Analysis and Design of Multi-storeyed building using Autodesk Robot Structural Analysis Professional 2016

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Abstract-Today all the structures even from 10m to the large sky scrapers like the BhurjKhalifa are designed with the help of software's to save time, achieve precession, bring economy and optimization. This leads us to design the multi storey building using Autodesk Robot Structural Analysis Professional 2016.The project consists of the design of multi-storey (G+10) building using Autodesk Robot Structural Analysis Professional 2016. The main objective of the project is to analyze the building for different load conditions and then design the structure to sustain these loads by some margin of safety. To fulfill these objectives, the irregular shaped residential building was taken for study. The location for this project is considered as Pune. The modal of whole building was developed in Autodesk Robot Structural Analysis 2016, then the loads are applied according to Indian Standards (IS 875(Other than seismic) and IS 1893(Seismic)). The behavior of the structure was then examined and analyzed in the software and finally the various structural members were designed accordingly. At last the random sample members were checked by manual calculations

Keywords— seismic analysis, base shear ,deflection, story, drift

I. INTRODUCTION

In current century the large number of land parcels are get converted into pro parties due to large population that is horizontal space is now getting exhausted completely. Now the situation is arisen that almost 90% useful land is covered with the development of infrastructures but still peoples are in search of shelter because the horizontal development proves to be inadequate for such a huge population. This leads to the idea that there is infinite space in vertical direction which can be used freely but the job was not as simple as it seems. But structural engineers make it possible and developed the structure from 20m height to 820m height. This development is not only for breaking the record but also for making the strong enough h safe structure which can prevent the loss from natural calamities, environmental conditions, terrorist attacks, etc. This cannot be done until proper analysis of structure which is to be brought in real life. Analysis is not enough alone, with that proper design is also important. Hence the design and analysis are the scientific art of evaluating the all possible worst condition that structure can face during its life cycle and finding the solution to prevent the structure from the effect of these conditions by deciding some structural geometries inside the structure.

1.1 Software available choice of software

Now a days accuracy is not the problem as all software's give fair results and hence the accuracy of the results became secondary criteria to choose the software package. The selection of software application is mainly based on the unique features it offers, reputation, service, and support to the local conditions. Also the software's are not cheap in cost and hence firm has to invest high capital in software's, hence the value of software is very essential thing. Hence the software which offers more features in same cost are look forward for selection. The software's available in market for analysis and design are ETABS, SAP, Robot Structural Analysis, Staad Pro, RISA 3D, CSC Struds, Nucleus RC 3D, NISA, Tekla Structural Designer, etc.

1.2 Robot Structural Analysis

Autodesk Robot Structural Analysis Professional software provides a scalable, country-specific analysis solution for the structural engineer to analyze many types of structures, including buildings, bridges, civil, and specialty structures.

Autodesk Robot Structural Analysis Professional calculates a wide variety of structures with a comprehensive collection of design codes, delivering results in minutes, not hours. This structural engineering software is versatile enough for simple frame or complex finite element analysis, steel and reinforced concrete design and offers seamless interoperability with other Autodesk structural engineering products or third-party applications.

Autodesk Robot Structural Analysis Professional provides flexibility in obtaining analysis results. Review results as visualizations and raw data in varying outputs, including detailing. The Wind loads simulation option allows you to simulate a wind flow around your structure, and generate wind loads automatically.

This can simulate and generate wind loads directly in Robot, and it can export your structure to Autodesk Simulation CFD if the program. This wind simulation technology acts as a wind tunnel, and enables you to visualize colored pressure maps on your model in order to understand the effects of the wind even with complicated structures.

II. MODELING IN ROBOT STRUCTURAL ANALYSIS

2.1 Working with Robot Structural Analysis

i Set the Job Preferences
ii Defining materials and their properties
iii Creating grids and storey levels
iv Defining trial Sections of members.
v Placing of members to its respective positions.
vi Verification for geometric imperfections
vii Defining load cases.
viii Applying loads on members in structure
ix Defining load combinations or auto load combinations
x Analyzing the model for worst combinations
xi Setting up design parameters for different members such as column, beams, slabs,etc.
xii Determining required reinforcement for members
xiii Providing reinforcement as per user choice and finalizing the design.
xiv Drafting final drawing for members.

The most important step in the project was modeling of the structure. The structure was having 10 floors along with parking and head room.

There are two types of the structure.
Regular Structure
Irregular Structure

In the regular structure, all frames parallel to each other are same. Many times regular structures are symmetrical about its axes. Grid layouts, Circular concentric layouts are considered as regular structure. The analysis of such structures are not complex and hence analysis and modeling of such structures are very easy.

III. SEISMIC LOAD

3.1 Design Lateral Force

The design lateral force shall first be computed for the building as a whole. This design lateral force shall then be distributed to the various floor levels. The overall design seismic force thus obtained at each floor level shall then be distributed to individual lateral load resisting elements depending on the floor diaphragm action.

3.2 Design Seismic Base Shear

The total design lateral force or design seismic base shear (V_b) along any principal direction shall be determined by the following expression:

$$V_b = A_h \times W$$

Where,

A_h = horizontal acceleration spectrum
W = seismic weight of all the floors

Fundamental Natural Period

$$T_a = 0.075 \ h^{0.75} \text{ for RC frame building}$$
$$T_a = 0.085 \ h^{0.75} \text{ for steel frame building}$$

Where,

h = Height of building, in m

This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But it includes the basement storeys, when they are not so connected.

The approximate fundamental natural period of vibration (T_a) in seconds, of all other buildings, including moment-resisting frame buildings with brick lintel panels, may be estimated by the empirical Expression:

$$\mathbf{Ta = \frac{0.09h}{\sqrt{D}}}$$

Where,

h = Height of building
d = Base dimension of the building at the plinth level, in m, along the
considered direction of the lateral force

3.4 Distribution of Design Force

Vertical Distribution of Base Shear to Different Floor Level The design base shear (V) shall be distributed along the height of the building as per the following expression:

$$\mathbf{Qi = Vb * \frac{Wihi^2}{\sum Wihi^2}}$$

Where,

Q_i = Design lateral force at floor i,
W_i = Seismic weight of floor i,
h_i = Height of floor i measured from base, and
n = Number of bays in the building is the number of levels at which the masses
are located.

Distribution of Horizontal Design Lateral Force to Different Lateral Force Resisting Elements in case of buildings whose floors are capable of providing rigid horizontal diaphragm action, the total shear in any horizontal plane shall be distributed to the various vertical elements of lateral force resisting system, assuming the floors to be infinitely rigid in the horizontal plane. In case of building whose floor diaphragms cannot be treated as infinitely rigid in their own plane, the lateral shear at each floor shall be distributed to the vertical elements resisting the lateral forces, Considering the in-plane flexibility of the diagram.

Table3.1 Factors considered for seismic analysis of given Building

Parameter	Value	Remark
Zone	3	Seismic Zone of India IS:1893
Zone Factor (Z)	0.16	Clause 6.4.2 & Table 2 IS:1893

Response reduction Factor	*3*			*Ordinary RC moment-resisting frame. Table 7 IS:1893*	
Importance Factor	*1*			*Ordinary Building Table 6 IS:1893*	
Damping Ratio	*0.05*			*Considering 5%damping*	*Factor=1*
Fundamental natural Period	T_{ax}	T_{ay}		$Ta = \dfrac{0.09h}{\sqrt{D}}$	
	0.69sec	*0.97sec*			
Type of Analysis	*Dynamic Analysis*			*Response Spectrum*	
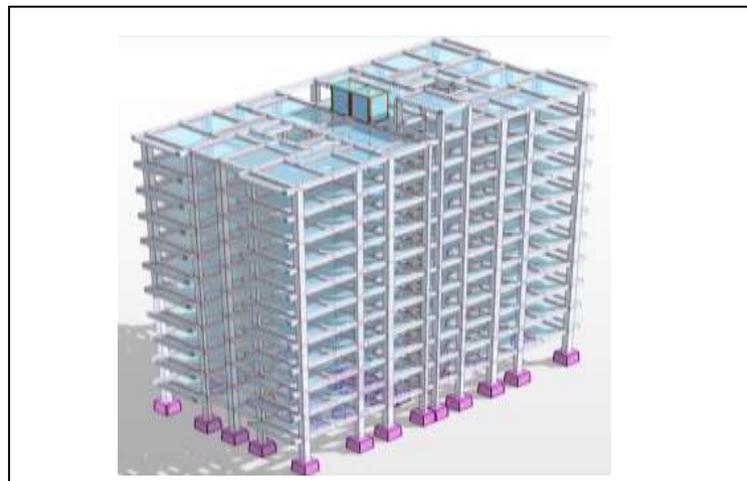
Fig 3.1 Robot Structural Analysis Model

IV. SESMIC FORCE CALCULATION

4.1 Steps for calculation
Step 1 calculation of various design parameters
Referring IS 1893:2002 part 1
Pune come under zone III
Hence Z = 0.16   from table 2 of IS 1893:2002
Importance factor (I) for residential building   from table 6 of IS 1893:2002
Step 2 calculation on time period building with brick infill
Ta = Fundamental natural period

$$Tax = \frac{0.09\ h}{\sqrt{d}}$$
$$Tax = \frac{0.09 * 42}{\sqrt{32.5}}$$

$$= 0.66$$
$$Tay = \frac{0.09 * 42}{\sqrt{15.9}}$$
$$= 0.94$$

For soft soil

$$\frac{Sa}{g} = \frac{1.36}{T}$$
$$\frac{Sa}{g} = 2.06$$

Step 3 calculation of design horizontal seismic coefficient (Ah)
Using clause 6.4.2 of   IS 1893:2002 part 1

$$Ah = \frac{Z}{2} * \frac{I}{R} * \frac{Sa}{g}$$

$$Ah = \frac{0.16}{2} * \frac{1}{3} * 2.06$$
$$= 0.054$$

Step 4 Calculation of seismic weight (w)
Self weight of beam
Main beam = (c/s area) x (length) x (Density)
= (0.4 x 0.6) x (209.9) x (25)
           = 1259.4
Secondary beam = (c/s area) x (length) x (Density)
= (0.3 x 0.5) x (59.57) x (25)
               = 223.38
Tertiary beam   = (c/s area) x (length) x (Density)
= (0.3 x 0.4) x (19.2) x (25)
             = 57.6
           Total self weight of beam = 1540.38 KN
Self weight of slab = (plan area) x (thickness) x (density)
= (431.26) x (0.200) x (25)
                 = 2156.3 KN
Self weight of column
Self weight of column = (c/s area) x (height) x (density) x (no. of column)
               = (0.6x 0.6) x (3.5) x (25) x (11)
               = 346.5 KN
Self weight of column = (c/s area) x (height) x (density) x (no. of column)
               = (0.4x 0.6) x (3.5) x (25) x (25)
               = 525 KN
Self weight of column = (c/s area) x (height) x (density) x (no. of column)
               = (0.3x 0.6) x (3.5) x (25) x (4)
               = 63 KN

Total self weight of column   = 934.5 KN

   Weight of water tank
= area x height x density
= 20 x 3.5 x 25
= 1750 KN
 Weight of head room   = (height) x (length) x (thickness) x (density)
                   = 3.5 x 175 x 1.7 x 0.300 x 25
                   = 312.375 KN
 Dead load of roof floor   = (wt. of slab) + (wt. of beam) + (wt. of column) +
                   (wt.of water tank) + (wt. of head room)
                  = (2156.3) + (1540.38) + (934.5) + (1750) + (312.375)

g) dead load of each floor = (wt.of slab) + (wt.of beam) + (wt. of column)
= (2156.3) + (1540.38) + (934.5)

$$= 4631.18 \text{ KN}$$

According to IS 1893:2000 clause 7.3.1 (table 8) 25 % of live load is added

h) Live load on each floor = plan area x 25% of LL

$$= (431.26) \times (3 \times 25/100)$$
$$= 323.445 \text{ KN}$$

Seismic weight of building on each floor

$$= \text{dead load} + \text{live load}$$
$$= 4631.18 + 323.445$$
$$= 4954.625 \text{ KN}$$

Seismic weight of each floor = 4954.625 KN
Seismic weight of roof floor = DL + LL = 6693.555 KN

Total seismic weight of building =[(no.of floors excluding roof floor) X
(seismic weight of each floor)] + (weight of roof floor)

$$= (11 \times 4954.625) + (6693.555)$$

= 61194.43 KN

4.1.1 determination of design seismic base shear (v$_b$)

$V_B = Ah * W$
  = 0.054 X 61194.43
  = 3304.499 KN

Step 6 Determination of design lateral force (Qi)

$$Qi = Vb * \frac{Wihi^2}{\sum Wihi^2}$$

storey	weight	height	$Wihi^2$	$\frac{Wihi^2}{\sum Wihi^2}$	Qi $= Vb * \frac{Wihi^2}{\sum Wihi^2}$
12	2062.375	42	3638029.5	0.099	325.5594
11	6693.55	38.5	9921514.49	0.269	887.85489
10	4954.625	35	6069415.63	0.164	543.13889
9	4954.625	31.5	4916226.66	0.133	439.9425
8	4954.625	28	3884426	0.105	347.60889
7	4954.625	24.5	2974013.66	0.081	266.13805
6	4954.625	21	2184989.63	0.059	195.53
5	4954.625	17.5	1517353.91	0.041	135.78472
4	4954.625	14	971106.5	0.026	86.902222
3	4954.625	10.5	546247.406	0.015	48.8825
2	4954.625	7	242776.625	0.007	21.725555
1	4954.625	3.5	60694.1563	0.002	5.4313889

			36926794.1	3438.6 KN

Table 6.1   seismic base shear (V_B)

By Manual calculation = 3438.6 KN

By software $= \dfrac{sum\ fY}{no.of\ story} = \dfrac{41444.34}{12} = 3453.7$ KN

V. CONCLUSION

i) The Autodesk Robot Structural Analysis proved that it is versatile and the most powerful tool for designing and analysing the structure with its advance features like wind simulation, phase construction and detailing.

ii) In phase of seismic analysis the result obtained by manual calculation and the and Autodesk Robot Structural Analysis 2016 are approximately same

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