Seismic Behavior of Reinforced Concrete Buildings under Varying Frequency Contents

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Abstract: **Earthquake is the result of sudden release of energy in the earth's crust that generates seismic waves. Ground shaking and rupture are the major effects generated by earthquakes. It has social as well as economic consequences such as causing death and injury of living things especially human beings and damages the built and natural environment. In order to take precaution for the loss of life and damage of structures due to the ground motion, it is important to understand the characteristics of the ground motion. The most important dynamic characteristics of earthquake are peak ground acceleration (PGA), frequency content, and duration. These characteristics play predominant rule in studying the behavior of structures under seismic loads.The strength of ground motion is measured based on the PGA, frequency content and how long the shaking continues. Ground motion has different frequency contents such as low, intermediate, and high. Present work deals with 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 reinforced concrete buildings under low, intermediate, and high-frequency content ground motions. Both regular and irregular three-dimension two, six, and twenty- story RC buildings with six ground motions of low, intermediate, and high-frequency contents having equal duration and peak ground acceleration (PGA) are studied herein. The response of the buildings due to the ground motions in terms of story displacement, story velocity, story acceleration, and base shear are found. The responses of each ground motion for each type of building are studied and compared. The results show that low- frequency content ground motions have significant effect on both regular as well as irregular RC buildings. However, high-frequency content ground motions have very less effect on responses of the regular as well as irregular RC buildings.**

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

I. INTRODUCTION

An earthquake is the result of a rapid release of strain energy stored in the earth's crust that generates seismic waves. Structures are vulnerable to earthquake ground motion and damages the structures. In order to take precaution for the damage of structures due to the ground motion, it is important to know the characteristics of the ground motion. The most important dynamic characteristics of earthquake are peak ground acceleration (PGA), frequency content, and duration. These characteristics play predominant rule in studying the behavior of structures under the earthquake ground motion. Severe earthquakes happen rarely. Even though it is technically conceivable to design and build structures for these earthquake events, it is for the most part considered uneconomical and redundant to do so. The seismic design is performed with the expectation that the severe earthquake would result in some destruction, and a seismic design philosophy on this premise has been created through the years. The objective of the seismic design is to constraint the damage in a structure to a worthy sum. The structures designed in such a way that should have the capacity to resist minor levels of earthquake without damage, withstand moderate levels of earthquake without structural damage, yet probability of some nonstructural damage, and withstand significant levels of ground motion without breakdown, yet with some structural and in addition nonstructural damage. In present work, two, six, and twenty-story regular as well as irregular RC buildings are subjected to six ground motions of low, intermediate, and high-frequency content. The buildings are modeled as three dimension and linear time history analysis is performed using structural analysis and design (STAAD Pro) software

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1.1 Behavior of RC Buildings Under Seismic Load

Mwafy & Elnashai [19], studied static pushover vs. dynamic collapse analysis of RC buildings. They studied natural and artificial ground motion data imposed on twelve RC buildings of distinct characteristics. The responses of over one hundred nonlinear dynamic analyses using a detailed 2D modeling approach for each of the 12 RC buildings are used to create the dynamic pushover envelopes and compare them with the pushover results with various load patterns. They established good relationship between the calculated ideal envelopes of the dynamic analyses and static pushover results for a definite class of structure. Pankaj & Lin [20] carried out material modeling in the seismic response analysis for the design of RC framed structures. They used two alike continuum plasticity material models to inspect the impact of material modeling on the seismic response of RC frame structures. In model one, reinforced concrete is modeled as a homogenized material using an isotropic Drucker-Prager yield condition. In model two, also based on the Drucker-Prager criterion, concrete and reinforcement are included independently; the later considers strain softening in tension. Their results indicate that the design response from response history analyses (RHA) is considerably different for the two models.

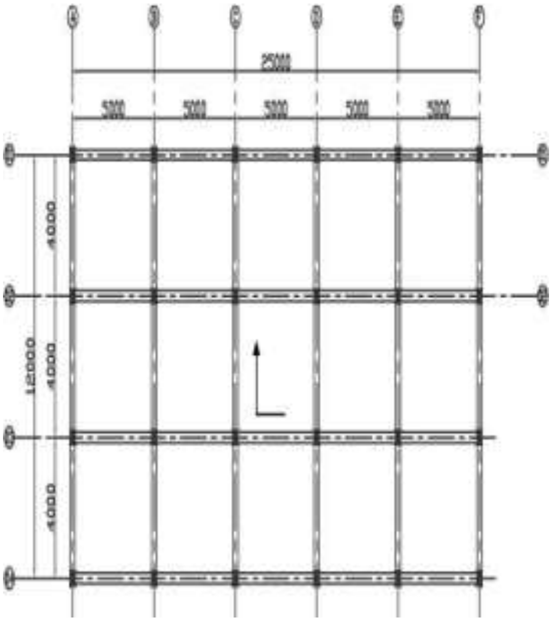
They compared the design nonlinear static analysis (NSA) and RHA responses for the two material models. Their works show that there can be important difference in local design response though the target deformation values at the control node are near. Likewise, the difference between the mean peak RHA response and the pushover response is dependent on the material model. Sarno [21] studied the effects of numerous earthquakes on inelastic structural response. Five stations are chosen to signify a set of sites exposed to several earthquakes of varying magnitudes and source-to-site distances. From the tens of records picked up at these five sites, three are chosen for each site to denote states of leading and lagging powerful ground motion. RC frame analysis subjected to the same set of ground motions used for the response of the RC frame, not only verify that multiple earthquakes deserve broad and urgent studies, but also give signs of the levels of lack of conservatism in the safety of traditionally designed structures when subjected to various earthquakes.

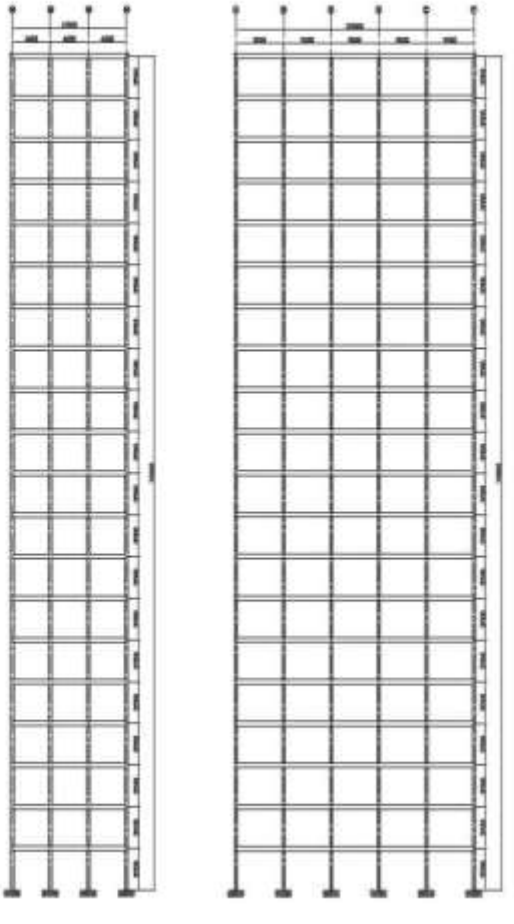
II. STRUCTURAL MODELING

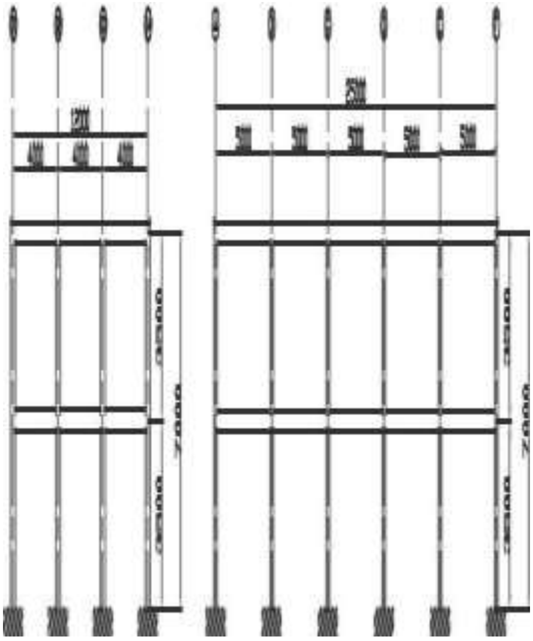
Concrete is the most widely used material for construction. It is strong in compression, but weak in tension, hence steel, which is strong in tension as well as compression, is used to increase the tensile capacity of concrete forming a composite construction named reinforced cement concrete. RC buildings are made from structural members, which are constructed from reinforced concrete, which is formed from concrete and steel. Tension forces are resisted by steel and compression forces are resisted by concrete. The word structural concrete illustrates all types of concrete used in structural applications. In the chapter, building description is presented. The plan, elevation of two, six, and twenty-story regular reinforced concrete buildings of low, mid, and highrise are shown in section 3.2. In section 3.3 the plan and elevation of the two, six, and twenty-story irregular reinforced concrete buildings which are considered as low, mid, and high-rise buildings are shown. Gravity loads, dead as well as live loads, are given in section 3.4. A brief description is provided for concrete and steel. Also, the concrete and steel bar properties which are used for modeling of the buildings are shown in section.

2.1 Regular RC Buildings

Two, six, and twenty-story regular reinforced concrete buildings, which are low, mid, and high-rise, are considered. The beam length in (x) transverse direction is 4m and in (z) longitudinal direction 5m. Figure 3.1 shows the plan of the three buildings having three bays in x-direction and five bays in z-direction. Story height of each building is assumed Figure 1 shows the frame (A-A) and (01-01) of the twenty, six, and two-story RC building respectively. For simplicity, both the beam and column cross sections are assumed 300 mm x 400 mm.







Frame (A-A) And (01-01) of Two-Story Regular RC Building (All Dimension are in Mm)

III. REGULAR RC BUILDINGS RESULTS AND DISCUSSION

3.1 Two-Story Regular RC Building

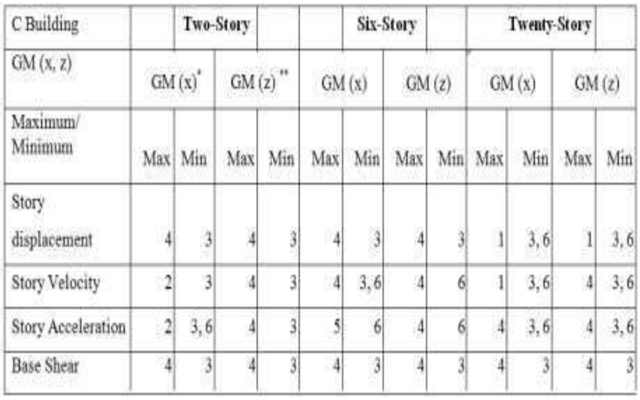
Figure shows story displacement, velocity, and acceleration of two-story regular RC building due to ground motion GM11, GM22, GM33, GM44, GM55, and GM66. The story displacement is maximum due to ground motion GM4 and minimum due to ground motion GM3. The story velocity is maximum due to ground motion GM2 and minimum due to ground motion GM3. The story acceleration is maximum due to ground motion GM2 and minimum due to ground motion GM3 and GM6. It indicates that the building undergoes high story displacement due to low-frequency content ground motion and high story velocity and The base shear of sixstory regular RC building due to ground motion GM1, GM2, GM3, GM4, GM5, and GM6 is shown in Figure 5.18. Figure 5.18 (a) shows that the building has maximum base shear of 4164.85 kN due to 1940 Imperial Valley (El Centro) elcentro_EW component and minimum base shear of 376.88 kN due to 1957 San Francisco (Golden Gate Park) GGP010 component ground motion in x-direction. Figure 5.18 (b) shows that the building has maximum base shear of 3587.44 kN due to 1940 Imperial Valley (El Centro) elcentro_EW and minimum base shear of 284.34 kN due to 1957 San Francisco (Golden Gate Park) GGP010 component ground motion in z-direction.

3.3 Twenty-Story Regular RC Building

Story displacement, velocity, and acceleration of twenty-story regular RC building due to ground motion GM1, GM2, GM3, GM4, GM5, and GM6. The story displacement is maximum due to ground motion GM1 and minimum due to ground motion GM3 and GM6. The story velocity is maximum due to ground motion GM1 and minimum due to ground motion GM3 and GM6. The story acceleration is maximum due to ground motion GM4 and minimum due to ground motion GM3 and GM6. It indicates that the building undergoes high story displacement, velocity, and acceleration due to low-frequency content ground motion. However, it experiences low story displacement, velocity, and acceleration due to high-frequency content ground motion in (x) transverse direction. Figure 5.20 shows story displacement, velocity, and acceleration of twenty-story regular RC building due to ground motion GM1, GM2, GM3, GM4, GM5, and GM6. The story displacement is maximum due to ground motion GM1 and minimum due to ground motion GM3 and GM6. The story velocity is maximum due to ground motion GM4 and minimum due to ground motion GM3 and GM6. The story acceleration is maximum due to ground motion GM4 and minimum due to ground motion GM3 and GM6. It indicates that the building undergoes high story displacement, velocity and acceleration due to low-frequency content ground motion. However, it experiences low story displacement, velocity, and acceleration due to high-frequency content ground motion in (z) longitudinal direction. The structure has maximum roof displacement of -696 mm at 9.93 s due to 1979 Imperial Valley-06 (Holtville Post Office) H-HVP225 component ground motion and minimum roof displacement of 4.83 mm at 3.13 s due to 1957 San Francisco (Golden Gate Park) GGP010 component ground motion.

It has maximum roof velocity of -1,105 mm/s at 8.69 s due to 1979 Imperial Valley-06 (Holtville Post Office) H-HVP225 component ground motion and minimum velocity of -74.7 mm/s at 2.27 s due to 1983 Coalinga-06 (CDMG46617) E-CHP000 component ground motion.

Table 5.1: Two, Six, and Twenty-Story Regular RC Building Responses Due to GM1-GM6 In X and ZDirection



C Building	Two-Story				Six-Story				Twenty-Story			
GM (x, z)	GM (x)*		GM (z)**		GM (x)		GM (z)		GM (x)		GM (z)	
Maximum/ Minimum	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Story displacement	4	3	4	3	4	3	4	3	1	3, 6	1	3, 6
Story Velocity	2	3	4	3	4	3, 6	4	6	1	3, 6	4	3, 6
Story Acceleration	2	3, 6	4	3	5	6	4	6	4	3, 6	4	3, 6
Base Shear	4	3	4	3	4	3	4	3	4	3	4	3

V. CONCLUSIONS

Following conclusions can be drawn for the two, six, and twenty-story regular RC buildings from the results obtained in chapter 5:

 Two-story regular RC building experiences maximum story displacement due to low-frequency content
ground motion in x and z-direction

- Two-story regular RC building experiences minimum story displacement due to high-frequency content ground motion in x and z-direction
- Two-story regular RC building experiences maximum story velocity due to intermediate-frequency content ground motion in x-direction and low-frequency content ground motion in z-direction
- Two-story regular RC building experiences minimum story velocity due to high-frequency content ground motion in x and z-direction
- Two-story regular RC building experiences maximum story acceleration due to intermediate-frequency content ground motion in x-direction and low-frequency content ground motion in z-direction Two-story irregular RC building experiences minimum story velocity due to high-frequency content ground motion in x and z-direction
- Two-story irregular RC building experiences maximum story acceleration due to intermediate-frequency content ground motion in x-direction and low-frequency content ground motion in z-direction.

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