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Linear Dynamic Analysis of High-Rise Building Using Etabs

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ABSTRACT: This research paper describes the results of linear dynamic analysis on the P+12 storey structure based on concept of Response Spectrum Method. In 3D analytical model of P+12 storied building have been generated for symmetric building models and analysed using structural analysis tool Etabs. The analytical model of the building includes all important components that influence the maximum displacement, maximum story drift, story stiffness, maximum story displacement of the structure. The total 2 types of models are analysed and compared 1 with Response Spectrum Method (Fixed support condition) and 1 with Response Spectrum Method (Flexible support condition) the main parameter of the seismic analysis of structure are load carry capacity, ductility, stiffness, damping and mass. The various response parameter like maximum story drift, story stiffness, maximum story displacement and the maximum displacement of the structure etc are calculated.

Keywords — Response Spectrum Method, Etabs, Maximum Story Drift, Story Stiffness, Maximum Story Displacement, Maximum Displacement.

I. INTRODUCTION

All over world, there is huge demand for construction of high-rise buildings due to increasing population Earthquake resistant design of engineering structures is one of the most important method of damage from future earthquake. The earthquake design of structure is based on the specification of ground motion of previous earthquake results. So, earthquake resistant design of any important structure according to the seismic frequency is very important to overcame from damage. However, the earthquake forces are different and un predictable .so the software tools need to be used for analyzing structures under any seismic forces.

Earthquake develops different intensities at different locations and the damage induced in buildings at these locations is also different according to the type of structure. Therefore, it is Necessary to study the seismic behavior of RC framed building for different seismic intensities.

The seismic intensities in terms of various responses such as base shear, lateral displacement. Different types of analysis are used to identify the seismic resistance and behavior of building under applied seismic frequencies.

The analysis can be performed on the basis of external applied loads, applied structural materials and type of structure, the analysis is classified as 1). Linear static Analysis 2) Nonlinear static analysis 3) Linear Dynamic Analysis 4) Nonlinear Dynamic Analysis.

The Time history analysis is response of the structure including inertial effects, this is advanced to response spectrum analysis, and gives base acceleration, displacement, and duration.

This is useful for very high-rise structures to know the behavior of structure under any seismic attacks. This analysis requires previous earthquake data to perform the analysis. It is a step-by-step analysis of response of structure under specified load that may vary with time.

Determination of earthquake demand on the structure is one of the challenging jobs in the field of structural engineering. Lot of research is carried out in this area to propose simplified methods that will predict results with reasonable accuracy. It was found that except detailed nonlinear time history analysis, the available methods have limited areas of the application and cannot be used for all types of buildings. Structural response to earthquakes is a dynamic phenomenon that depends on dynamic characteristics of structures and the intensity, duration and frequency content of the existing ground motion. Although the seismic action is dynamic in nature, building codes often recommend equivalent static load analysis for design of earthquake resistant buildings due to its simplicity. This is done by focusing on the predominant first mode response and developing

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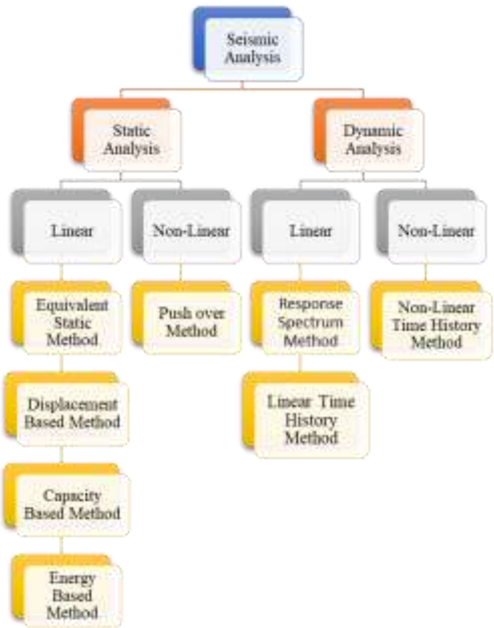
equivalent static forces that produce the corresponding mode shape, with some empirical adjustments for higher mode effects. The use of static load analysis in establishing seismic design quantities is justified because of the complexities and difficulties associated with dynamic analysis. Dynamic analysis becomes even more complex and questionable when nonlinearity in materials and geometry is considered. Therefore, the analytical tools used in earthquake engineering have been a subject for further development and refinement, with significant advances achieved in recent year. Despite the aforementioned concerns over the use of dynamic analysis in seismic design, it is used in practice to carry out special studies of tall buildings and irregular structures because of its superiority in reflecting seismic response more accurately, when used properly. These studies often include a large amount of analysis under different ground motion record and different structural parameters to provide insight into the structural behavior. With the advent of personal computers and the subsequent evolution in information technology, coupled with the extensive research in nonlinear material modelling, more reliable computational tools have become available for use in design of buildings.

Static Analysis: - Seismic load and design earthquake motion. For ordinary buildings, an equivalent static load is calculated using a response spectrum method and is to be used for static stress analysis (this series of procedure may be referred to as the equivalent static analysis).

Dynamic Analysis: - Dynamic analysis procedures are categorized as either linear (elastic) dynamic analysis, consisting of the elastic modal response spectrum method or the numerical integration linear time history method, or nonlinear (inelastic) response history analysis. While both linear and nonlinear analyses require careful analytical modelling, the latter requires additional considerations for proper simulation of hysteretic response and necessitates a special study that involves detailed review of design and supporting analyses by an independent team of engineers.



II. BASIC TERMINOLOGY

Design Horizontal Seismic Design coefficient (A_h):

The design horizontal seismic coefficient Ah for a structure shall be determined by the following expression:

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{Sa}{g}$$

Provided that Ah will not be less than Z/2 for T ≤ 0.1 sec. whatever be the value of I/R. Sa / g depends upon the time period and the site condition. For the calculation of the earthquake forces by seismic coefficient method the soils are divided in three categories hard, medium and soft.

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Fundamental natural period (T):
The approximate fundamental natural period of vibration (**T),** in seconds, of a moment-resisting frame building without brick infill panels may be estimated by the empirical expression:
T = 0.075 sec …………. for RC frame building
T = 0.085 sec…………. for steel frame building
Were,
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) in seconds, of all other buildings, including moment resisting frame buildings with brick infill panels, may be estimated by the empirical expression.

$$T_a = 0.0075 \times h$$

Seismic Weight:
The seismic weight of each floor is taken as its full dead load and appropriate amount of imposed load as given below. The seismic weight of each floor is worked out by distributing equally the weights of walls and columns in any storey to the floor above and below that storey.
Seismic weight of building is the sum of seismic weights of all the floors.

Importance factor:
The structures are assigned an importance factor depending upon the functional use of the structure, characterized by hazardous consequences of its failure and its post-earthquake need etc.

Response Reduction Factor:
Depending upon the perceived seismic damage performance the structure can give based on the ductile or brittle deformation the factors called as response reduction factors is defined.

Design Seismic base shear:
The total design lateral forces or the design base shear (V_b) along any principal direction shall be determined by the following expression.
$V_b = A_h W$

Distribution of Design force
The design base shear (V_b)computed by the above equation shall be distributed along the height of the building as per the expression given below.

$$Q_i = V_b \frac{W_i h_i^2}{\sum_i^n W_i h_i^2}$$

Where,
Q_i = Design lateral force at floor i
Wi= Seismic weight of floor i
hi = Height of floor i measured from base
n = Number of storeys in the building is the number of levels at which the masses are located.

Dynamic Analysis Procedure:
IS 1893(Part I)-2002 has recommended the method of dynamic analysis of building in section 7.8 in the case of a) Regular building – those higher than 40m height in Zones IV and V, and those higher than 90m in height in zones II and III. b) Irregular building – all framed building higher than 12m in zone IV and V, and those higher than 40m in height in zones II and III. The purpose of dynamic analysis is to obtain the design seismic forces, with its distribution to different levels along the height of the building and to the various lateral loads resisting element similar to equivalent lateral force method. The procedure of dynamic analysis described in the code is valid only for the regular type of building, which is almost symmetrical in plan and elevation about the axis having uniform distribution of the lateral load resisting element. It is further assumed that all the masses are lumped at the storey level and only way displacement is permitted at each story.

Response Spectrum Method:
In order to perform the seismic analysis and design of a structure to be built at a particular location, the actual time history record is required. However, it is not possible to have such records at each and every location. Further, the seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depend upon the frequency content of ground motion and its own dynamic properties. To overcome the above difficulties, earthquake response spectrum is the most popular tool in the seismic analysis of structures. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode of vibration using smooth design spectra that are the average of several earthquake motions. This chapter deals with response

spectrum method and its application to various types of the structures. The codal provisions as per IS 1893(Part 1)-2002 code for response spectrum analysis of multi-story building is also summarized.

In this method the load vectors are calculated corresponding to predefined number of modes. These load vectors are applied at the design centre of mass to calculate the respective modal responses. These modal responses are then combined according to square root of the sum of the squares (SRSS) or complete quadratic combination (CQC) rule to get the total response. From the fundamentals of dynamics, it is quite clear that modal response of the structure subjected to particular ground motion, is estimated by the combination of the results of static analysis of the structures subjected to corresponding modal load vector and dynamic analysis of the corresponding single degree of freedom system subjected to same found motion.

Static response of MDOF system is then multiplied with the spectral ordinate obtained from dynamic analysis of SDOF system to get that modal response. Same procedure is carried out for other modes and the results are obtained through SRSS or CQC rule.

In response spectrum analysis the spectral values are read from the design spectrum which are directly multiplied with the modal load vector and the static analysis is performed to determine the corresponding modal peak responses. This method is known as the classical modal analysis.

Etabs:

ETABS is one of the most powerful software tools for structural analysis. 3D modeling, visualization, and automatic code-based learning are some of the unique features of this software. ETABS also supports several analytical models like response spectrum analysis, time-history analysis, and line direct integration time-history analysis. ETABS is engineering software which is used to analysis and design multi-storey building. ETABS stands for Extended Three-Dimensional (3D) Analysis of Building Systems. CAD drawings can be converted directly into ETABS models or used as templates in which ETABS objects may be overlaid. Report is generated directly in the software with complete reinforcement details. Many of the floor levels in buildings are similar which reduce modelling and design time. Fast model generation using the concept of similar stories. Different materials can be assigned to the structural elements within the same model such as steel, RCC, composite or any other user-defined material.

III. METHODOLOGY

The study is carried out for the behavior of P+12 storied RC bare frame model RC bare frame model (P+12) are developed using ETAB with M25 grade concrete for beams, M25 grade concrete for columns and Fe 500 Mpa grade of steel for reinforcement are taken as material properties. Dead load and Live load acting on the frame are taken as per IS 875 (Part1) and IS 875 (Part 2), codal provisions respectively. and zone IV of IS 1893 (Part 1 2002) is considered in the development of RC frame models.

- **Modal Description**

Plan	52.6 X 20.23M
Number of stories	P+12
Height of each storey	3M
Plinth height above GL	2M
Support condition	Fixed/Flexible
Total height of building	41M

- **Material Properties**

Sr. No	Design Parameter	Value
1	Unit weight of concrete	25 kN/m3
2	Unit weight of Infill walls	18kN/m3
3	Characteristic Strength of concrete	25 MPa
4	Characteristic Strength of concrete	415 MPa
5	Compressive strength of strong masonry (Em)	5000MPa
6	Compressive strength of weak masonry (Em)	350MPa
7	Modulus of elasticity of Masonry Infill walls (Em)	750f'm
8	Damping ratio	5%
9	Modulus of elasticity of steel	2E5 MPa
10	Frame Type	Special Moment Resisting Frame
12	Slab thickness	150 mm
13	Wall thickness	230 mm

- **Member Properties**

Beam	200 x 600 mm
Column	300 x 900 mm
Shear wall thickness	250mm
Beam cover	40mm
Column cover	40mm
Thickness of brick wall	Outer 230mm Inner 150mm
Slab thickness	125mm
Height of parapet wall	1.2m

- **Seismic Design Data**

Sr. No.	Content	Description
1	Type of structure	Special moment resistant frame
2	Response Reduction Factor	5
3	Seismic zone	III
4	Zone factor	0.16
5	Importance factor	1.2
6	Damping ratio	5%
7	Soil type	Hard/Medium/Soft soil

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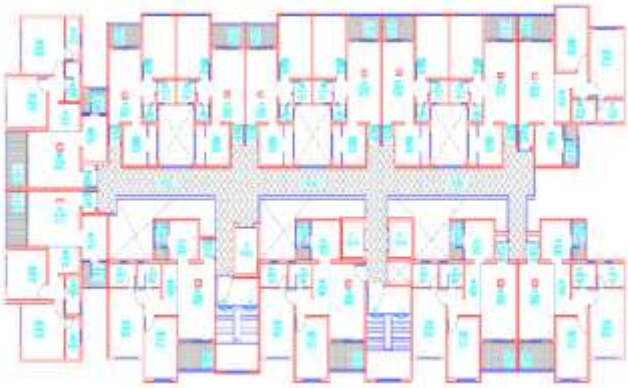
- **Structural Elements**

1. Beam: 230 mm x 600 mm
2. Column: As per axial load mm
3. Slab thickness: 125/150 mm
4. Wall thickness :150 mm
5. Parapet height :1200 mm
6. Founding depth: 1500 mm

- **Typical Plan layout: -**



IV. ANALYSIS RESULTS

This chapter represents the obtained results by analysis of different structure in Etab software. Total 2 types of models are analyzed 1 with response spectrum method (fixed support condition) and 1 with response spectrum method (flexible support condition) results are display in tabulated and graphical.

In first phase comparison is made for part-01 and part-02 models.
Part-01 Response spectrum analysis with fixed support condition
Model 1: Model with bare frame with infill wall having hard soil type

Part-02 Response spectrum analysis with flexible support condition
Model 1: Model with bare frame with infill wall having hard soil type

Maximum displacement Results: -

Displacement is studied for EQX, EQY, SPECX, WINDX and WINDY load case and results are calculated tabulated below. Following table and graph represent comparison for model -1 of part-01 and part-02 for soil-I
FL- Flexible support condition
FF- Fixed support condition

DISPLACEMENT FOR SOIL TYPE-I		
	FL BASE	FF BASE
EQX	74.87	64.68
EQY	38.13	31.07
SPECX	12.77	11.76
SPECY	11.14	9.92
WX	8.5	7.18
WY	18.32	14.66

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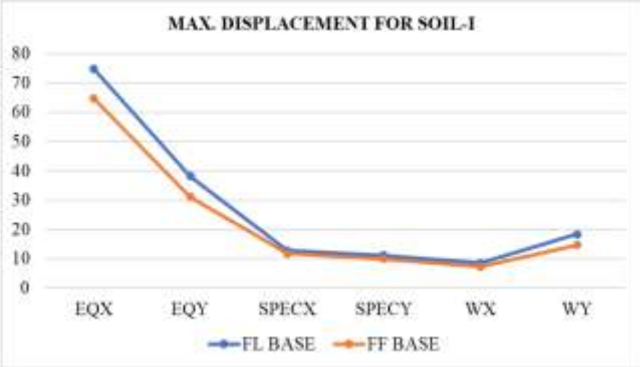


Discussion: -

Above results are for soil type-I condition.

As shown in the above graph, story displacement for flexible support condition is more as compared with fixed support condition.

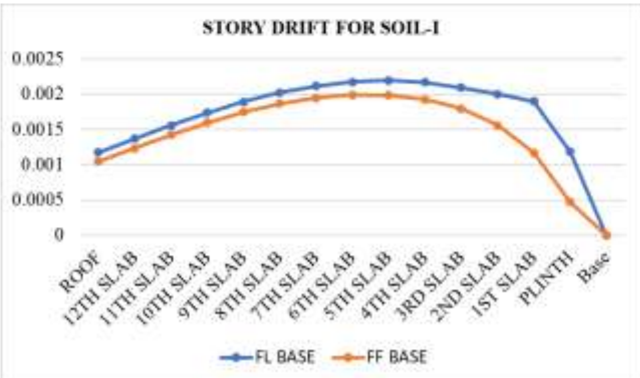
Specification for flexible support condition is taken from soil type report.

Maximum story drift

Results: -

Displacement is studied for EQX and EQY load case and results are calculated and tabulated below. Following table and graph represent comparison of story drift for model-1 of part-01 and part-02 for soil I

STORY	FL BASE	FF BASE
ROOF	0.001177	0.001043
12TH SLAB	0.001369	0.001234
11TH SLAB	0.001561	0.001424
10TH SLAB	0.001739	0.001597
9TH SLAB	0.001896	0.001747
8TH SLAB	0.002023	0.001866
7TH SLAB	0.002117	0.001948
6TH SLAB	0.002175	0.001989
5TH SLAB	0.002195	0.001986
4TH SLAB	0.002172	0.001928
3RD SLAB	0.002097	0.001797
2ND SLAB	0.002004	0.001559
1ST SLAB	0.001899	0.001167
PLINTH	0.001188	0.000472
Base	0	0



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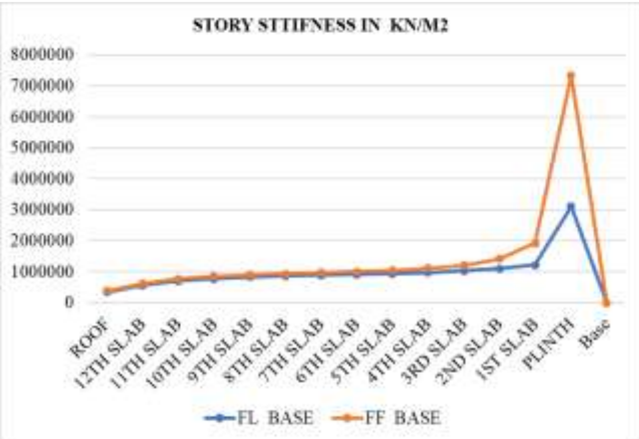
Discussion:-
Above results are for soil type-I condition.
As shown in the above graph, story drifts for flexible support condition are more as compared with fixed support condition.

Story Stiffness
Results: -
Displacement is studied for EQX and EQY load case and results are calculated and tabulated below. Following table and graph represent comparison of story stiffness for model-1of part-01 and part-02.

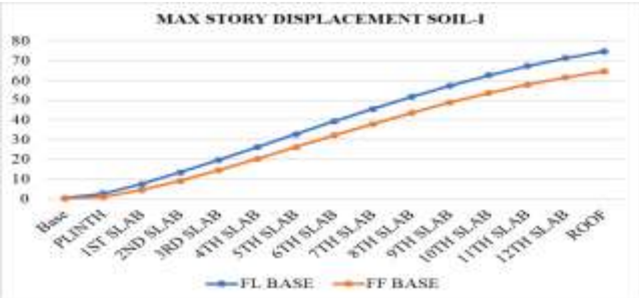
STORY STTIFNESS IN KN/M2		
Story	FL BASE	FF BASE
ROOF	341259.364	386835.619
12TH SLAB	562918.451	626599.616
11TH SLAB	698160.788	768339.561
10TH SLAB	779438.962	851753.21
9TH SLAB	830524.524	904265.804
8TH SLAB	865142.337	941466.233
7TH SLAB	891908.531	973163.757
6TH SLAB	916263.62	1006146.721
5TH SLAB	942911.132	1047496.448
4TH SLAB	977676.59	1108223.828
3RD SLAB	1029395.648	1211108.338
2ND SLAB	1098767.213	1414595.754
1ST SLAB	1220350.891	1927757.558
PLINTH	3104017.119	7333388.09
Base	0	0



Discussion: -
As shown in the above graph, story stiffness for fixed support condition is more as compared with flexible support condition.

Maximum Story Displacement
Results: -
Displacement is studied for EQX and EQY load case and results are calculated and tabulated below. Following table and graph represent comparison of story displacement for model-1 of part-01 and part-02 for soil-I.

STORY	FL BASE	FF BASE
ROOF	74.879	64.685
12TH SLAB	71.415	61.627
11TH SLAB	67.309	57.928
10TH SLAB	62.635	53.666
9TH SLAB	57.422	48.878
8TH SLAB	51.735	43.638
7TH SLAB	45.665	38.04
6TH SLAB	39.313	32.196
5TH SLAB	32.787	26.228
4TH SLAB	26.202	20.27
3RD SLAB	19.686	14.488
2ND SLAB	13.397	9.099
1ST SLAB	7.444	4.437
PLINTH	2.628	0.944
Base	0.325	0



Discussion: -
Above results are for soil type-I condition.
As shown in the above graph, story displacement for flexible support condition is more as compared with fixed support condition.
Specification for flexible support condition is taken from soil type report.

V. CONCLUSION

- Story displacement for flexible support condition is 74.87 more as compared with fixed support condition 64.68.
- Story drifts for flexible support condition are more as compared with fixed support condition.
- Story stiffness for fixed support condition is more as compared with flexible support condition.
- Story displacement for flexible support condition is more as compared with fixed support condition.
- Lateral deflection values of fixed base building were found to be lower as compared to flexible base building.

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