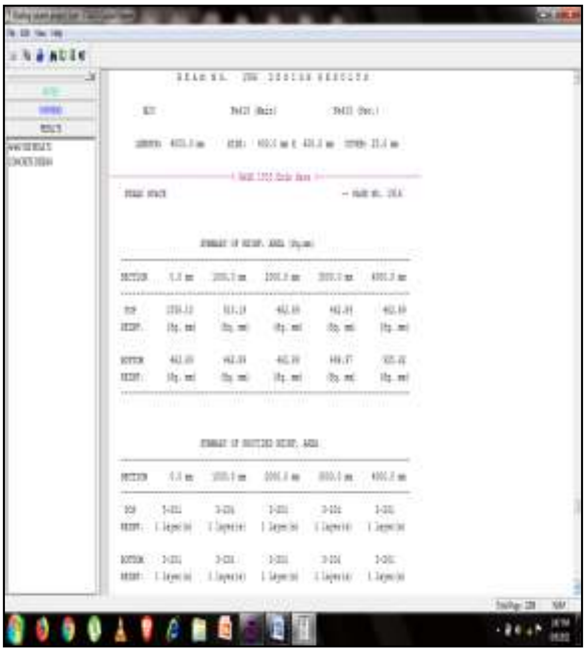

Fig. 23: (b)

Fig. 23: (c) Reinforcement Details in RCC Beam no. 1586

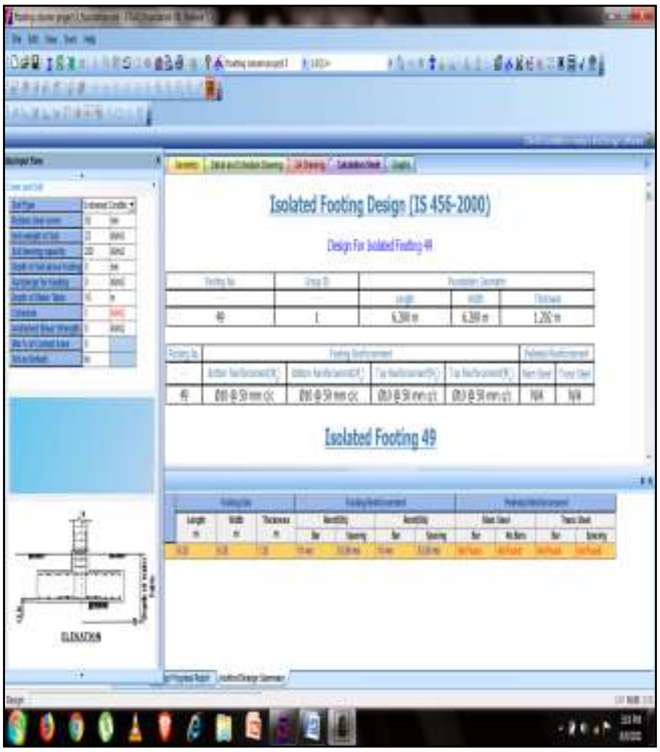

Fig. 24: (a)

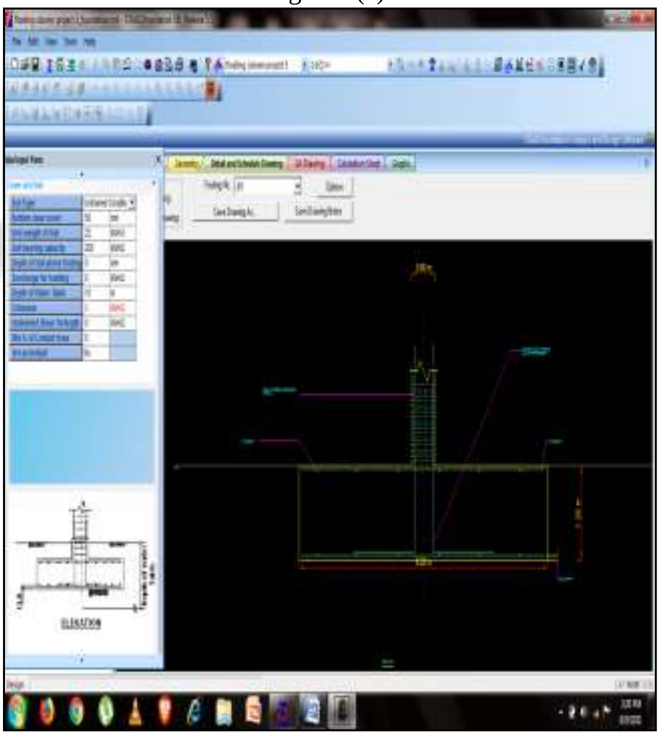

Fig. 24: (b) Reinforcement Details in RCC footing no. 49

X. CONCLUSION

STAAD Pro software has become more and more critical in the analysis of engineering and scientific problems. Much of the reason for this change from manual methods has been the advancement of computer techniques development by the research community and in particular universities. As technology and engineering adoptions are advertising new methodology of interlinking and completing the industries via computer applications are created with a similar improvement in hardware capacities. This is turn facilities the implementations of more effective and professional engineering software. As the applications adventure in functionality, one can hope that they will be more affordable to promote their widespread usage amongst civil engineering at a global scale. Taking into account the technological advance, this project has been dealt with using the latest design software.

– Designing using software's like STAAD.Pro reduces alots of time in design work.
– Details of each and every member can be obtained using STAAD.Pro.
– All the list of failed beams can be obtained and also better section can be given.
– Building provided with floating column shows more storey drift and storey displacement as compare to building without floating columns.
– The optimum position to provide floating column is at 1^{st} floor alternatively so that moment, shear, and steel requirement of the whole building can be minimized.
– Hence provide the floating column is advantageous in provide good floor index but risky and vulnerability of the building increases.
– The use of floating column in modern building are increasing vastly.

NOTE – THE BUILDING IS SAFE AND CAPABLE TO RESIST ALL THE WORST COMBINATION OF LOADS.

XI. Scope For Future

In modern times the buildings are becoming complex particularly the mix use ones. There are different uses on different floors and hence to follow it structural grid becomes difficult as columns on any floor would become a hindrance. Even in residential buildings when there is a parking on ground floor or lower stories or huge cantilevers are taken to exploit ambiguities in Local bye-laws for gaining more FSI (Floor Space Index), the lower floors need column-free spaces for easy movement of vehicles; while on upper floors which are more in number, the columns have been designed based on room layout. They are also frequently used when there are shops on ground floor and residence on upper floors. Rather than finding an architectural solution one easily take recourse to floating columns and remove columns on lower stories, which is "a dangerous proposal".

Those architects who are not able to find design solutions in their design or those who do not respect the structural engineering and force the structural engineer to alter the uniform vertical alignment of columns and to provide floating columns. What has happened during last few years is that; that someone took a risk and the building survived and hence architects and structural engineers thought that this could be done. Hence now this practice has reached a stage where it is followed by many in violation of all norms. People do not understand that the building has survived in Gravity loads only. But they forget that how it would behave in Earthquake or wind i.e. when subjected to horizontal loads. They also forget that earthquake occurs once in a life of building i.e. once in 50 or 100 years and at such times it might prove absolutely fatal. In our opinion taking floating columns is not a sound engineering practice.

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