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SEISMIC ANALYSIS OF RC BUILDINGS UNDER CHANGING FREQUENCY CONTENT

V.S. Mali*[1], V.M. Bogar[2] & Y. M. Ghugal[3]
[*1]P. G. Student (M-Tech Structures), G.C.E. K., Karad-415124
[2] Assistant Professor (Applied Mechanics Department), G.C.E. K., Karad-415124
[3]H.O.D. (Applied Mechanics Department), Government College of Engineering Karad, Karad-415124

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ABSTRACT
The most important dynamic characteristics of earthquake are peak ground acceleration (PGA), frequency content, and duration. These characteristics play major role in studying the behavior of structures under seismic loads. Ground motion has different frequency contents such as low, intermediate, and high.
In this paper study of frequency content of ground motion on reinforced concrete (RC) buildings. Linear time history analysis is performed in structural analysis and design (STAAD Pro) software. The proposed method is to study the response of low, mid, and high- rise RC buildings under low, intermediate, and high- frequency content ground motions. Both regular and irregular three-dimension three, ten, and twenty- story RC buildings with three ground motions of low, intermediate, and high-frequency contents having equal duration and peak ground acceleration (PGA) are studied herein.

KEYWORDS: Reinforced concrete building, ground motion, peak ground acceleration, frequency content, time history analysis.

1. INTRODUCTION
Severe shakings happen rarely. Even though it is technically possible to designs and build structures for these earthquake event, it is considered uneconomical .The seismic design is performed with the probability that the severe earthquake would result in little damage, and a seismic design philosophy on this premise has been created through the years. The aim of the seismic constraint the damage in the structure to worthy sum. The structure design in a way that should have the capacity to resist the minor level of earthquakes without damage, survive moderate level of earthquake without structural damage and probably of some non-structural damage and resist significant level of ground motion without breakdown, yet with some structural and in addition non-structural damage.

In this work three, ten and twenty story regular as well as irregular buildings are subjected to ground motion of low, intermediate and high frequency content. The buildings are modelled as three dimensional and linear time history analysis is performed using STAAD Pro. Software.

2. MATERIALS AND METHODS

Methodology
The following three ground motion records which have frequency content have been considered for the analysis:
1. CHAMOLI (NW HIMALAYA) EARTHQUAKE, MARCH 29, 1999.
2. PANIMUR, NE-INDIA EARTHQUAKE, MAY 18, 1987.
3. SHILONG, NE-INDIA EARTHQUAKE, AUG 6, 1988.

The basics of the work is to study the behavior of reinforced concrete buildings under varying frequency content. This study shows how low, mid and high rise RC building behave in low, intermediate and high frequency content ground motions. Here, the story displacement, story velocity, story acceleration and base shear of low, mid and high-rise regular and irregular building due to the three ground motions are obtained. The methodology, which is followed.

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1. Collection of ground motion record.
2. Analyzing the linear time history in STAAD Pro. Software.
3. Response of the RC building such as Story velocity, story displacement, story acceleration also base shear are found because of ground motion.
4. Results of regular and irregular buildings are compared with three ground motions.

Modeling

Overview

In this information regarding building is presented. The plan and elevation of three, ten and twenty story regular buildings are shown. The plan and elevation of three, ten and twenty story irregular buildings are shown. All the loads are described and description regarding concrete and steel is provided. Also the properties of steel and concrete are described which are used for buildings. And at the last the properties of structural element are presented.

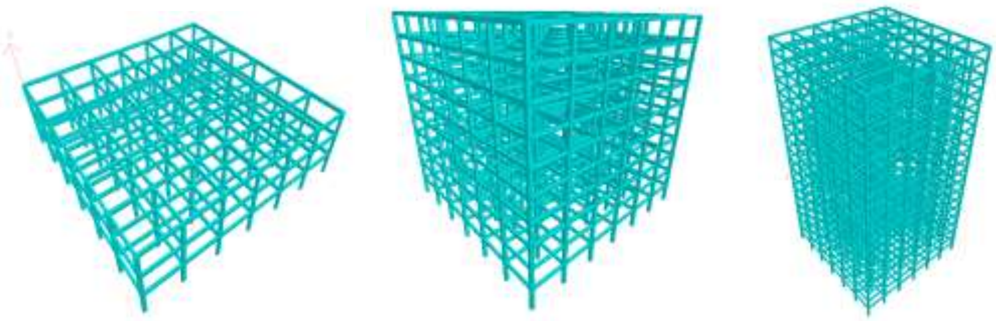
Structural Elements

Linear time history analysis is performed on three, ten, and twenty-story regular and irregular reinforced concrete buildings and three ground motions of low, intermediate, and high-frequency content are introduced to STAAD Pro. In order to compare the results, for simplicity beam and column dimensions are assumed 300 mm x 400 mm. Height of the story is 3.5m and beam length in transverse direction is taken 5m and in longitudinal direction 5m.

Structural Element	Cross section (mm x mm)	Length (m)
Beam	230 x 450	5
Column	450 x 230	3

Regular RC Building

Three, ten and twenty story regular RC buildings which are low, mid and high are considered. The beam length in X direction i.e. in longitudinal direction is 5m. And in Z i.e. transverse direction is also 5m. Figure shows 3 dimensional view of regular RC building. Story height is assumed as 3m.figure shows the elevation of three, ten and twenty story regular RC building.



Irregular RC Building

The beam length in X direction i.e. in longitudinal direction is 5m. And in Z i.e. transverse direction is also 5m. Story height is assumed as 3m.figure shows the 3 dimensional view of three, ten and twenty story irregular RC building. The plan configuration of three, ten and twenty story building are shown where both projections of the RC building beyond the re-entrant corners are 40 percent which is more than 15 percent of their plan dimensions hence corresponding RC buildings are considered as irregular structures.

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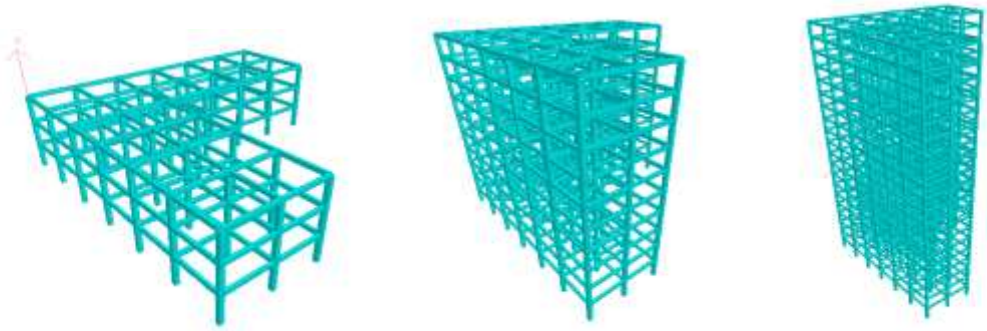

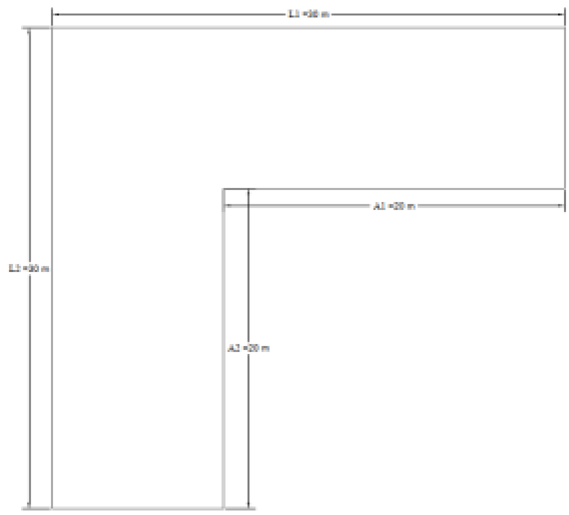

$L_1/A_1 > 0.15$ (20/30=0.667 > 0.15)
$L_2/A_2 > 0.15$ (20/30=0.667 > 0.15)
Re-entrant corners as per IS 1893 (part 1): 2002

Gravity loads

Slab load of 4.75kN/m^2 is considered for the analysis and live load is about 3kN/m^2. Is provided according to IS 875 (part 2) Table shows the load description.

Gravity load	Value
Slab load (dead load)	4.75 kN/m^2
Wall load (dead load)	13.5 kN/m^2
Live Load	3 kN/m^2

Ground motion records

Ground motion is the movement of the earth's surface from blasts or earthquakes. In this project, the characteristics of the three ground motions, which are used for the time-history analysis of the RC buildings, are explained. The ground motion has dynamic characteristics, which are peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), frequency content, and duration. These dynamic characteristics play important role in studying the behaviour of RC buildings under seismic loads. The structure stability depends on the structure slenderness, as well as the ground motion amplitude, frequency and duration. The ratio of peak ground acceleration in terms of acceleration of gravity (g) to peak ground velocity in unit of (m/s) is defined as the frequency content of the ground motion. Based on the frequency content, which is the ratio of PGA/PGV the ground motion records are classified into three categories,

- High-frequency content PGA/PGV > 1.2
- Intermediate-frequency content 0.8< PGA/PGV< 1.2
- Low-frequency content PGA/PGV < 0.8

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The ratio of peak ground acceleration to the peak ground velocity is defined as the frequency content of the ground motion.

Ground Motion Record	Region	Station	Latitude	Longitude	Depth(km)	Hypo central Distance
Chamoli	India	Gopeshwar	30.1100	79.3500	10	33.8 km
Panimur	India	Panimur	25.2700	94.2000	49	155 km
Shilong	India	Shilong	25.5700	91.9000	90	340 km

Ground Motion Characteristics

Ground Motion Record	Magnitude	Duration	PGA	PGV	PGA/PGV	Frequency Content
Chamoli	4.5	38.99	0.927	0.192	4.828	High
Panimur	5.9	39.48	0.1720	0.168	1.023	Intermediate
Shilong	7.2	48.09	0.351	0.975	0.3600	low

Frequency Content Classification

Time history analysis
Time history analysis is the study of the dynamic response of the structure at every addition of time, when its base is exposed to a particular ground motion. In order to study the seismic behaviour of structures subjected to low, intermediate, and high-frequency content ground motions, dynamic analysis is required. The STAAD Pro. Software is used to perform linear time history analysis.

3. RESULTS AND DISCUSSION

Three Story Regular RC Building									
		Displacement (mm)		Acceleration m/s2		Velocity (kmph/s) (x10e-6)		Base Shear(kN)	
	Height (m)	X	Z	X	Z	X	Z	X	Z
Chamoli	0	0	0	0	0	0	0	300.71	515.38
	3	1.35	0.707	0.68	0.345	35.9	28.7		
	6	2.71	1.6	0.9	0.751	71.7	64.9		
	9	3.48	2.17	0.748	0.979	107	87.6		
Panimur	0	0	0	0	0	0	0	653.91	1042.66
	3	3	1.32	0.466	0.21	72	48.4		
	6	5.87	3.02	0.523	0.467	146	107		
	9	7.48	4.11	0.601	0.621	198	142		
Shilong	0	0	0	0	0	0	0	693.64	846.95
	3	2.89	1.23	0.781	0.405	95.9	55.8		
	6	5.53	2.76	1.03	0.887	158	122		
	9	6.89	3.7	0.855	1.16	209	159		

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Ten Story Regular RC Building									
		Displacement (mm)		Acceleration m/s2		Velocity (kmph/s) (x10e-6)		Base Shear (kN)	
	Height (m)	X	Z	X	Z	X	Z	X	Z
Chamoli	0	0	0	0	0	0	0	209.74	352.96
	15	5.04	3.52	0.893	0.756	66.1	56.5		
	30	8.92	5.77	0.686	0.827	90.3	83.2		
Panimur	0	0	0	0	0	0	0	685.07	1303.58
	15	18.5	17	0.451	0.423	204	235		
	30	27.6	27.5	0.365	0.538	257	303		
Shilong	0	0	0	0	0	0	0	796.63	780.48
	15	25.5	10.9	1.04	0.878	282	156		
	30	41.5	16.6	0.808	0.967	301	223		

Twenty Story Regular RC Building									
		Displacement (mm)		Acceleration (m/s2)		Velocity (kmph/s) (x10e-6)		Base Shear (KN)	
	Height (m)	X	Z	X	Z	X	Z	X	Z
Chamoli	0	0	0	0	0	0	0	211.25	224.65
	30	10.6	7.12	0.813	0.87	70.2	57.8		
	60	15.4	11.7	0.834	0.723	81.4	73.8		
Panimur	0	0	0	0	0	0	0	433.89	550
	30	20.5	18.6	0.454	0.325	171	122		
	60	31.4	28.7	0.35	0.502	210	189		
Shilong	0	0	0	0	0	0	0	267.02	863.87
	30	20	29.2	1.04	0.745	151	179		
	60	34.4	45.1	0.801	1.15	233	277		

Three Story Irregular RC Building									
		Displacement		Acceleration m/s2		Velocity (kmph/s) (x10e-6)		Base Shear	
	Height (m)	X	Z	X	Z	X	Z	X	Z
Chamoli	0	0	0	0	0	0	0	181.66	286.6
	3	1.37	0.733	0.684	0.373	34.3	25.6		
	6	2.74	1.66	0.895	0.771	75.4	58.3		
	9	3.52	2.23	0.74	0.955	110	79.2		
Panimur	0	0	0	0	0	0	0	299.73	723.83
	3	2.19	1.82	0.466	0.268	85.8	67.4		
	6	4.23	4.17	0.541	0.572	138	151		
	9	5.31	5.67	0.521	0.733	147	202		
Shilong	0	0	0	0	0	0	0	367.71	420.48
	3	1.08	1.08	0.801	0.463	102	49.5		
	6	5.02	2.42	1.04	0.926	162	105		
	9	6.23	3.24	0.863	1.11	174	134		

Ten Story Irregular RC Building									
		Displacement (mm)		Acceleration (m/s2)		Velocity (kmph/s) (x10e-6)		Base Shear (kN)	
	Height (m)	X	Z	X	Z	X	Z	X	Z
Chamoli	0	0	0	0	0	0	0	125.13	178.88
	15	5.71	4.07	0.901	0.717	77.4	67		
	30	9.83	6.82	0.678	0.873	96.1	99.8		
Panimur	0	0	0	0	0	0	0	395.67	819.01
	15	17.2	18.1	0.453	0.432	208	229		
	30	26.7	28	0.408	0.577	283	384		
Shilong	0	0	0	0	0	0	0	510.95	418.45
	15	22.4	9.22	1.05	0.833	222	152		
	30	36.2	14.1	0.8	1.02	259	224		

Twenty Story Irregular RC Building									
		Displacement (mm)		Acceleration (m/s2)		Velocity (kmph/s) (x10e-6)		Base Shear (KN)	
	Height (m)	X	Z	X	Z	X	Z	X	Z
Chamoli	0	0	0	0	0	0	0	120.99	131.54
	30	10.7	8.31	0.908	0.628	75.6	46.4		
	60	15.3	12.8	0.671	1.01	82.8	72.8		
Panimur	0	0	0	0	0	0	0	282.23	355.85
	30	17.7	22.8	0.463	0.321	178	140		
	60	28.9	34.9	0.345	0.157	222	214		
Shilong	0	0	0	0	0	0	0	212.57	494.7
	30	23.4	30.3	1.06	0.736	168	195		
	60	36.3	46.5	0.78	1.1	242	306		

4. CONCLUSION

In this chapter, low, intermediate and high rise regular and irregular RC buildings are studied under high, low and intermediate frequency content ground motion. Three ground motions are introduced to the buildings. Linear time history analysis is performed in STAAD Pro. Software. The results of the structure are given in the form of story acceleration, displacement and velocity and base shear. Study and comparison of the responses of all the ground motions for each type of structure is done in this chapter.

Conclusions

For three, ten and twenty story regular RC buildings, following conclusions can be drawn:

- ❖ Maximum story displacement occurs due to intermediate frequency content ground motion in three story regular RC building in X direction and Z direction.
- ❖ Minimum story displacement occurs due to high frequency content ground motion in three story regular RC building in X direction and Z direction respectively.
- ❖ Maximum story acceleration occurs due to low frequency content ground motion in three story regular RC building in X direction and Z direction.
- ❖ Minimum story acceleration occurs due to high and intermediate frequency content ground motion in three story regular RC building in X direction and Z direction respectively.
- ❖ Maximum story velocity occurs due to low frequency content ground motion in three story regular RC building in X direction and Z direction.

- ❖ Minimum story velocity occurs due to high frequency content ground motion in three story regular RC building in X direction and Z direction.
- ❖ Maximum base shear is occurs due to low and intermediate frequency content ground motion in three story regular RC building in X direction and Z direction respectively.
- ❖ Minimum base shear is occurs due to high frequency content ground motion in three story regular RC building in X direction and Z direction.
- ❖ Maximum story displacement occurs due to low and intermediate frequency content ground motion in ten story regular RC building in X direction and Z direction respectively.
- ❖ Minimum story displacement occurs due to high frequency content ground motion in ten story regular RC building in X direction and Z direction.
- ❖ Maximum story acceleration occurs due to low frequency content ground motion in ten story regular RC building in X direction and Z direction.
- ❖ Minimum story acceleration occurs due to intermediate frequency content ground motion in ten story regular RC building in X direction and Z direction.
- ❖ Maximum story velocity occurs due to low frequency content ground motion in ten story regular RC building in X direction.
- ❖ Maximum story velocity occurs due to intermediate frequency content ground motion in ten story regular RC building in Z direction.
- ❖ Minimum story velocity occurs due to high frequency content ground motion in ten story regular RC building in X direction and Z direction.
- ❖ Maximum base shear is occurs due to low frequency content ground motion in ten story regular RC building in X direction.
- ❖ Maximum base shear is occurs due to intermediate frequency content ground motion in ten story regular RC building in Z direction.
- ❖ Minimum base shear is occurs due to high frequency content ground motion in ten story regular RC building in X direction and Z direction.
- ❖ Maximum story displacement occurs due to low frequency content ground motion in twenty story regular RC building in X direction and Z direction.
- ❖ Minimum story displacement occurs due to high frequency content ground motion in twenty story regular RC building in X direction and Z direction.
- ❖ Maximum story acceleration occurs due to low frequency content ground motion in twenty story regular RC building in X direction and Z direction.
- ❖ Minimum story acceleration occurs due to intermediate frequency content ground motion in twenty story regular RC building in X direction and Z direction.
- ❖ Maximum story velocity occurs due to low frequency content ground motion in twenty story regular RC building in X direction and Z direction.
- ❖ Minimum story velocity occurs due to high frequency content ground motion in twenty story regular RC building in X direction and Z direction.
- ❖ Maximum base shear is occurs due to low frequency content ground motion in twenty story regular RC building in X direction and Z direction.
- ❖ Minimum base shear is occurs due to high frequency content ground motion in twenty story regular RC building in X direction and Z direction.

For three, ten and twenty story irregular RC buildings, following conclusions can be drawn:

- ❖ Maximum story displacement occurs due to low frequency content ground motion in three story irregular RC building in X direction.
- ❖ Maximum story displacement occurs due to intermediate frequency content ground motion in three story irregular RC building in Z direction.
- ❖ Minimum story displacement occurs due to high frequency content ground motion in three story irregular RC building in X direction and Z direction.
- ❖ Maximum story acceleration occurs due to low frequency content ground motion in three story irregular RC building in X direction and Z direction.
- ❖ Minimum story acceleration occurs due to intermediate frequency content ground motion in three story irregular RC building in X direction and Z direction.

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- ❖ Maximum story velocity occurs due to low frequency content ground motion in three story irregular RC building in X direction.
- ❖ Maximum story velocity occurs due to intermediate frequency content ground motion in three story irregular RC building in Z direction.
- ❖ Minimum story velocity occurs due to low and intermediate frequency content ground motion in three story irregular RC building in X direction and Z direction respectively.
- ❖ Maximum base shear is occurs due to low frequency content ground motion in three story irregular RC building in X direction and Z direction.
- ❖ Minimum base shear is occurs due to intermediate frequency content ground motion in three story irregular RC building in X direction and Z direction.
- ❖ Maximum story displacement occurs due to low and intermediate frequency content ground motion in ten story irregular RC building in X direction and Z direction.
- ❖ Minimum story displacement occurs due to high frequency content ground motion in ten story irregular RC building in X direction and Z direction.
- ❖ Maximum story acceleration occurs due to low frequency content ground motion in ten story irregular RC building in X direction and Z direction.
- ❖ Minimum story acceleration occurs due to intermediate frequency content ground motion in ten story irregular RC building in X direction and Z direction.
- ❖ Maximum story velocity occurs due to intermediate frequency content ground motion in ten story irregular RC building in X direction and Z direction.
- ❖ Minimum story velocity occurs due to high frequency content ground motion in ten story irregular RC building in X direction and Z direction.
- ❖ Maximum base shear is occurs due to low frequency content ground motion in ten story irregular RC building in X direction.
- ❖ Maximum base shear is occurs due to intermediate frequency content ground motion in ten story irregular RC building in Z direction.
- ❖ Minimum base shear is occurs due to high frequency content ground motion in ten story irregular RC building in X direction and Z direction.
- ❖ Maximum story displacement occurs due to low frequency content ground motion in twenty story irregular RC building in X direction and Z direction.
- ❖ Minimum story displacement occurs due to high frequency content ground motion in twenty story irregular RC building in X direction and Z direction.
- ❖ Maximum story acceleration occurs due to low frequency content ground motion in twenty story irregular RC building in X direction and Z direction.
- ❖ Minimum story acceleration occurs due to intermediate frequency content ground motion in twenty story irregular RC building in X direction and Z direction.
- ❖ Maximum story velocity occurs due to low frequency content ground motion in twenty story irregular RC building in X direction and Z direction.
- ❖ Minimum story acceleration occurs due to high frequency content ground motion in twenty story irregular RC building in X direction and Z direction.
- ❖ Maximum base shear is occurs due to low and intermediate frequency content ground motion in twenty story irregular RC building in X direction and Z direction respectively.
- ❖ Minimum base shear is occurs due to high frequency content ground motion in twenty story irregular RC building in X direction and Z direction.

Final Conclusion

It can be conclude that,

- There is significant effect of low frequency content on all the structures.
- High frequency content ground motion has less effect on all regular as well irregular RC structures.
- Structure experiences less effect from intermediate frequency content ground motion than low frequency content ground motion and more effect from high frequency content ground motion.

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