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Seismic Analysis and Design of G+18 Floors Multistoried Building using ETABS 2013

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ABSTRACT

One of the major problems that the country facing is the rapidly growing population, which necessities more facilities in the restricted availability of land. This can be solved to a certain extent with the construction of multistoried building, which can serve many people in available limited area. Hence it is the necessary requirement of multistoried building with all facilities. Hence an attempt is made in the project by SEISMIC ANALYSIS AND DESIGN OF G+18 FLOORS MULTISTORIED BUILDING USING ETABS 2013. Earthquake Engineering was developed a lot from the early days and seismically analyzing the structures requires specialized explicit finite element analysis software, which divides the element into very small slices and models the actual physics. The seismic analysis of the proposed building was done in the software ETABS 2013, which is one of the most advanced software in the structural design field. The loads applied on the structure were based on IS:875 (part I)-1987 [dead load], IS:875(part II)-1987 [live load], IS:875(part III)-1987 [wind load], IS:1893-2000 [Earthquake load]. Scale factor is calculated from the design base shear (Vb) to the base shear calculated using fundamental time period (Ta). Once the analysis was completed all the structural components were designed according to Indian standard code IS:456-2000. Footing, columns, beams, slab, staircase and shear wall were designed. Ductile detailing of the structural elements were done as per code IS: 13920-1993.

Keywords: Earthquake, Seismic Analysis, Ductility, ETABS, FEM.

I. INTRODUCTION

Civil engineering is the oldest engineering among all the engineering branches. For the past two decades information technology has bought revolutionary changes in engineering, civil engineering in not exceptional. Many softwares which are useful for civil engineering were developed such as Autocad, Staad, Etabs, SAP200, Midas, Teckla Structures, etc. For analysis design, planning and detailing of the structures. In the contemporary engineering field it is necessary to have strong fundamental knowledge regarding the subject and relative software's for economical and safe design of engineering structures. Therefore, in the present study a G+20 residential Reinforced Cement Concrete (RCC) structure have been analyzed, designed for earthquake loads using software's ETABS 2013, AUTOCAD. Loads coming on to the structure were considered from IS 875:1987 and IS 1893-2002(I) and the structure was designed in accordance with IS 456: 2000.

The objectives of the present study include:

1. Finalized plan and elevation of the structure
2. Analysis and design of structural elements using software's: ETABS 2013
3. Detailing of structural elements using AutoCAD.
4. Study on earthquake response of structure.

Earthquake forces are generated by the dynamic response of the building to earthquake induced ground motion. Thus the earthquake forces imposed are directly influenced dynamic inelastic characteristics of the structure itself. The importance of dynamic effects in structural response depends on the rate of change of external forces and the dynamic properties

of structures. Dynamic responses are stresses, strains, displacement, acceleration etc. The design of buildings for seismic loads
is special, when compares to the design for gravity loads (dead loads and live loads).

Gravity loads are relatively constant, in terms of their magnitude and are treated as 'static loads'. In contrast, seismic loads are predominantly horizontal (lateral), reversible (the forces are back-forth), dynamic (the forces rapidly vary with time) and of very short duration. In order to make a building seismo resistant it should have good building configuration, lateral strength, lateral stiffness, ductility, stability and integrity. Seismic response of different buildings in Fig 1.1.

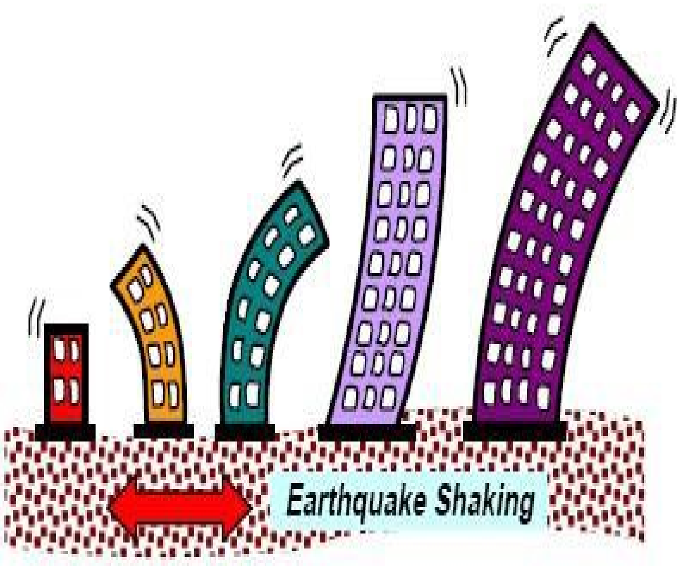


Figure 1. Seismic response of different buildings

In recent years due to the development of design technology and material qualities in civil engineering, the structures (high rise buildings, long span bridges) have become more light and slender. This will cause the structure to develop the initial vibrations. Earthquakes are the Earth's natural means of releasing stress. When the Earth's plates move against each other, stress is put on the lithosphere. When this stress is great enough, the lithosphere breaks or shifts. When the break occurs, the stress is released as energy which moves through the earth in the form of waves, which can be felt and called as an earthquake. There are many different types of earthquake: tectonic, volcanic, collapse and explosion. The type of earthquake depends on the region where it occurs and the geological make-up of that region. The most common are tectonic earthquakes these occurs when the rock in the earth's crust break due to geological forcescreatedby movementof tectonicpla tes. Another type volcanic earthquake occurs in conjunction with volcanic activity. Collapse earthquakes are small earthquakes in underground caverns and mines. Explosion earthquakes results from explosion of nuclear and chemical devices.

BUILDING FREQUENCY AND PERIOD

To begin with the magnitude of the building response that is the accelerations which it undergoes depends primarily upon the frequencies of the input ground motion and the building's natural frequency. In some circumstances, this dynamic amplification to a value two times or more that of the ground acceleration at the base of the building. Generally, buildings with higher natural frequencies, and a short natural period, tend to suffer higher accelerations but smaller displacements. In the case of buildings with lower natural frequencies, and a long natural period, this is reversed the building will experience lower accelerations but larger displacements. When the frequency contents of the ground motion are around the building's natural frequency, it is said that the building and the ground motion are in resonance with one another. Resonance tends to increase or amplify the building's response. Because of this building suffer the greatest damage from ground motion at frequency close or equal to own natural frequency.

II. INTRODUCTION TO STRUCTURAL DESIGN

Exact seismic analysis of the structure is highly complex and to tackle this complexity, number of researches has been done with an aim to counter the complex dynamic effect of seismic induced forces in structures. This re-examination and continuous effort has resulted in several revisions of Indian Standard: 1893 (1962, 1966, 1970, 1975, 1984 and 2002) code of practice on ―Criteria for earthquake resistant design of structures by the Bureau of Indian Standards (BIS), New Delhi. Many of the analysis techniques are being used in design and incorporated in codes of practices of many countries. However, since in the present study our main focus is on the IS a codal provision, the method of analysis described in IS 1893 (Part 1): 2002.

DESIGN LATERAL FORCE

The procedure recommended for the determination of lateral force in IS: 1893-2002(Part 1) performing are based on the approximation that effects of yielding can be accounted for by linear analysis of the building using design spectrum. This analysis is carried out by either equivalent lateral force procedure or dynamic analysis procedure given in the clause 7.8 of IS: 1893-2002 (Part 1). The main difference between the two procedures lies in the magnitude and distribution of lateral forces over the height of the building. In the dynamic analysis procedure, the lateral forces are based on properties of the natural vibration modes of the building which are determined by distribution of mass and stiffness over the height. In the equivalent lateral force procedure the magnitude of forces is based on an estimation of the fundamental period and on the distribution of forces as given by a simple empirical formula that is appropriate only for regular buildings. The following sections will discuss in detail the above mentioned procedures of seismic analysis.

III. RESPONSE0SPECTRUM0METHOD

The response spectrum technique is really a simplified special case of modal analysis. The modes of vibration are determined in period and shape in the usual way and the maximum response magnitudes corresponding to each mode are found by reference to a response spectrum. The response spectrum method has the great virtues of speed and cheapness. There are two major disadvantages of using this approach. First, the method produces a large amount of output information that can require an enormous amount of computational effort to conduct all possible design checks as a function of time. Second, the analysis must be repeated for several different earthquake motions in order to assure that all the significant modes are excited, since a response spectrum for one earthquake, in a specified direction, is not a smooth function.

According to the code, dynamic analysis may be performed using either response spectrum method or the time history method. In either method, the design base shear (VB) is compared with a base shear VB calculated using the fundamental period Ta. It suggests that when VB is less than VB, all the response quantities (for example member forces, displacements, Storey force, Storey shears and base reactions) must be suitably scaled by multiplying with VB/VB. As per IS: 1893-2002 (PART 1) provisions, dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements, for the following buildings:

(a) Regular buildings: Those greater than 40 m in height in Zones IV and V, and those greater than 90 m in height in Zones II and III.

(b) Irregular buildings: All framed buildings higher than 12m in Zones IV and V, and those greater than 40m in height in Zones II and III.

IV. NON0LINEAR0STATIC0ANALYSIS

Pushover analysis is one of the methods available to understand the behavior of structures subjected to earthquake forces. As the name implies, it is the process of pushing horizontally with a prescribed loading pattern incrementally until the structure reaches a limit state [ATC- 40 1996]. The static approximation consists of applying a vertical distribution of lateral loads to a model which captures the material non - linearity of an existing or previously designed structure, and monotonically increasing those loads until the peak response of the structure is obtained on a base shear vs. roof displacement plot. The Selection of Lateral load pattern for a performance evaluation is likely to be more critical than the accurate determination of the target displacement. It plays an important role due to the fact that it is supposed to deform the structure in a similar manner experienced in earthquake occurrence. Conventionally, as shown in fig below an inverted triangular or uniform shape is used consistent with the codified static lateral force distribution but use of adaptive load shape is on the increase. The importance of the loading shape increases when the response is not dominated by the single mode.

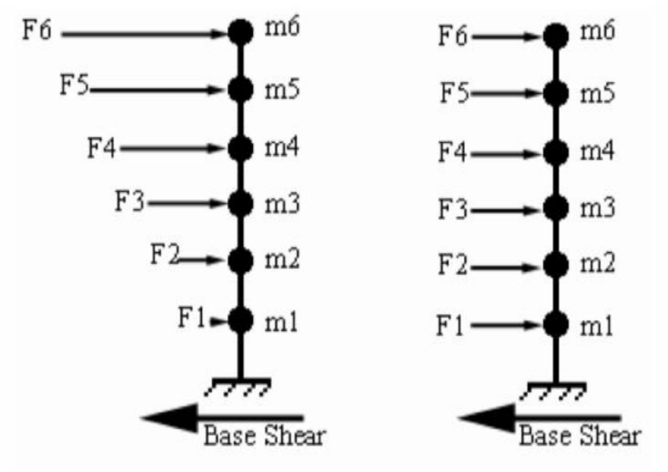


Figure 1. Conventional lateral load distribution

An engineering structure is an assembly of members or elements transferring the load or resisting external actions and providing a form to serve the design function. The structural design is a science and art of designing with economy and elegance. A durable structure, which can safely carry the forces and can serve the desired function satisfactory during its expected service life span.

V. STAGES IN SRUCTURAL PLANNING

Once the type of structure is finalized and planned, design of structure involves the corresponding stage in the planning.

- Column positioning
- Orientation of columns
- Beam location
- Spanning of slabs
- Lay out and planning of stairs
- Type of footings

COLUMN POSITIONING:

Column should perfectly located at or near the corner of building and at intersections of walls because basically the function of the column is to support beams, which are placed under the walls to support them. When the center distance between the intersections of walls is larger or where there are not cross wall, the spacing between the two columns is governed by limitations on span of the beam. As the span of the beam increases. Therefore large span of beam should be avoided for economy reasons and from the consideration of controlling the deflection and cracking.

ORIENTATION OF COLUMNS:

Columns provided in a building are rectangular with width of column not less than the width of the supported beam for effective load transfer. According to requirements of aesthetic and utility, projection of column outside the wall. In the room should be avoided as they not only give bad appearance but also obstruct the usage of corners and create problems in placing furniture flush with the wall. The depth of column should be in the plane of the wall to avoid such offsets. When a column is rigidly connected to beams at rigid angles. It as required to carry moments in additional to axial load in such cases, the column should be so oriented that the depth of column perpendicular to major axis of building so as to get moment resisting capacity.
Also when the effective length of the column in one plane is greater than that in other plane at right angles, the greater dimensions shall be the plane of having larger effective length. The size of columns which has been used for design of residential building are 230*400, 230*450, 230*500, 230*550, 300*550mm and 300*600mm.

POSITION OF BEAMS:

Beams shall normally be provided under the walls or below a heavy concentrated load to avoid these loads directly coming on to slabs. Since beams are primarily provided to support slabs, its spacing shall be decided by the maximum spans of slabs.

SPANNING OF SLABS:

This is decided by the positions of supporting beams or walls. When the supports are only opposite sides or only one direction, when the slab act as a one way supported slab. However the two way action of slab does depend only on the manner in which it supported but also on the aspect ratio or reinforcement in two directions and boundary conditions.

LAYOUT OF STAIRS:

The available size of staircase rooms and positions of beams and column along the boundary of staircase govern the type of stair and its layout.

CHOICE OF FOOTING TYPE:

Among the various types of footings the suitable type of footing required for the structure shall be based on the applied loads, moments. Force and the induced reactions are to ensure that settlement of any kind shall be as uniform as possible. For trained structures\, isolated column footings are usually preferred, except in the case soil with low bearing capacity of soil with low raft foundation is used. If any column of a structure is near to the property line. Combined footing or strap footing may be provided.

VI. DESIGN OF ELEMENTS

WORKING STRESS METHOD:

This method is based on classical elastic theory and basically developed for purely elastic materials. It assumed that the structure made up, viz. concrete and steel provided for the available stresses. IS 456-2000 code of practice specifying different permissible stresses for different materials?

ULTIMATE STRENGTH METHOD:

This method is based on the strength capacity of member just before the collapse stage. In this method safety has been specified with respect to the behavior at the ultimate stage of member are proportioned, to that the full strength of concrete and steel utilized. When the ultimate load occurs on it the ultimate load is obtained by multiplying the working load by a factor known as load factor.

LIMIT STATE METHOD:

Limit state method of design is adopted in the design of all the component of the structure. From observations it is found that M20 is most economical and suitable grade of concrete for the structure with T or 40 steel for reinforcement. For the design IS456-2000, SP-16 and national building code have been followed. In this method of design based on limit state concept, the structure shall be designed to withstand safely all loads liable to act on it throughout its lifespan. It shall also satisfy the serviceability requirements, such as limitations on deflections and cracking. The acceptable limit for the safely and serviceability requirements before failure occurs is called limit state. The aim of design is to achieve acceptable probabilities that the structure will not become unfit for the use for which it is intended, i.e, that it will not reach a limit state.

LIMIT STATE OF COLLAPSE:

The limit state of collapse of the structure or part of the structure could be assessed from rupture of one or more critical sections and from bucking due to elastic or plastic in stability (including the effects of sway wherever appropriate) or over turning. The resistance to bending shear, torsion and axial loads at a section shall not be less than appropriate value at that section procedure by the probable most unfavorable combinations of loads on the structure suing the appropriate partial safely factors.

VII. DESIGN OF BEAMS

A reinforced concrete beam should be able to resist tensile, compressive and shear stresses as induced in it by the loads on the beam. Concrete is fairly strong in compression but very weak in tension. The plain concrete beams are thus limited in carrying capacity by the low tensile strength. Steel is very strong in tension, thus the tensile weakness of concrete is overcome by the provision of reinforcement in tension zone to make a reinforced concrete beam. Mulim of the given section is calculated and is compared with the maximum bending moment of the section. If Mulim is greater than Mu, the section is designed as singly reinforced section. If Mulim is less than Mu , the section is designed as a doubly reinforced section. Mu /bd2 is calculated and percentage of steel is required in tension and compressions corresponding to grade of steel are obtained from SP 16-1980.

SINGLY REINFORCED BEAMS:

In singly reinforced simply supported beams reinforcing steel bar are placed near the bottom of the beam where they are most effective in resisting the tensile bending stresses. In singly reinforced cantilever beams steel is placed near the top of the beam for the same reason.

DOUBLY REINFORCED BEAMS:

A doubly reinforced beam is reinforced in both compression and tension regions. The section of the beam may be rectangle or T/L in shape. The necessity of using steel in the compression region arises due to two main reasons.

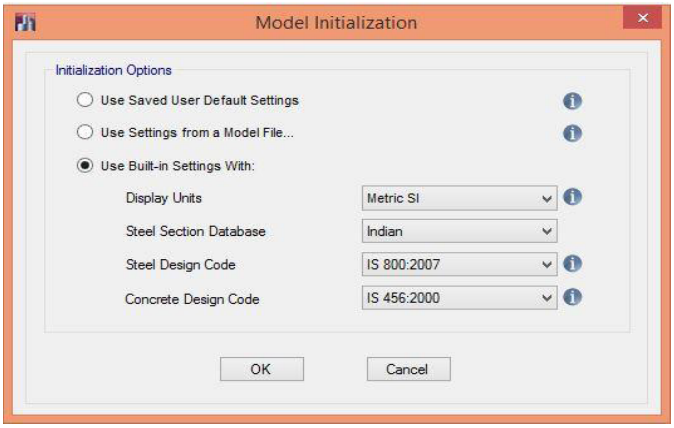
FLANGED BEAMS:

In most of R.C structures, concrete slabs and beams are cast monolithic. Thus beams form a part of the floor system together with the slab. In bending slab forming the part of the beam at mid span would be in compression for a width greater than the width of the rib, thus increasing the moment of resistance for a given rib width. At continuous supports, the position is reversed, the slab is in tension and part of the rib is in compression. Since concrete is assumed to have cracked in tension, this beam is equivalent to a rectangular section at the supports.

VIII. MODELLING AND ANALYSIS

DEFINE GEOMETRY:

The Building Plan Grid System and Storey Data form is used to specify horizontal and vertical grid line spacing, storey data, storey elevation and units. They automatically add the structural objects with appropriate properties to the model.



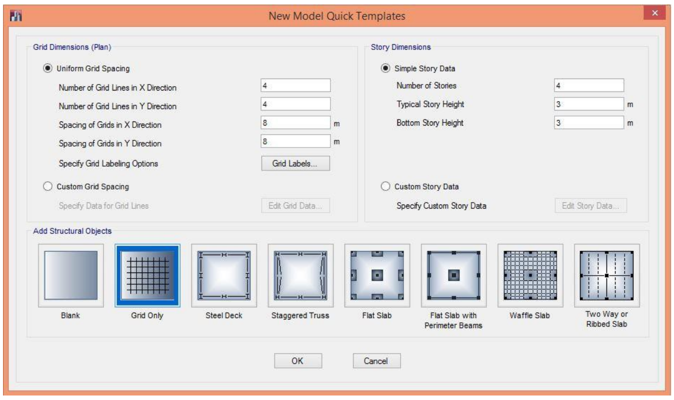
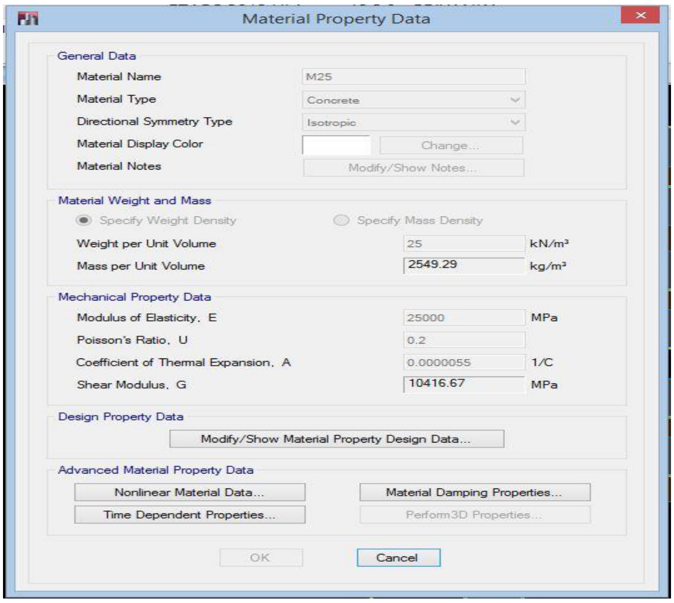
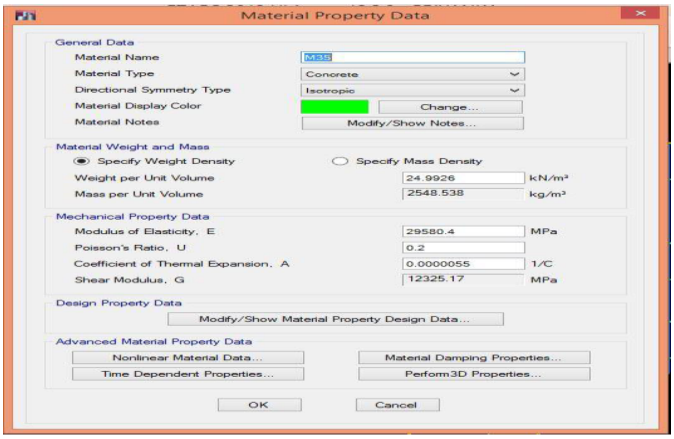


Figure 1 & 2 - Building Plan Grid System and Storey Data Definition

DEFINE MATERIAL PROPERTY:

The material properties of each object in the model are specified in the appropriate form. The material used is concrete, the grade of concrete, the properties of concrete such as Mass per unit volume, Modulus of Elasticity of concrete, Poisson ratio are specified and for steel yield strength is specified.





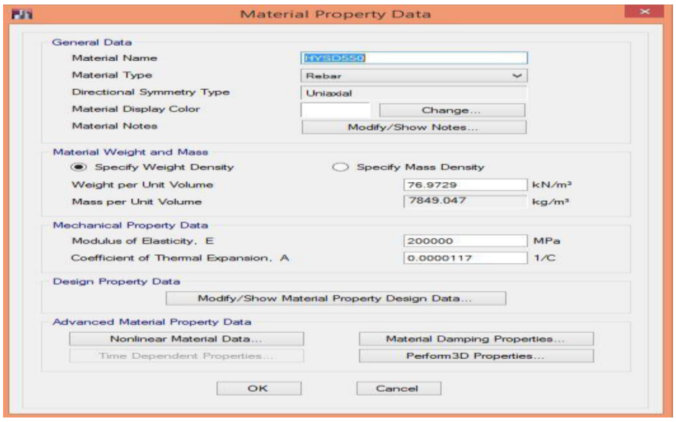
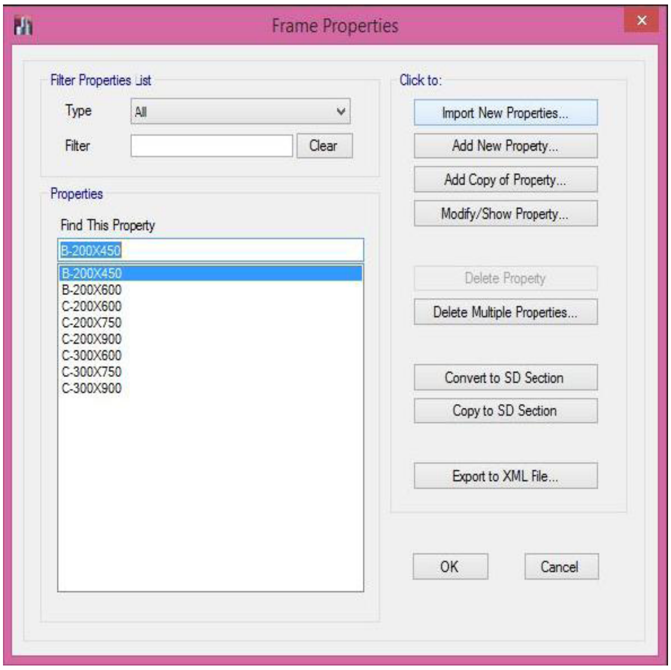
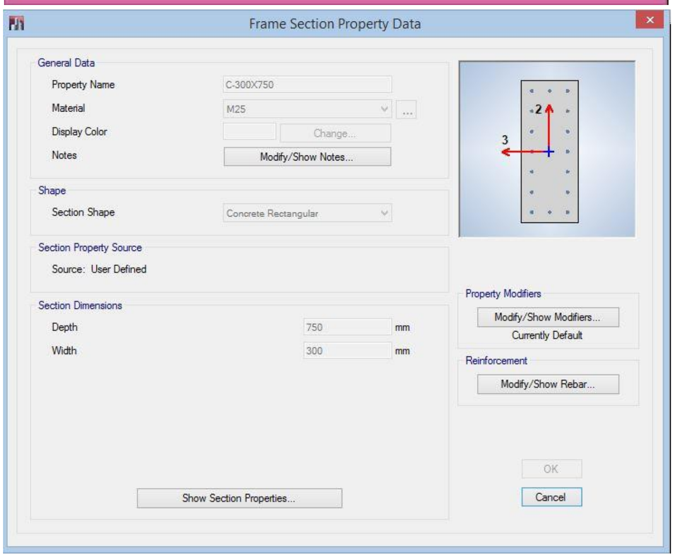


Figure 3, 4 & 5 - Material property data form.

DEFINE FRAME SECTION:

Assign the frame section such as Column and beam. Select the section property as Rectangle and define the depth, width and reinforcement details, cover provisions. Similarly for various sections like circular pipe, steel joist sections also assigned with suitable data.





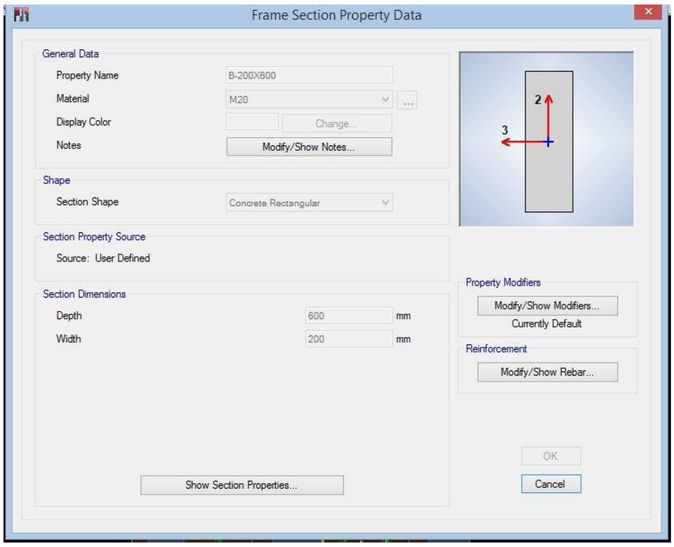
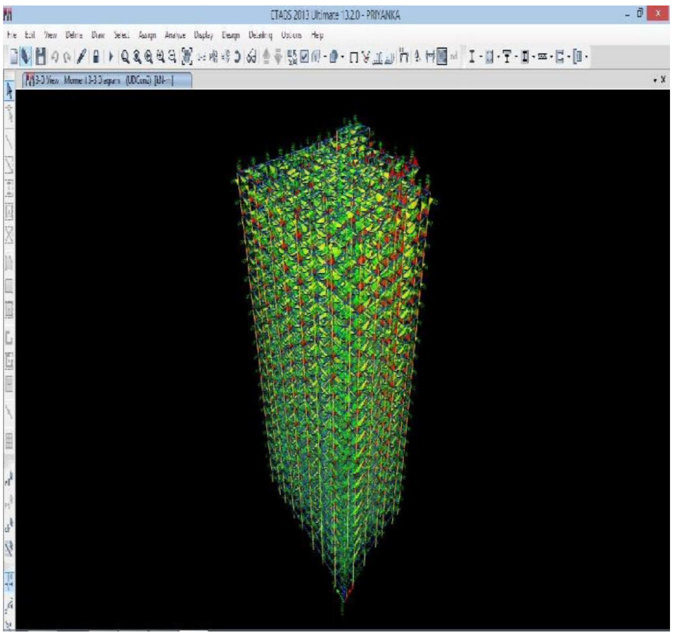
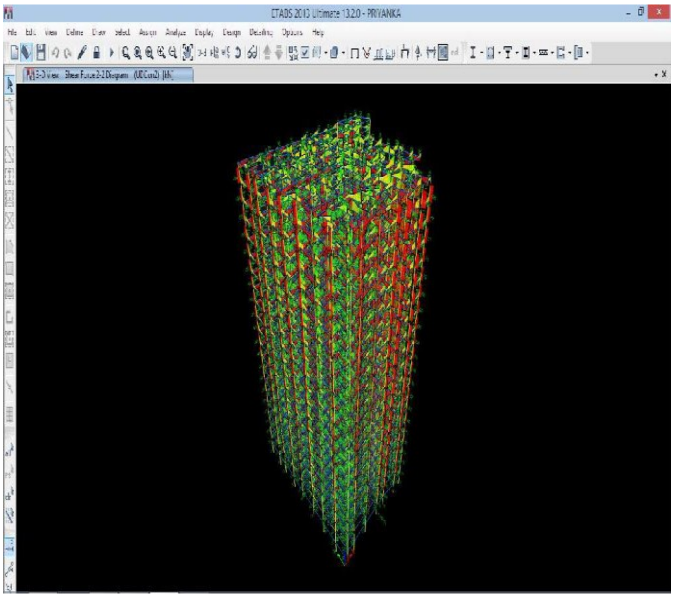


Figure 6, 7 & 8 Section properties and Reinforcement details.

BENDING MOMENT DIAGRAM FROM ANALYSIS



SHEAR FORCE FROM ANALYSIS



IX. CONCLUSION

The New Residential building was designed with the earthquake resistant design consideration. Seismic analysis and design were done by using ETABS software. The detailing of the structural elements were done as per IS 13920-1993 (Ductile detailing for Earthquake resistant structures). To conclude a complete design involving several parameters so as to result the earthquake has been done.

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