ijiTECH International Journal of Innovative Technologies

WWW.IJITECH.ORG

ISSN 2321-8665
Volume.06, Issue.01,
January-June, 2018,
Pages:0197-0202

Analysis of Multi-Storey Building with Floating Column

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Abstract: Many urban multi-storey buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first storey. Whereas the total seismic base shear as experienced by a building during an earthquake is dependent on its natural period, the seismic force distribution is dependent on the distribution of stiffness and mass along the height. In present scenario buildings with floating column is a typical feature in the modern multi-storey construction in urban India. Such features are highly undesirable in building built in seismically active areas. This study highlights the importance of explicitly recognizing the presence of the floating column in the analysis of building. Alternate measures, involving stiffness balance of the first storey and the storey above, are proposed to reduce the irregularity introduced by the floating columns. In this paper a Multi Storey Framed Structure with a Floating Column is Taken And Analysed in ETABS.

Keywords: ETABS, Multi Storey Framed Structure, STAADPro.

I. INTRODUCTION

Many urban multistorey buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first storey. Whereas the total seismic base shear as experienced by a building during an earthquake is dependent on its natural period, the seismic force distribution is dependent on the distribution of stiffness and mass along the height. The behavior of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. The earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path; any deviation or discontinuity in this load transfer path results in poor performance of the building. Buildings with vertical setbacks (like the hotel buildings with a few storey wider than the rest) cause a sudden jump in earthquake forces at the level of discontinuity. Buildings that have fewer columns or walls in a particular storey or with unusually tall storey tend to damage or collapse which is initiated in that storey. Many buildings with an open ground storey intended for parking collapsed or were severely damaged in Gujarat during the 2001 Bhuj earthquake. Buildings with columns that hang or float on beams at an intermediate storey and do not go all the way to the foundation, have discontinuities in the load transfer path.

A column is supposed to be a vertical member starting from foundation level and transferring the load to the ground. 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. There are many projects in which floating columns are adopted, especially above the ground floor, where transfer girders are employed, so that more open space is available in the ground floor. These open spaces may be required for assembly hall or parking purpose. The transfer girders have to be designed and detailed properly, especially in earth quake zones. The column is a concentrated load on the beam which supports it. As far as analysis is concerned, the column is often assumed pinned at the base and is therefore taken as a point load on the transfer beam. STAAD Pro, ETABS and SAP2000 can be used to do the analysis of this type of structure. Floating columns are competent enough to carry gravity loading but transfer girder must be of adequate dimensions (Stiffness) with very minimal deflection.

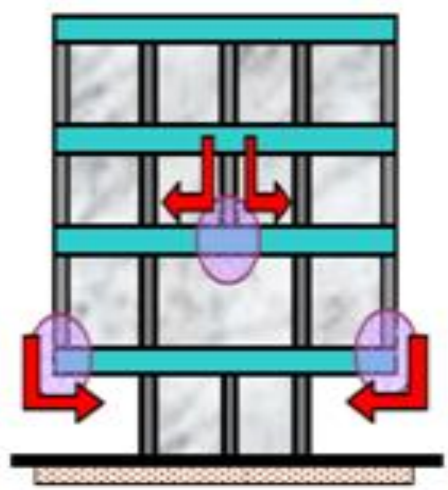

Fig1. Hanging or Floating Columns

Looking ahead, of course, one will continue to make buildings interesting rather than monotonous. However, this need not be done at the cost of poor behavior and earthquake safety of buildings. Architectural features that are detrimental to earthquake response of buildings should be avoided. If not, they must be minimized. When irregular features are included in buildings, a considerably higher level of engineering effort is required in the structural design and yet the building may not be as good as one with simple architectural features. Hence, the structures already made with these kinds of discontinuous members are endangered in seismic regions. But those structures cannot be demolished, rather study can be done to strengthen the structure or some remedial features can be suggested. The columns of the first storey can be made stronger, the stiffness of these columns can be increased by retrofitting or these may be provided with bracing to decrease the lateral deformation. Some pictures showing the buildings built with floating columns:

Fig2. 240 Park Avenue South in New York, United States

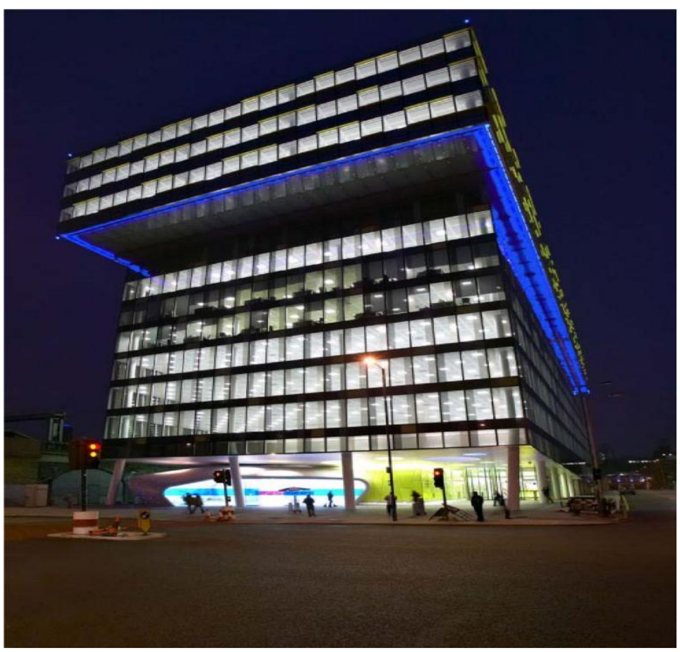

Fig3. Palestra in London, United Kingdom.

II. OBJECTIVE AND SCOPE OF PRESENT WORK

The objective of the present work is to study the behavior of multistory buildings with floating columns under earthquake excitations. Finite element method is used to solve the dynamic governing equation. Linear time history analysis is carried out for the multistory buildings under different earthquake loading of varying frequency content. The base of the building frame is assumed to be fixed. Newmark's direct integration scheme is used to advance the solution in time. Usually all multistoried buildings (structures) are of 3 types they are

- Load bearing construction
- Framed construction
- Composite construction

But among the above 3 types, in the present stage all the multistoried structure are framed construction which are durable. An engineering structure is an assembly of member of elements transferring the loads and providing a firm space to serve the desired function.The structural design is a science and art of designing, with economy and elegance, a durable structure is that which can safely carry the forces and can serve the desired function satisfactorily during its expected service life span. The entire process of structural planning and designing requires not only imagination and conceptual thinking (which forms arts of designing) but of practical aspects, such as relevant design codes and bye-laws, backed up by ample experience, institution and judgment. The process of design commences with planning of a structure, primarily to meet the functional equipment of the user or client. The functional requirements and the aspects of the aesthetics looked in to normally by an architect while the aspect of safety, serviceability, durability and economy of the structure for its intended use over the life span.

III. COMPONENTS OF A BUILDING:

A Building Can Be Broadly Divided Into Two Parts Viz.

- Sub-Structure
- Super Structure.

The portion of the building above the ground is termed as super structure. The portion of the building below the ground is termed as sub-structure. The components of a building can be broadly summarized as under.

1. Foundation
2. Plinth
3. Walls 4. Columns
5. Floors 6. Doors/Windows & Ventilators
7. Staircase 8. Roofs
9. Building Finishes
10. Building services.

The object of reinforced concrete design is to achieve a structure that will result in a safe and economical solution. For a given structural system, the design problem consists of the following steps:

- Idealization of structure for analysis,
- Estimation of loads,

- Analysis of idealized structural model to determine axial thrust, shear, bending moments and deflections,

A. Limit State Method

In the limit state design method, non-deterministic parameters are determined based on observations taken over a period of time. The object of design based on the limit state concept is to achieve an acceptable probability that a structure will not become unserviceable in its life time for the use for which it is intended, that is, it will not reach a limit state. A structure with appropriate degrees of reliability should be able to withstand safely all loads that are liable to act on it throughout its life and it should also satisfy the serviceability requirements, such as limitations on deflections and cracking. It should also be able to maintain the required structural integrity during and after accidents such as fires, explosions and local failure. Due to its realistic approach, limit state method is used in design of structures. The most important limit state which must be examined in design are as follows:

Limit state of Collapse: This state corresponds to the maximum load carrying capacity. Violation of collapse limit state implies failure in the sense that a clearly defined limit state of structural usefulness has been exceeded. However, it does not mean a complete collapse. Thus limit state may correspond to: i. Flexure, ii. Compression, iii. Shear,iv. Torsion

Limit state of serviceability: This state corresponds to development of excessive deformation and is used for checking members in which magnitude of deformations may limit the use of the structure or its components. This limit state may correspond to i. Deflection, ii. Cracking, iii. Vibration.

B. Loads And Load Combination

Gravity Loads:

Dead Load (DL):-Dead Load is defined as the the load on a structure due to its own weight (self-weight). It also added other loads if some permanent structure is added to that structure.

Live Load (LL):-Live Load or Imposed Load is defined as the load on the structure due to moving weight. The Live Load varies according to the type of building. For example generally for a Residential Building the Live Load is taken as 2kn/m2.

Dead Load Calculation: Main Wall Load (From above plinth area to below the Roof) should be the cross sectional area of the wall multiplied by unit weight of the brick. (unit weight of brick is taken as 19.2 kn/m3). According to the IS-CODE PLINTH LOAD should be half of the MAIN WALL LOAD. Internal PLINTH LOAD should be half of the PLINTH LOAD. PARAPATE LOAD should be the cross sectional is multiplied by unit weight. SLAB LOAD should be combination of slab load plus floor finishes. SLAB LOAD can be calculated as the thickness of slab multiplied by unit weight of concrete (according to IS-CODE unit weight of concrete is taken as 25 kn/m^3).and FLOOR FINISHES taken as .1.5 kn/m2.

Live Load Calculation: Live Load is applied all over the super structure except the plinth .Generally LIVE LOAD varies according to the types of building. For Residential building LIVE LOAD is taken as ----2kn/m2 on each floor and 2kn/m2 on roof.

Critical Load Combinations: While designing a structure, all load combinations, in general are required to be considered and the structure is designed for the most critical of all. For building upto 4 storeys, wind load is not considered, the elements are required to be designed for critical combination of dead load and live load only. For deciding critical load arrangements, we are required to use maximum and minimum loads. For this code prescribes different load factors as given below:

$$\text{Maximum load} = w_{max} = 1.5(DL + LL)$$

$$\text{Minimum load} = w_{min} = DL$$

The maximum positive moments producing tension at the bottom will occur when the deflection is maximum or curvature producing concavity upwards is maximum. This condition will occur when maximum load (i.e. both DL and LL) covers the whole span while minimum load (i.e. only DL) is on adjacent spans. consideration may be limited to combination of Design dead load on all spans will full design live loads on two adjacent spans (for obtaining maximum hogging moment.)

C. Analysis of Structure

The primary function of a structure is to receive loads at certain points and transmit them to some other point. In performing this primary function the structure develops internal forces in its component members known as structural elements. It is the duty of the structural engineer to design it in such a way that the structural elements perform their functions adequately. The inadequacy of one or more structural element may lead to malfunctioning or even collapse of the entire structure. The object of structural analysis is to determine the internal forces and the corresponding displacements of all the structural elements as well as those of the entire structural system. The safety and proper functioning of the structure can be ensured only through a thorough structural analysis. The importance of proper structural analysis cannot, therefore, be over emphasized. A systematic analysis of structural system can be carried out by using matrices. The matrix approach for the solution of structural problems is also eminently suitable for a solution using modern digital computers. Hence the advantage of using the matrix approach for large structural problems is evident. By using matrix approach, the structural analysis can be performed in two methods:

i) Flexibility method
ii) Stiffness method

In this project, the frames have been analyzed by using ETABS., Which uses stiffness method for analysis of structure. ETABS, over the years, has developed to become the world's most popular and powerful structural engineering software. ETABS features a state-of-the-art user interface, visualization tools, powerful analysis and design engines with advanced finite element and seismic analysis capabilities. From model generation, analysis and design to visualization and result verification, ETABS is the choice of the design professionals around the world for the analysis and design of steel, concrete, composite, timber, aluminum and cold-formed steel structures.

Why ETABS?

- Developed by practicing engineers for practicing engineers around the globe.
- Evolved over 20 years and is constantly guided by a premier industry-based steering committee
- Has building codes for most countries including US, Britain, Canada, Australia, France, Germany, Spain, Norway, Finland, Sweden, India, China, Euro Zone, Japan, Denmark, and Holland. More are constantly being added.
- Fully COM (Component Object Model) compliant and is designed using an open architecture.
- ETABS User Interface is the industry standard. Its powerful graphics, text and spreadsheet interfaces provide true interactive model generation, editing, analysis & easily generates comprehensive custom reports.
- Can export all data to Microsoft Word or Microsoft Excel!
- Supports multi-material design codes such as timber, steel, cold-formed steel, concrete and aluminum.
- Dynamic and soil-structure interaction capabilities along with exhaustive design output.

Introduction to the calculation of the loads: The load on a structure varies in nature. In general all the buildings will be subjected two types of loading-Dead loads and live loads. Dead or Static loads include the self-weight of roof slabs, beams, columns, footings, lintels, brick work, furniture, static machinery, etc. These loads do not change their place where as live load include all such loads, which are liable to change their position from time to time. The live load varies in magnitude from building to building from a minimum of 2 KN/m^2 for dwelling houses, to a 10 KN/m^2 for factories. In the present case of the building project, slabs are assumed 130mm thickness from stiffness/deflection, consideration. Beams are taken separately and the self-weight is calculated and added separately on the frame.

D. Loads On Beams: Dispersion of load on slab to the beam: The load of slab is dispersed on to the supporting beams in accordance with clause 24.5 of IS: 456 -2000, which states that the load on beams supporting solid spans, spacing in two directions at right angles and supporting uniformly distributed loads, may be assumed to be in accordance with Fig 7

Load due to trapezoidal loading = $\frac{W_u \times L_x}{6}\left[3-\left(\frac{L_x}{L_y}\right)^2\right]$

Load due to triangular loading = $\frac{W_u \times L_x}{3}$

W_s= load/m on slab.

Self-weight of beams: This load acts on the beams as a UDL. this is calculated after assuming the suitable cross section (by stiffness / deflection consideration) of the beam.

Load due to brick masonry wall*:* Since the loads are transferred to the column by beams, in framed structure wall does not play any significant part in carrying loads and transference of loads, wall need not be excessively thick. Nominal thickness of wall, so as to shield the wall will be transferred to the beams.

Point load from intersecting beam: If there is any beam meeting the beam, then the load of that beam is considered as point load.

Dimensions of beams and columns: The assumed dimensions are:

Beam: B_1 = 230 x 450mm B_2 = 230 x 600 mm

Column: C_1 = 300 x 600mm C_2 = 300 x 750mm

Height of wall =3.3m

Loading consideration: This stage involves determination of various types of loads that are acting on the structures. The values of types loads are taken from the relevant IS-codes.

Types of loads: Various types of loads on a structures and requiring consideration in design are

1.Dead load
2.Live load

Dead load: This is the permanent or stationary load like self-weight of structural elements. This includes

1. Self-weight
2. Weight of Finishes
3. Weight of partition walls etc

Dead loads are based on the unit weight of elements, which are established taking into account materials specified for constructions in IS 1911-1967

Live loads: (as per IS 875 (part 2) – 1987)

These are non permanent are moving loads. This type of load includes the following

- Imposed loads (Fixed) weight of fixed seating in auditoriums, fixed machinery, partition walls. This loads, through, fixed in positions cannot be relieved upon to act permanently throughout the life of the structure.
- Imposed loads (not fixed) these loads change either in magnitude or position very often such as traffic loads, weight of furniture etc

Loading standards : The loads that are considered in the design are basedon IS-875-1964

1. The dead loads	
R.C.C	25 KN/m^3
P.C.C	24 KN/m^3
BRICK MASONRY	19 KN/m^3
FLOO FINISHES	1.5 KN/m^3
2.The Live loads	
On floors	2 KN/m^2
On roofs	2 KN/m^2

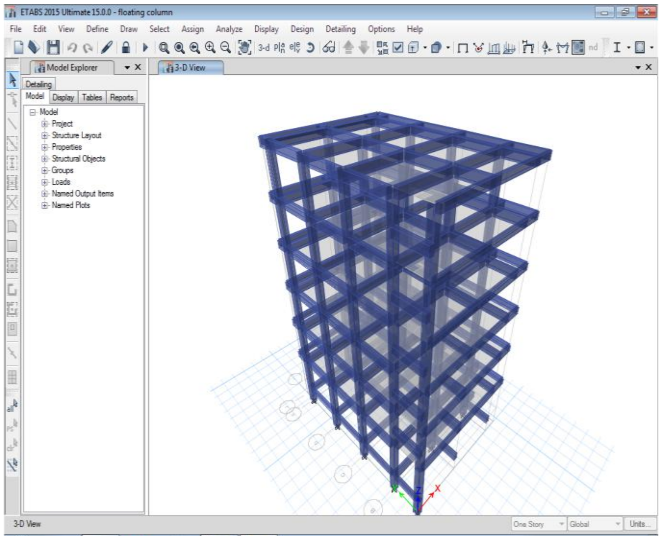

Fig4. 3D View of The Structure.

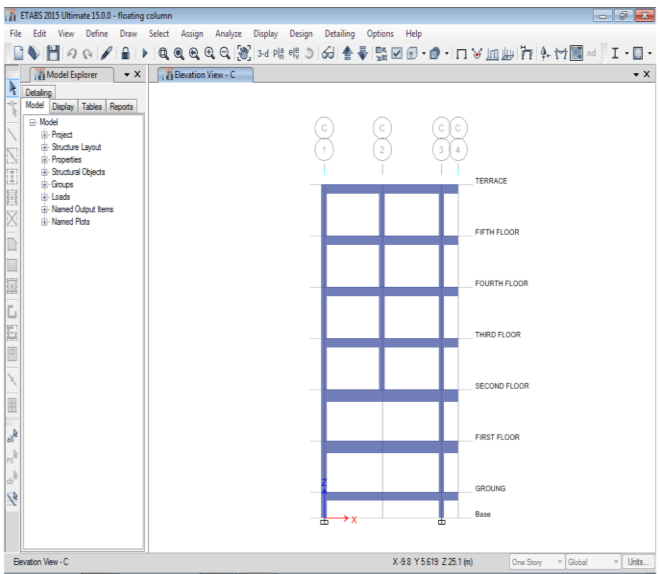

Fig5. Elevation of the Structure.

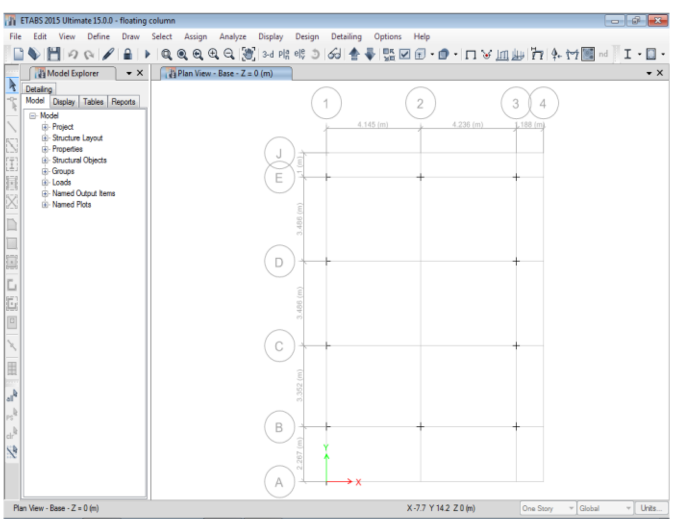

Fig6. Supports.

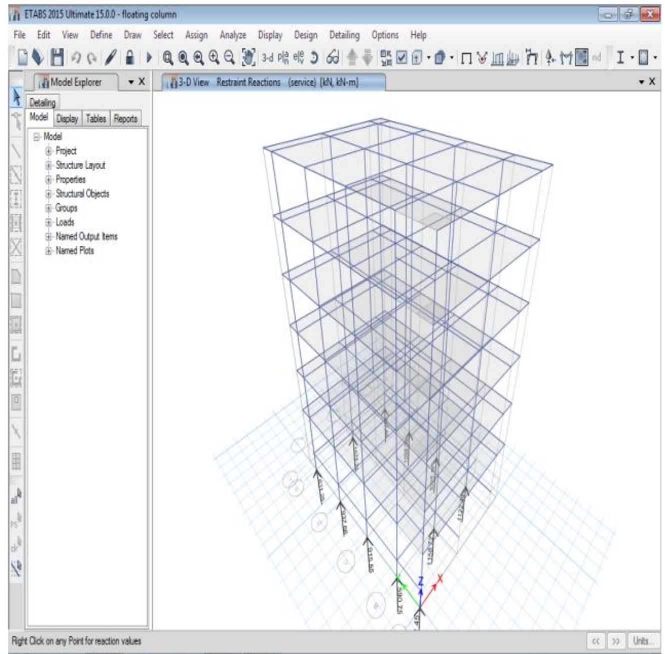

Fig7. Base Reactions.

ETABS 2015 Concrete Frame Design IS 456:2000 Column Section Design(Envelope)

IV. CONCLUSION

ETABS 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. It is shown by analysis in ETABS that the amount of axial load on the the columns as mentioned above is reduced to an larger extent, not only axial load but also the moments i.e. internal stress also reduced to a larger extent in floating columns. 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.

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