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Behavioral Analysis of High-Rise RCC Moment Resisting Frame Using Response Spectrum Analysis

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Abstract -An RCC building framework is basically an assembly of slabs, beams, columns and foundation encapsulated into a unit. The load transfer, in such structures occurs from the slab to the beams, from beams to columns and then finally to the foundation which eventually transfers it to the soil. The results of analysis are used to ascertain the structures' fitness for use. Currently software's are also being put to use for the calculation of forces, bending moment, stress, strain & deformation or deflection for a complex structure. The prime objective of this project is "The Study on Analysis Results of Multistoried Commercial Building (G+20) by STAADPRO".

STAADPRO is one of the finest tools for the design of structures. In this project we analyzed the G+20 building through response spectrum analysis to develop the economic design. IS: 1893 (2016) for seismic design is utilized to perform the dynamic analysis. The results show that multistoried buildings are generally stiff for earthquake excitation as modal participation factor is more than 75 percent.

Key Words: STAADPRO, Response Spectrum Analysis, Storey drift, storey displacement and base shear.

1.INTRODUCTION

Earthquakes generate random ground motion in all possible directions, radiating away from the epicentre. This ground motion causes structures to oscillate and induces inertia forces in them. For any structure to perform better during earthquakes, it must be designed with keeping in mind the due guidelines from Indian seismic code IS 1893 (2016). In the past, several major earthquakes have shed light on the drawbacks in building design methodologies adopted, which caused them severe damage or in some cases, led to their collapse. It has been observed that regular shaped buildings perform better during earthquakes. Earthquakes cause ground to shake and structures based on ground are subjected to this wavy motion. Thus we can conclude that the dynamic loading on a structure during an earthquake is not an external loading, but due to relative motion of support w.r.t. the superstructure. A building can be designed in accordance with standard protocols to resist earthquakes with certain amount of damage, but without causing collapse/failure and affecting the livelihood, causing threat to life and property. The response spectrum represents an interaction between ground acceleration and the structural system, by envelope of several different ground motion records. For the purpose of the seismic analysis the design spectrum given in fig.2 of IS 1893 (2016) is used. Response spectrum analysis of the building model is performed using STAADPRO. The lateral loads generated by STAADPRO correspond to the seismic zone IV and 5% damped response spectrum given in IS 1893 (2016).

A. Response Spectrum Analysis

The response spectrum method (RSM) was introduced in 1932 in the doctoral dissertation of Maurice Anthony Biot at Caltech University. It is a scientific approach to estimate earthquake response of structures using waves and vibration mode shapes. The concept of the "response spectrum" was realistically put to use in design requirements only in the mid-20th century in building codes of various countries. The biggest computational advantage in using the response spectrum method of seismic analysis is the prediction of displacement and member forces in structural systems. The method comprises of calculation of only max values of the displacement and member forces in each mode using smooth design spectra that are the average of several earthquake motions.

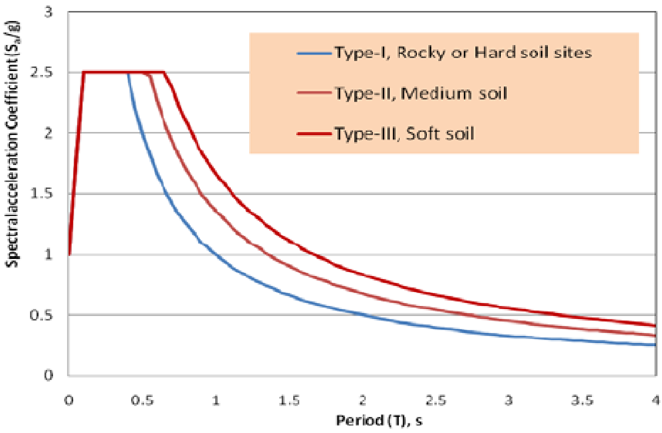

Figure.1 Design Response Spectrum for different soil (5% damping)

Necessity of seismic zoning in India

Seismic zoning is a process, which calibrates information about any decision making criterion for regional planning and/or for earthquake design in earthquake prone locations. In theory, seismic zoning map is the primary source of zoning in India, which displays metrics related to the plausible frequency and intensity of shaking caused by an impending earthquake. The procedure of seismic zoning is multidisciplinary and requires the best of inputs from geologists, geotechnical, seismologists, earthquake and structural engineers. The rapid urbanization due to population explosion, brooding of mega cities in potential seismic zones is the primary reason of the seismic hazards in the Indian Subcontinent.

IS 1893:2016 provisions for zones:

According to IS 1893 code, seismic zoning map of a country is a guide to seismic status of a region and its susceptibility to earthquake. India has been divided into four zones with respect to severity of earthquakes Zone factor (Z) given in table 4.1, is for the maximum considered earthquake (MCE) and service life of a structure in a zone. For design horizontal seismic coefficient

$$A_h = (Z/2)(S_a/g)(I/R)$$

Factor 2 in the denominator of Z is used to reduce the Maximum Considered Earthquake zone factor to the factor for design basis earthquake (DBE). For any structure with t<0.1 s, the value of Ah will not be taken less than Z/2 whatever be the value of I/R

Seismic Zone	II	III	IV	V
Intensity	Low	Moderate	Severe	Very Severe
Z	.10	.16	.24	.36

2. Body of Paper

The body of the paper consists of numbered sections that present the main findings. These sections should be organized to best present the material.

It is often important to refer back (or forward) to specific sections. Such references are made by indicating the section number, for example, “In Sec. 2 we showed…” or “Section 2.1 contained a description….” If the word Section, Reference, Equation, or Figure starts a sentence, it is spelled out. When occurring in the middle of a sentence, these words are abbreviated Sec., Ref., Eq., and Fig.

At the first occurrence of an acronym, spell it out followed by the acronym in parentheses, e.g., charge-coupled diode (CCD).

LITERATURE REVIEW

S. R. Kangle, D. S. Yerudkar, “Response Spectrum Analysis for Regular Multistory Structure in Seismic Zone III”: International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 IJERTV9IS090262 (This work is licensed under a Creative Commons Attribution 4.0 International License.) Vol. 9 Issue 09, September-2020

Objectives

Determination of dynamic response of multi-storey building for earthquake load, and story displacement, storey shear, storey drift using response spectrum analysis for a regular multi-storeyed building. Also studied response spectrum analysis of regular multi-storeyed building using computer programs (STAADPRO,ETABS)

Resurreccion Villa Garrote, Rizalyn C. Ilumin, “Comparative Analysis on Seismic Provisions of the National Structural Codes of the Philippines (NSCP) 1992 and 2010 as Applied to the Design of Reinforced Concrete Public School Building”, Proc. of Sixth International Conference On Advances in Civil, Structural and Mechanical Engineering -ACSM 2017

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ISBN: 978-1-63248-118-4 doi: 10.15224/ 978-1-63248-118-4-62:

The main target of this research work is to show the differences of the provisions of seismic analysis and design of structures under the National Structural Codes of the Philippines (NSCP) by preparing a comparative evaluation of the 2 codes— NSCP 1992 and the new one, NSCP 2010 in applying to the Design of Multi-Story Public School Building.

Dr. S.K. Dubey, Prakash Sangamnerkar, Ankit Agrawal, “Dynamics Analysis Of Structures Subjected To Earthquake Load”; Volume 2,Issue 9, September -2015 e-ISSN(O): 2348-4470 p-ISSN(P): 2348-6406

Analyzing and designing a structure in such a way that the damage to the structure and its structural components during an earthquake is minimum. Dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building. It should be performed for both regular and irregular building. To perform dynamic analysis this are provision laid down in IS 1893 (part 1) 2002, with respect to height of building and according to irregularity of the building.

Vinay K. Gupta, “Developments in Response Spectrum Based Stochastic Response Of Structural Systems”; ISET Journal of Earthquake Technology, Paper No. 429, Vol. 39, No. 4, December 2002, pp. 347-365:

This paper considers a review of alternative methods which have been developed since mid-1970’s to give probabilistic estimates of response peaks, while continuing to use the information available through response spectra. These methods have the convenience of being applied in a variety of situations, do not usually suffer from the inaccuracies associated with the use of modal combination rules, and present state-of-the-art methodology in linear seismic response analysis. The limitations of various formulations proposed under these methods are identified, and future directions of required work are suggested.

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MODELING AND ANALYSIS

Model and Material which are used is presented in this section. Table and model should be in prescribed format.

RC moment resisting frame building of similar story heights is considered. A typical height of 3.5 m is kept for the entire story in the building. The aim of the study is to find the difference of base reactions, modal participation factors and periods and frequencies using STAADPRO.

The STAADPRO software is used for modelling as well as analysis of the structure. A symmetrical plan of reinforced concrete structure having G+20 storeys is considered. First the Earthquake loads are considered as per IS 1893-2016, Part-1 are applied for structure located in zone IV. And response spectrum method of analysis is carried out for 5% damping and scale factor considered as per IS code in both X and Y directions. Assuming that material property is linear static and Response spectrum analysis is performed.

Loadings and material properties

M25 grade of concrete and Fe 500 grade of Steel are used for all slabs and beams of the building whereas M30 is used for columns with same grade of Steel. Elastic material properties of these materials are taken as per IS 456-2000. The short-term modulus of elasticity (EC) of concrete is taken as

$$\mathbf{E_C = 5000\sqrt{f_{ck}}\ Mpa}$$

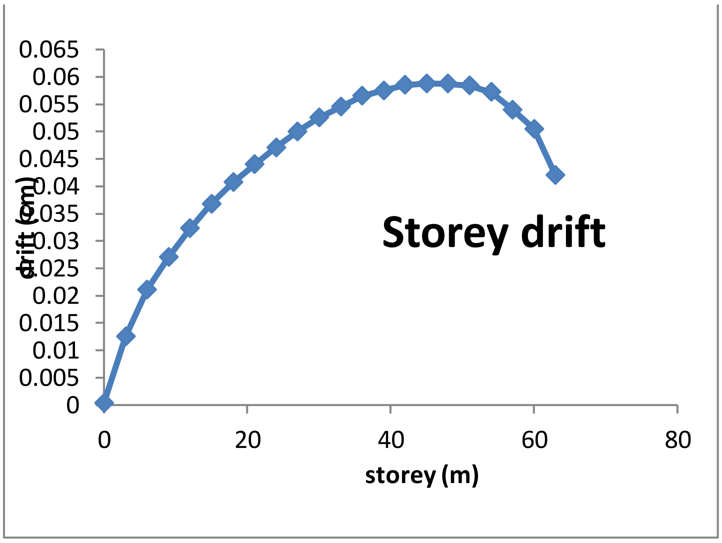
$\mathbf{f_{ck}}$ =characteristic compressive strength of concrete cube For the Steel rebar with stress and modulus of elasticity is taken as per IS 456-2000. While applying the loads to the structure we consider only the external loads which are actually acting on the members neglecting its self-weight because STAADPRO automatically takes the members' self weight. The Seismic loads EQ-x and EQ-y are given in Load patterns directly using Code IS1893:2016.

Type of Building	Commercial
Length of the building	25 m
Width of the building	25 m
Height of the building	82.3 m
Height of each storey	3.5 m
Number of storey	G+20
Beam size	(450*450)mm
Column size	(500*500)mm
Surface thickness	260mm
Concrete grade	M25
Steel reinforcement	Fe500
Zone	IV
Soil type	Medium
Damping Ratio	5%
Concrete cover	30 mm
Storey drift	0.004
Dead load	24 KN/m^2
Live load	3.75 KN/m^2
Support Condition	Fixed

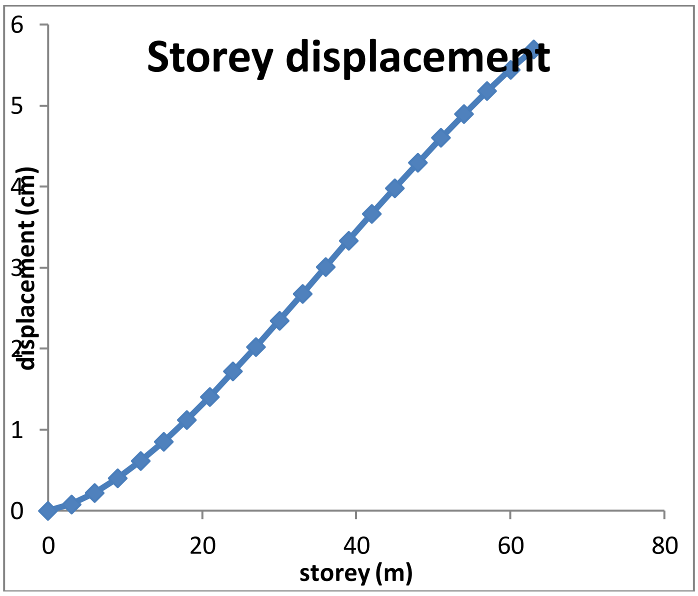
Result

Result obtained from the analysis are recorded in tabular form for the different loading conditions.And for the three different parameters the graphs are plotted:

1. STOREY DRIFT:



STOREY DISPLACEMENT:



BASE SHEAR:

MASS PARTICIPATION FACTORS IN PERCENT / BASE SHEAR IN KN

MODE	X	Y	Z	SUMM-X	SUMM-Y	SUMM-Z	X	Y	Z
1	73.86	0.00	0.00	73.861	0.000	0.000	8667.98	0.00	0.00
2	0.00	0.00	0.00	73.861	0.000	0.000	0.00	0.00	0.00
3	12.02	0.00	0.00	85.877	0.000	0.000	4431.96	0.00	0.00
4	0.00	0.00	0.00	85.877	0.000	0.000	0.00	0.00	0.00
5	3.54	0.00	0.00	89.418	0.000	0.000	2155.05	0.00	0.00
6	0.00	0.00	0.00	89.418	0.000	0.000	0.00	0.00	0.00

TOTAL SRSS SHEAR	9970.98	0.00	0.00
TOTAL 10PCT SHEAR	9970.98	0.00	0.00
TOTAL ABS SHEAR	15254.99	0.00	0.00
TOTAL CSM SHEAR	9970.98	0.00	0.00

CALCULATED FREQUENCIES FOR LOAD CASE:

MODE	FREQUENCY (CYCLES/SEC)	PERIOD (SEC)
1	0.355	2.82064
2	0.616	1.62255
3	1.114	0.89748
4	1.765	0.56654
5	2.015	0.49624
6	2.779	0.35985

1893 RESPONSE SPECTRUM LOAD 4

Mode	Modal Weight(Modal mass times G)in kN			Generalised Weight
	X	Y	Z	
1	1.997486E+05	0.000000E+00	0.000000E+00	1.068013E+05
2	1.071067E-11	0.000000E+00	0.000000E+00	5.322264E+04
3	3.249658E+04	0.000000E+00	0.000000E+00	1.141232E+05
4	1.313379E-08	0.000000E+00	0.000000E+00	5.444908E+04
5	9.577985E+03	0.000000E+00	0.000000E+00	1.199269E+05
6	4.672827E-08	0.000000E+00	0.000000E+00	5.701564E+04

MODE	SPECTRAL ACCELERATION	DESIGN SEISMIC COEFFICIENT		
		X	Y	Z
1	0.48216	0.0434	0.0000	0.0000
2	0.83819	0.0754	0.0000	0.0000
3	1.51536	0.1364	0.0000	0.0000
4	2.40054	0.2160	0.0000	0.0000
5	2.50000	0.2250	0.0000	0.0000
6	2.50000	0.2250	0.0000	0.0000

3. CONCLUSIONS

Based on the response spectra study on multi-story regular building, following points are concluded:

The spectral analysis must be carried out for high rise structure with vertical regularities having height more than 40 m.

Since the modal mass participating factor is greater than 75% in higher modes, the structure in study is stiff for earthquake excitation.

From the response spectrum analysis, performed on the building, it was deduced that the structure has good resistance to small earthquakes of moderate magnitude and intensity.

The storey displacement in X- direction is found more when compared to Y and it is due to the fact that the earthquake motion was applied in X-direction.

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