Seismic Analysis of Multi-Storey Structure Subjected To Different Ground Motions

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Abstract: Major Construction project in urban India is incorporated with Reinforced Concrete (RC) frames, which experience both static and dynamic forces during their lifetime. Static forces can easily be analysed whereas dynamic force analysis is very time consuming, but it can't be left unanalysed as the results may be catastrophic. Earthquake is an important dynamic force which a building may experience during its lifespan and is therefore its analysis becomes a critical step in design.

The present work in its utmost sense, aim at understanding the influence of different ground motions on the structure over its life span. This providing new parameters and information to help improve design work.

INTRODUCTION

During an earthquake, the structure undergoes dynamic motion due to reaction of the inertia forces built up in the direction against the acceleration of seismic forces. These inertia forces, also known as seismic forces, are considered by assuming pseudo external forces acting on the building. Excluding gravity loads, predominant structure experiences significant lateral forces of considerable magnitude during seismic action. Thus, before the designing of the structure is carried out, it becomes integral to identify and estimate the magnitude of lateral forces acting on the structure.

Reinforced concrete structures are routinely designed for higher strength parameters than the necessary service load constraints. In general, the members are designated with greater dimensions and higher material standards than the minimum strength requirements specified in the IS design codes. The design procedures for seismic loads also results with greater strength parameters. Furthermore, the redundancy of the structure under the account of division of stresses will also lead to increased overall strength. The current study understands the comparison of storey displacement, base shear, and storey drift of RC framed structure with in individual seismic regions of Indian sub-continent.

Keywords: Seismic Analysis, Multi- Storey Structure, Storey Displacement, RC Structure

1. Literature Review

Numerous studies have been accomplished for seismic analysis of multistorey structure due to different ground motions. Some of them were discussed below.

• Mr. Dr.B.Panduranga Rao, Mr. S.Mahesh, et al (2014). Taking into account the importance of a building to resist earthquake loads, the paper focuses on using ETABS to help analyse and design of multi-storied buildings in various regions and different soils in regular and irregular conFigureuration. Base shear and storey drift were identified as the main parameters and values obtained from both the software's were plotted for different regions and soil. Results are analysed and appropriate conclusion are drawn.

• Mohit Sharma and Dr. Savita Maru et al (2014). The paper focuses on the static and dynamic analysis of a G+30 storied regular building for regions-2 and region-3 using STAAD. Axial forces, torsion, moment, displacement were some of the parameters considered and values for static and dynamic analysis were compared and reported. The performance of RCC Framed Structure is analysed. For the same points and conditions, it was observed that values obtained in dynamic analysis were greater than those obtained in static analysis

• Anirudh Gottala, Kintali Sai Nanda et al (2015). The paper focuses on the study the seismic performance of ten storey building taking into account different setbacks and ductility classes. Inter storey drifts, performance of structural members, over strength factors and pushover curves are some of the parameters considered to compare and arrive at the results and draw appropriate conclusions

• Athanassiadou et al (2008) the effect of earthquake load on structures cannot be overlooked. Keeping this in mind, the following paper constitutes the analysis of a multi-storied framed structure (G+9) building under static and dynamic forces. Bending moment, Nodal Displacements, Mode shapes were the parameters used to draw the comparisons between static and dynamic analysis. From the values obtained, appropriate conclusions were arrived upon.

2...Methodology

The present study about the multi-storey seismic analysis will proceed in two stages-

i. Performance differentiation of a reinforced concrete structure for all present seismic regions in India i.e., II(Two), III(Three), IV(Four), and V(Five). For the desired structure, it will consist of the following steps-

- Modelling of the structure with all the mandatory parameters.
- Structure design adequate for the four seismic regions in India.

ii. Analysis of factors like base shear, storey drift and storey displacement of designed structure for various seismic sectors.

Type of Structure	Familial Building
Number of Stories	16
Typical Floor Height	3.2m
Size of Column	300mm X 500mm
Slab Thickness	150 mm
Masonry Wall's Thickness	230 mm
Live Load	2 kN/m^2
Miscellaneous Load	1 kN/m^2
Soil Types Considered	Type II
Characteristic Compressive Strength of	20 N/mm ²
Concrete, F _{ck}	
Steel's Grade	500 N/mm ²
Concrete's Density	25 N/mm ²
Modulus Elasticity of Concrete	2000 N/mm ²
Poison's Ratio of Concrete(M)	0.3
Density of Brick Masonry(P)	19.2 kN/m ³
Modulus of Elasticity for The Brick Masonry	14000 N/mm ²
Poison's Ratio of Brick Masonry	0.2

A. Details of the structure and properties of the materials

 Table 1: Structural details.

B. Seismic Parameters of respective regions

Characteristics	Region 2	Region 3	Region 4	Region 5
Number of stories	16	16	16	16
Typical storey height, m	3.2	3.2	3.2	3.2
Seismic region, Z	0.10	0.16	0.24	0.36
Response reduction factor, R	3	3	3	3
Importance factor, I	1	1	1	1
Soil type	II	II	II	II

 Table 2: Seismic Attributes

C. Modelling Procedure in ETABS

1. Selection of new model template to create new model.

and Demensions (Ref.)		Story Dimensione.	
Centerie Ord Specing		Employ Skory Cello	
Number of Grid Lines in X Direction	3	Number of Stories	·3
Number of Grid Units in Y Direction	4	Typical Story Height	3 0
Specing of Grids in X Direction	7.5 m	Bottom Story Height	3 8
Specing of Gridain Y Deution	503 m		
Specify Edit Labeling Options	Citri Labaix		
C CLEAR CHIE Samong		C Caston Story Data	
Specify Data for Grid Lines	Eds Gird Data	Specify Custow Stary Date	Edd Story Onto .
lidd Stratture Disects			
	K K b		
Stark Circl Circl Circl Circl	el Dock Saggared Tross	Plat State Plut Study with TW Perimeter Beams	Two Way at Rided Stop

Figure.1 New Model Quick Templates

2. Define new materials.

General Data							
Material Name	M25						
Material Type	Concrete		~				
Directional Symmetry Type	Isotropic		~				
Material Display Color		Change					
Material Notes	Modif	y/Show Notes					
Material Weight and Mass							
 Specify Weight Density 	O Spe	cify Mass Density					
Weight per Unit Volume		24.9926	kN/m ³				
Mass per Unit Volume		2548.538					
Mechanical Property Data							
Modulus of Elasticity, E		25000 0.2					
Poisson's Ratio, U							
Coefficient of Thermal Expansion	n. A	0.0000055	1/C				
Shear Modulus, G		10416.67					
Design Property Data							
Modify/Sho	w Material Property	Design Data]				
Advanced Material Property Data							
Nonlinear Material Data		Material Damping P	roperties				
Tim	ne Dependent Prop	erties					

Figure. 2: Material Property Data

3. Defining M25 grade concrete as material.

Th Defi	ine Materials
Materials	Click to:
A992Fy50	Add New Material
A615Gr60	Add Copy of Material
MEU	Modify/Show Material
	Delete Material
	OK Cancel

Figure.3: Define Materials

4. Define frame section.

6 E	rame Properties	· · · · · · · · · · · · · · · · · · ·
Filter Properties List		Click to:
Type All	\sim	Import New Properties
Filter	Clear	Add New Property
Properties		Add Copy of Property
Find This Property		Modify/Show Property
A-CompBm		
A-CompBm A-GravBm		Delete Property
A-GravCol A-LatBm		Delete Multiple Properties
A-LatCol ConcBm		
ConcCol ISLB600		Convert to SD Section
ISWB550 SteelBm		Copy to SD Section
SteelCol		
		Export to XML File
		UK Cancel

Figure. 4: Frame Properties

5. Define rectangular section.

16	Frame Pro	pperty Shape Type
Shape Type	Section Shape	Concrete Rectangular
Frequently Used Shape Types Concrete	TT	
Special Section Designer	ismatic	Steel Composite
	ОК	Cancel

Figure.5: Frame Property Shape Type

6. Define rectangular beam section of 400x500mm.

deneral Data				
Property Name	beam 400x50	0		
Material	M25		×	2 🔶
Display Color		Change		3
Notes	Modif	y/Show Notes		↓ ↓
Shape				
Section Shape	Concrete Rec	tangular	~	
Section Dimensions				Modify/Show Modifiers
				Property Modifiers
Depth		500	mm	Modify/Show Modifiers
Width		400	mm	
				Reinforcement
				Modify/Show Rebar
				ОК

Figure. 6: Frame Section Property Data

7. Define rectangular column section of 600x600mm.

General Data					
Property Name	column600	600			
Material	M25		×	21	
Display Color		Change		• 3	•
Notes	Mo	dify/Show Notes		• ~ +	
Shape					
Section Shape	Concrete R	ectangular	~		•
Section Dimensions		600		Modify/Show Mo	dfiers
Section Dimensions				Madh/Shaw He	dfian
Liepon		600	mm	Currently Del	ault
Width		600	mm	Reinforcement	
				Modify/Show R	lebar
				ОК	

Figure. 7: Frame Section Property Data

8. Define slab section.

200 C	Slab Properties	×
Slab Property	Click to:	
Plank1 Slab1	Add New Property	
	Add Copy of Property	
	Modify/Show Property	
	Delete Property	
	OK Cancel	

Figure. 8: Slab Properties

9. Create slab section of 150mm thick.

	Slab	Property Data		>
Ger	neral Data			
r i	Property Name	Slab]
4	Slab Material	M25	~	
, in the second s	Modeling Type	Membrane	~]
l l	Modifiers (Currently Default)	Modify	/Show	
ſ	Display Color		Change	
ſ	Property Notes	Modify	/Show	
0	Use Special One-Way Load D	istribution		
Prop	perty Data			
-	Туре	Slab	~]
-	Thickness		150	mm
	OK	Cancel		

Figure. 9: Slab Property Data

10. Plan view of the building.



Figure. 10: Plan View

11. 3D Rendered view of building



Figure. 11: 3D Rendered View

12. Define different load types.

1			Define Load	Patterns		>
	Loads Load	Туре	Self Weight Multiplier	Auto Lateral Load	Click To: Add New Load	
	EQy	Seismic	✓ 0	IS1893 2002	Modify Load	
	Dead Live II ff EQX	Dead Live Super Dead Seismic		IS1893 2002	Modify Lateral Load Delete Load	
					OK Cancel	

Figure. 12: Define Load Patterns

5-3		5-2		5-2		5-2	
4	beam 400+500	4	beam 400+500	φ	beam 400+500	Y	Story1
Divella:	beam 400+500	- and the	beam 400+500	- Aller	beam 400+500	and the second	Story1
Condition	beam 400x500	Condition	beam-400+500	Condition	beam-400x500	Covella	Story1
Clovella -	beam-400+500	Dondlin 1	beam 400x500	divid 0	beam 400x500	D ocean	_ Story1
Cland	beam 400+500	ding.	beam 400+500	ding.	beam-400x500	0.00	_ Story1
- Book	beam 400x500	9	beam 400x500	divid.	beam 400+500	0.0	_Story1
Clinelli	beam 400+500	9	beam 400x500	C rively	beam-400+500	940	Story9
1000	teeam 400x500	divid.	beam 400x500	Civel.	beam 400x500	9	_ Story®
Claired)	beam 400+500	C indi	beam 400+500	C triedly	beam 400+500	C contra	_Story7
guig	beam 400+500	and a	beam 400+500	E and	beam-400+500	Covello -	_ 510176
fil sirell	beam 400+500	fl indi	beam-400+500	fl indi	beam 400+500	10.00	Siory
Condition of the local sector of the local sec	beam-400x500	ding.	beam-400+500	Ding.	beam-400x500	000	Storyd
- Cline	beam 400+500	9	beam-400+500	ding.	beam 400+500	Chine	_ 500ry3
flored)	beam-400+500	and a	beam-400+500	Divid	beam-400+500	Divid.	-910ry2
-	beam 400+500	Direll.	beam 400+500	R inte	beam-400x500	100	_ Story1
1		100		in the second		and a second	Base

13. Elevation of typical 16 storey building.

Figure. 13: Typical Elevation

14. Assigning different types of loads.



15. Define typical mass source data.

Neas Source Name	sSrc		Mass Wultplans *	for Load Poltanns Vidern Wultipler	
			n	v 1	405
Cevert Sel* Vass			Dead Live	125	Tedty
Actional Mass					Deista
Specified Last Parterns					
Adjust Disphragm Lateral Mass to Max	e Wass Certrad		Mess Optices		
Nove Direction (countercookwise fr	00+00)	(8)	🖌 Include Lab	eral Pass	
Nove (rate to dephrage cheersice)	a wove direction)		🗌 Include Ver	fical Mees	
			🗹 Lung Later	n Maes n. Slavy Levels	

Figure. 15: Mass Source Data

16. Clasic response spectrum function as per IS 1893:2002.

Define Response	Define Response Spectrum Functions			
Response Spectra	Choose Function Type to Add IS1893:2002 Click to: Add New Function Modify/Show Spectrum Delete Spectrum OK Cancel			
	Add New Function Modify/Show Spectrum Delete Spectrum OK Cancel			

Figure. 16: Define Response Spectrum Function

- Response Spectrum Function Definition - IS 1893:2002 Function Damping Ratio Func1 0.05 Function Name Defined Function Parameters Period Acceleration 0.36 Seismic Zone Factor, Z Soil Type Ш ~ 0.36 0.9 0.612 0.4896 0.408 0.3497 0.306 0.272 0 0.1 0.55 0.8 1 1.2 1.4 1.6 1.8 ^ Convert to User Defined ~ Function Graph Plot Options Linear X - Linear Y E-3 960 Linear X - Log Y 840 -O Log X - Linear Y 720 O Log X - Log Y 600 480 -360 240 -120 ок 1.0 2.0 3.0 4.0 5.0 10.0 6.0 7.0 8.0 9.0 Cancel
- 17. Defining load combination data for modal combination

Figure. 17: Response Spectrum Function Definition

18. Defining load combination data for modal combination.

I and Combination Name	Combill				
	COMPTS				
Combination Type	SESS		~		
Notes	Modify/Show Notes				
Auto Combination	No				
Uve		1	Add		
Load Name	Mode	Scale Factor			
Mortal	1				
Dead		1	Desete		
EQX		1			
Deed ~		1			

Figure.18: Load Combination Data

19. Defining time history function

III Defi	ne Time History Functions
Functions	Choose Function Type to Add
RampTH UnifTH	From File V
	Click to:
	Add New Function
	Modify/Show Function
	Delete Function
	OK Cancel

Figure. 19: Define Time History Functions

20. Selection of Default time history data from ETABS

т	me History Funct	ion Definition - From File
Time Histo	ry Function Name	ALTADENA-1
Function File File Name C:Program Files\Computers ar 2015\Time History Functions\/ Header Lines to Skip Prefix Chars. Per Line to Skip Number of Points per Line	Browse d Structures\ETABS LTADENA-1.TH 2 0 8	Values are: Time and Function Values Values at Equal Intervals of 0.02 Format Type Fixed Format
Function Graph		
-240	12.0 16.0	20.0 24.0 28.0 32.0 38.0 40.0
	ок	Cancel

Figure.20: Time History Functions Definition.

21. Defining load case data for response spectrum analysis.

			time history				Design
Load Case Type/Subtyp	e Tir	me History	~ Li	near Moda	əl	\sim	Notes
Exclude Objects in this (Group		Not Applicable				
Mass Source		Previous (MsS	Previous (MsSrc1)				
ads Applied							
Load Type	Load	l Name	Function		Scale Factor		•
Acceleration	U2		ALTADENA-1	0.9	8		Add
Acceleration ~	U1		ALTADENA-1	0.9	8	1	Delete
Acceleration ~	U1		ALTADENA-1	0.9	8	×	Delete
Acceleration v	U1		ALTADENA-1 Modal	0.9	8	~	Delete
Acceleration ~ her Parameters Modal Load Case Time History Motion Typ Number of Output Time	e Steps		ALTADENA-1 Modal Periodic	0.9	300	~ ~	Delete
Acceleration ~ her Parameters Modal Load Case Time History Motion Typ Number of Output Time Output Time Step Size	U1 He Steps		ALTADENA-1 Modal Periodic	0.9	300	> >	Delete Advanced

Figure. 21: Load Case Data



22. Bending moment diagram over the entire height of the building.

Figure. 22: Bending Moment Diagram of the Designed Structure

23. Shear force diagram over the entire height of the building.



- Figure. 23: Shear Force Diagram
- 24. Typical variation of shear, moment and deflected profile for any beam considered.



Figure. 24: Diagrams for beam B7

3.Results

The following results have been obtained when the ETABS analysis was conducted on the desired structure model:

Regions	Base Shear (kN)
П	442.15
III	707.46
IV	1061.18
V	1591.75

A. Base Shear of the structure:

Table 3: Base shear of structure for respective regions

The value for maximum base shear obtained in seismic region 5 is 1591.75 kN. The trend also indicates that the base shear increments with increments in seismic regions.

Regions	Displacement (mm)
П	22
III	35.2
IV	52.8
V	79.1

B. Storey Displacement for Various Seismic Regions:

Table 4: Storey displacement of the structure for different regions

Similar to base shear, storey displacement also increases with increases in region with region 5 having highest value of storey displacement i.e.79.1 mm.

C. Storey Drift At Each Floor



Figure.25: Graphical Comparison of Storey drifts w.r.t Storeys in the designed structure

It can be concluded that from base to the 14th storey, storey drift moderately increases, whereas under 15th and 16th storey, a rapid decrease in storey drift takes place. This is due to the fact that maximum storey drift occurs at the central part of the structure.

4. Conclusions

When analysis of desired structure is done using ETABS and response spectrum analysis is considered for the different seismic regions, the following conclusions can be drawn for the structure:

• With increment in region factors, there's gradual increase in the base shear and lateral displacement in the structure.

• The drift is observed to be increasing with increase in storey levels until 14th storey after which there's a rapid decline in storey drift.

• Stiffness becomes directly proportional to the frequency of the structure.

From the present study, it can be concluded that with increases in seismic activity; base shear and storey displacement shows increment from seismic region-2 to seismic region-5, indicating that to endure higher seismic action, the strength parameters should be altered equally or proportionally.

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