STUDY ON SEISMIC BEHAVIOR OF VARIOUS RC BUILDINGS UNDER VARIOUS FREQUENCY CONTENT GROUND MOTIONS

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ABSTRACT

Earthquake causes loss of life, 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 important dynamic characteristics of earthquake are PGA, frequency content, and duration. These characteristics play predominant role in studying the behaviour of structures under seismic loads. Ground motion has different frequency contents such as low, intermediate and high. Present work deals with study of frequency content of ground motion on RC buildings. Linear time history analysis is performed in structural analysis and design (SAP2000) 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. The responses of each ground motion for each type of building in terms of floor displacement, storey drift and floor acceleration are studied and compared. The results show that high frequency content ground motions have significant effect on RC buildings.

Keywords:* *Frequency content, Ground Motion, Reinforced concrete buildings, 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 behaviour of structures under the earthquake ground motion. Cakir [1] studied the evaluation of the effect of earthquake frequency content on seismic behavior of cantilever retaining wall involving soil-structure interaction. Also, seismic behaviour of partially filled rigid rectangular tank with bottom-mounted submerged block are studied under low, intermediate, and high-frequency content ground motions. M.R. Kianoush [2] investigated the effect of earthquake frequency content on the seismic behaviour of fluid rectangular tank system using four different seismic motions. Six different soil types defined in the well-recognized seismic codes are considered. Two different finite element models corresponding with flexible shallow and tall tank configurations are studied under the effects of longitudinal, transversal and vertical ground motions. By changing the soil properties, comparisons are made on base shear, base moment and sloshing responses under different ground motions. It is concluded that the dynamic behaviour of the fluid tank soil system is highly sensitive to frequency characteristics of the earthquake record. Şafak & Frankel [3] studied the effects of ground motion characteristics on the response of base-isolated structures. They presented response of base-isolated structures in two models to show the effects of ground motion characteristics. They considered one and three- dimension velocity models for a six and seven-story base- isolated buildings, which are subjected to ground motions. Their results indicate that efficiency of base isolators is greatly dependent on the frequency characteristics as well as amplitudes of ground motion. Nayak & Biswal [4] studied seismic behaviour of partially filled rigid rectangular tank with bottom-installed submerged block. They used six different ground motions of low, intermediate and high-frequency content to examine the dynamic behaviour of tank liquid-submerged block system. They established a velocity potential based Galerkin finite element model for the analysis and showed the effect of submerged block on impulsive and convective response components of hydrodynamic behaviour in terms of base overturning moment, base shear, and enumerated pressure distribution along both the tank and block wall. 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 predominant rule in studying the behaviour of RC buildings under seismic loads. 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 the ground motion records are classified into three categories [2].

High-frequency content PGA/PGV > 1.2

Intermediate-frequency content 0.8< PGA/PGV< 1.2

Low-frequency content PGA/PGV < 0.8

A few research is carried out to study the frequency content of the ground motion. The purpose of this project is to study the response of low, mid, and high rise RC buildings under low, intermediate, and high- frequency content ground motions in terms of story displacement, story velocity and story acceleration preforming linear time-history analysis using structural analysis and design (SAP 2000) software. The responses of RC buildings are strongly dependent on the frequency content of the ground motions.

II. MODELLING AND ANALYSIS

The building is modeled using SAP 2000 software. Beams and columns are modeled as two node beam element with six degrees of freedom at each node. Slabs are modeled as rigid membrane elements and diaphragm constraint is assigned. The area loads are applied on the slabs. Building modeled as a bare frame however the dead weight of infill is assigned as uniformly distributed load over beams. Model is consists of two storey, eight storey and twenty storey reinforced concrete buildings, which are considered as low, mid and high-rise building. The beam length in x-direction is 5m and in y-direction is 3m. Figure 1 shows the plan of the three buildings having five bays in x-direction and three bays in y-direction. The storey height for each floor and plinth height is kept as 3m and 1.5m respectively. The RC frame consists of beam and column of sizes 0.3m x 0.5m and 0.5m x 0.5m respectively also slab thickness is taken as 0.12m. The concrete of grade M20 and steel of grade Fe 415 is considered. Self weight of building is automatically calculated by the software. Live load of 3.5 kN/m^2 is provided in accordance to IS 875 (Part2) Floor finishes of 1.875kN/ m^2, Wall load of 12 kN/m, Live load on floor 3.5 kN/m^2, Live load of 1.75 kN/m^2 on roof is provided.

There are three ground motion records are considered which have low, intermediate and high-frequency content as shown in Table 1. Two storey, eight storey and twenty storey buildings, which are considered as low, mid and high-rise reinforced building are modeled as three-dimension reinforced concrete buildings in SAP 2000 software. These ground motions are introduced to the software and linear time history analysis is performed. The responses of each ground motion for each type of building in terms of floor displacement, storey drift and floor acceleration considered. The seismic analysis of all building is carried by linear time history in accordance with IS: 1893 (Part 1):2002. In the analysis the number of modes considered is more than 90 percent of the total seismic mass.

Table 1: Ground motion characteristics and classification of its frequency-content

Ground Motion Records	Component	Notation	PGA (g)	PGV (m/s)	PGA/ PGV	Frequency content classification
San Fernando Earthquake - 8244 Orion Blvd.(1971)	DEGREES 180, CALTECH IIC048	LGM	0.1319	0.239	0.55	Low
Kern Country Earthquake - Taft Lincoln Tunnel (1952)	69 DEGREES , CALTECH IIA004	IGM	0.155	0.157	0.98	Intermediate
Northridge Earthquake – Santa Monica, City Hall (1994)	90 DEGREES, CDMG QN94A538	HGM	0.882	0.417	2.11	High

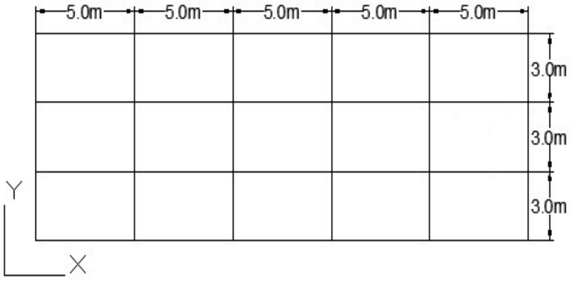


Figure 1: Plan of two, eight and twenty storey building

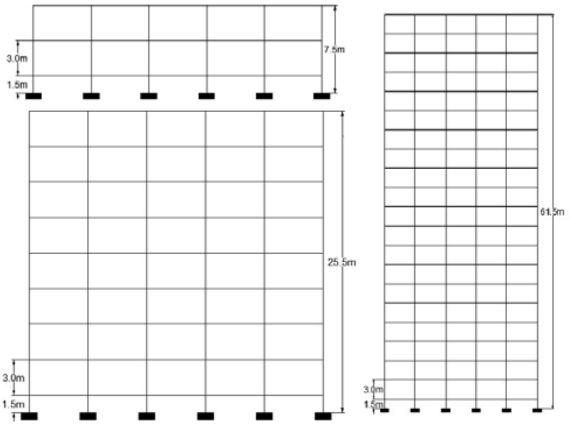


Figure 2: Elevation of two, eight and twenty storey building

III. RESULTS AND DISCUSSION

The results of two storey, eight storey and twenty storey reinforced concrete buildings in terms of floor displacement, storey drift and floor acceleration are presented in longitudinal(x) and transverse(y) direction. Also roof displacement, storey drift and roof acceleration for each building due to each ground motions is illustrated in longitudinal and transverse direction.

a) G+2 Story RC Building

Following figure shows floor acceleration, floor displacement and storey drift of two storey RC building due to ground motion LGM, IGM and HGM.

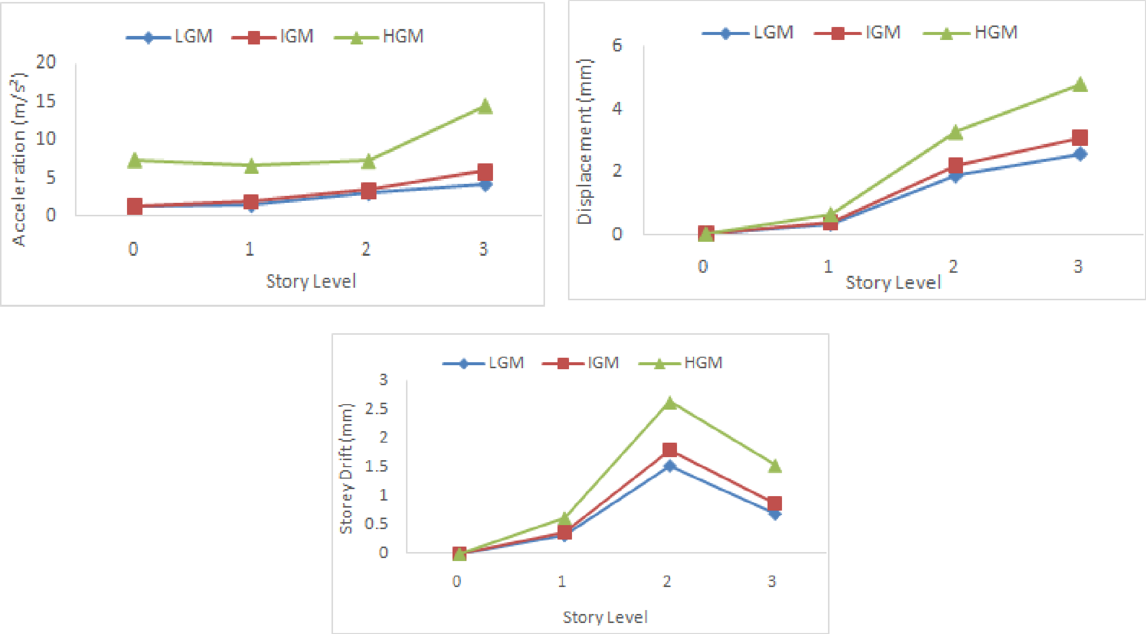


Figure 3(a): Floor Acceleration, floor displacement and storey drift of two storey building in x direction due to ground motion LGM, IGM and HGM

Figure 3(a) shows floor acceleration is maximum due to HGM and minimum due to LGM. The floor displacement is maximum due to HGM and minimum due to LGM. The storey drift is maximum due to HGM and minimum due to LGM. It indicates that the building undergoes high floor acceleration, floor displacement and storey drift due to high-frequency content ground motion. However, it experiences low floor displacement, storey drift and floor acceleration due to low frequency content ground motion in (x) longitudinal direction.

Figure 3(b) shows floor acceleration, floor displacement and storey drift of two storey RC building due to LGM, IGM and HGM. The floor acceleration is maximum due to HGM and minimum due to LGM. The floor displacement is maximum due to HGM and minimum due to LGM. The storey drift is maximum due to HGM and minimum due to LGM. It indicates that the building undergoes high floor acceleration, floor. displacement and storey drift due to high-frequency content ground motion. However, it experiences low floor displacement, storey drift and floor acceleration due to low frequency content ground motion in (y) transverse direction.

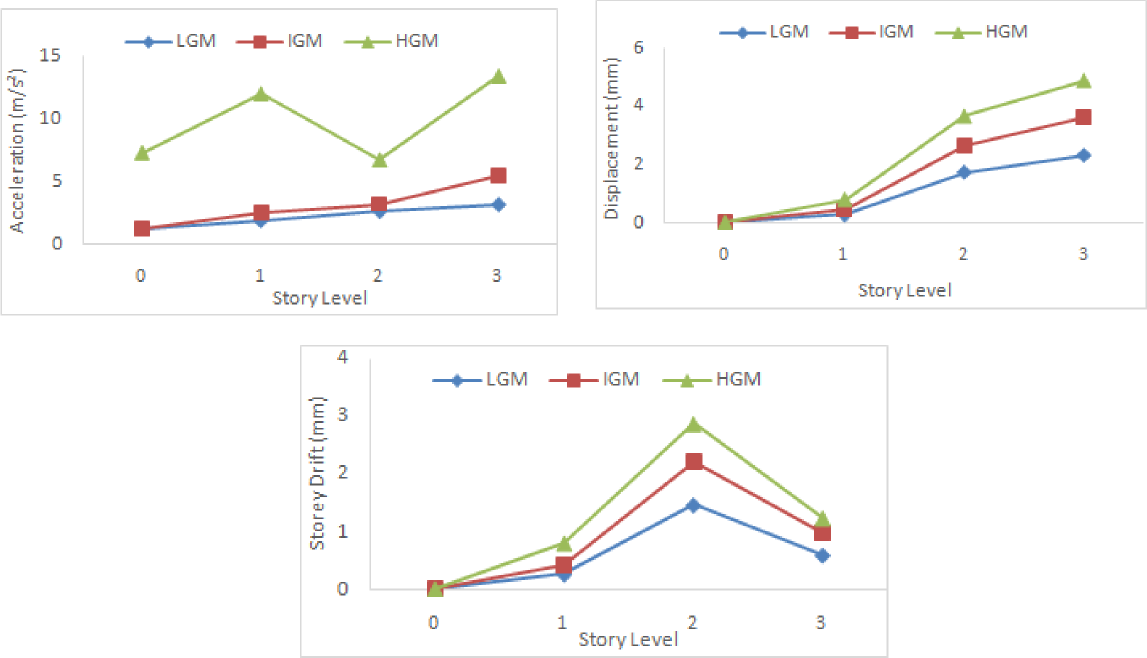
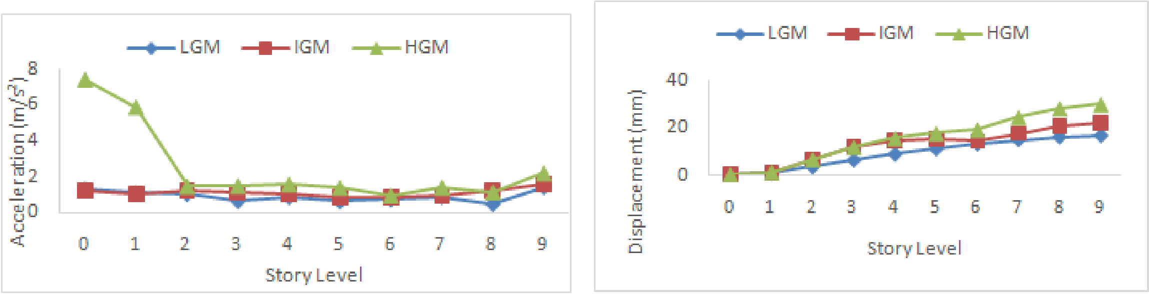


Figure 3(b): Floor Acceleration, floor displacement and storey drift of two storey building in x direction due to ground motion LGM, IGM and HGM

b) Eight Storey RC Building

Figure 4.4 shows floor acceleration, floor displacement and storey drift of eight storey RC building due to LGM, IGM and HGM. The floor acceleration is maximum due to HGM and minimum due to LGM. The floor displacement is maximum due to HGM and minimum due to LGM. The storey drift is maximum due to HGM and minimum due to LGM. It indicates that the building undergoes high floor acceleration, floor displacement and storey drift due to high-frequency content ground motion. However, it experiences low floor displacement, storey drift and floor acceleration due to low frequency content ground motion in (x) longitudinal direction.



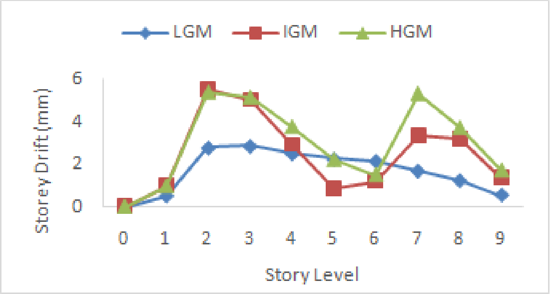


Figure 4(a): Floor acceleration, displacement and storey drift of eight storey building due to Ground motions LGM, IGM and HGM in x direction

Figure 4(b) shows floor acceleration, floor displacement and storey drift of eight storey RC building due to LGM, IGM and HGM. The floor acceleration is maximum due to HGM and minimum due to LGM. The floor displacement is maximum due to HGM and minimum due to LGM. The storey drift is maximum due to IGM and minimum due to LGM. It indicates that the building undergoes high floor acceleration, and floor displacement due to high-frequency content ground motion and maximum storey drift due to IGM ground motion. However, it experiences low floor displacement, storey drift and floor acceleration due to low frequency content ground motion in (y) transverse direction.

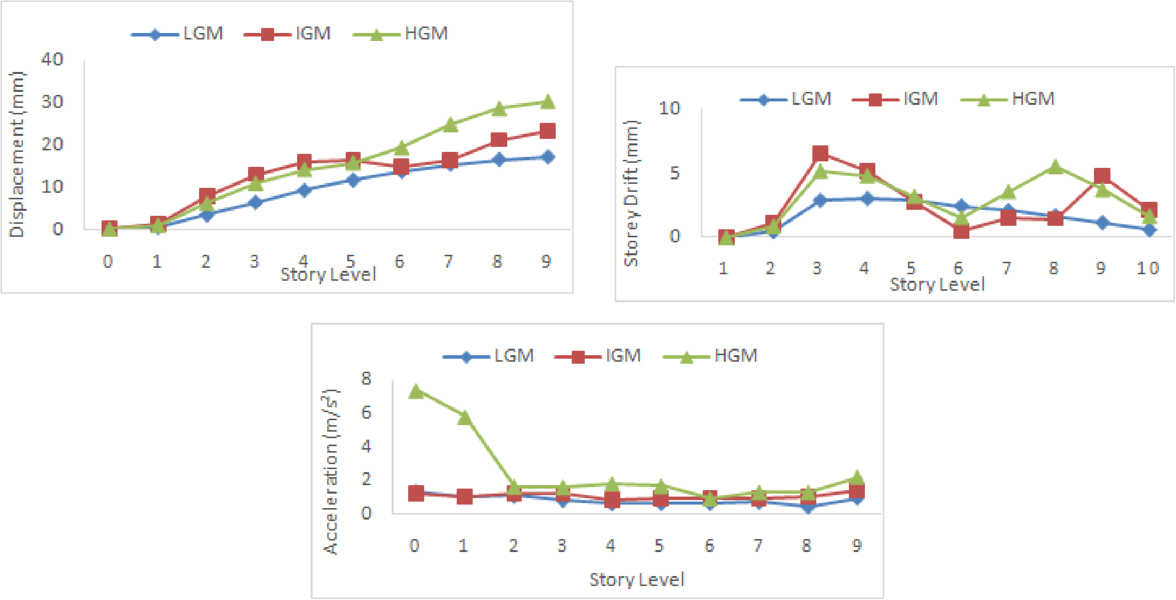


Figure 4(b): Floor acceleration, velocity and displacement of eight storey building due to Ground motions LGM, IGM and HGM in y direction

c) Twenty Storey RC Building

The responses of given RC building includes floor acceleration, floor displacement and storey drift along longitudinal and transverse direction. Figure 5(a) shows floor acceleration, floor displacement and storey drift of twenty storey RC building due to LGM, IGM and HGM. The floor acceleration is maximum due to HGM and minimum due to LGM. The floor displacement is maximum due to HGM and minimum due to LGM. The storey drift is maximum due to HGM and minimum due to IGM. It indicates that the building undergoes high floor acceleration, floor displacement and storey drift due to high-frequency content ground motion. However, it experiences low floor acceleration and floor displacement due to low frequency content ground motion and low storey drift due to intermediate frequency content ground motion in (x) longitudinal direction.

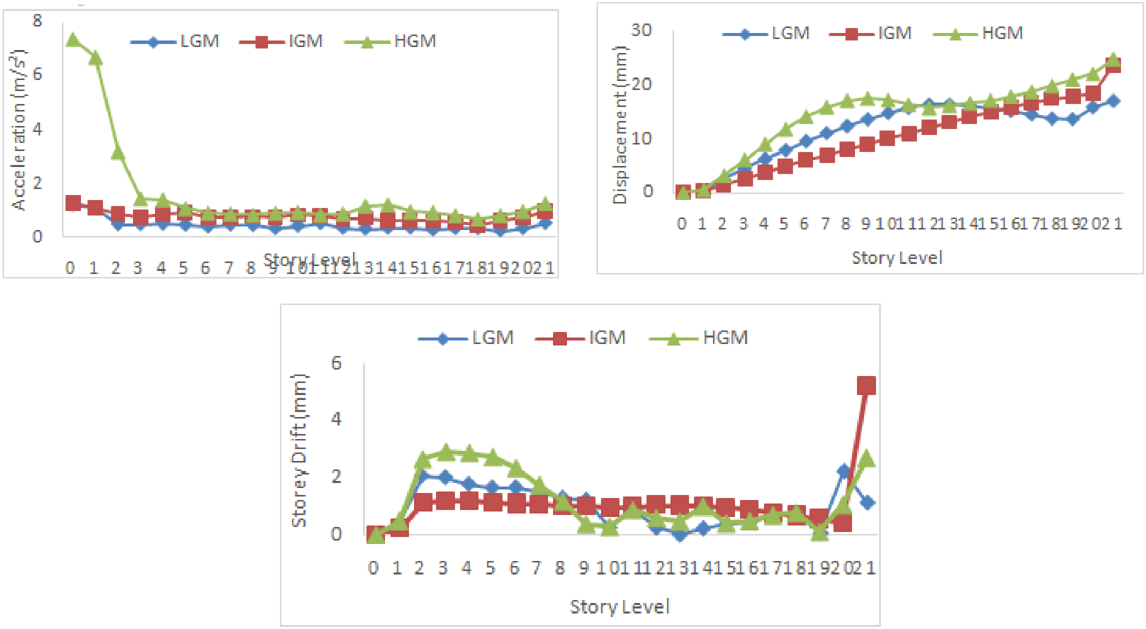
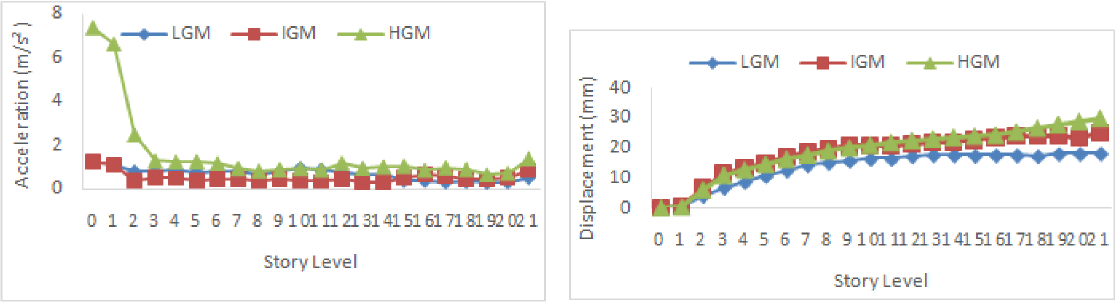


Figure 5(a): Floor acceleration, Floor displacement and Storey drift of twenty storeys RC building due to LGM, IGM and HGM in longitudinal direction

Figure 5(b) shows floor acceleration, floor displacement and storey drift of twenty storey RC building due to LGM, IGM and HGM. The floor acceleration is maximum due to HGM and minimum due to LGM. The floor displacement is maximum due to HGM and minimum due to LGM. The storey drift is maximum due to IGM and minimum due to LGM. It indicates that the building undergoes high floor acceleration, floor displacement due to high-frequency content ground motion and high storey drift due to intermediate frequency content ground motion. However, it experiences low floor acceleration, floor displacement and storey drift due to low frequency content ground motion in (y) transverse direction.



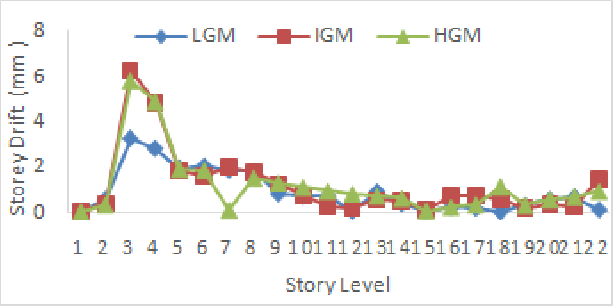


Figure 5(b): Floor acceleration, Floor displacement and Storey drift of twenty storeys RC building due to LGM, IGM and HGM in transverse direction

The maximum and minimum values of floor acceleration, floor displacement and storey drift of two, eight and twenty storey RC building due to LGM, IGM and HGM in (x) longitudinal and (y) transverse direction are summarized in Table 2

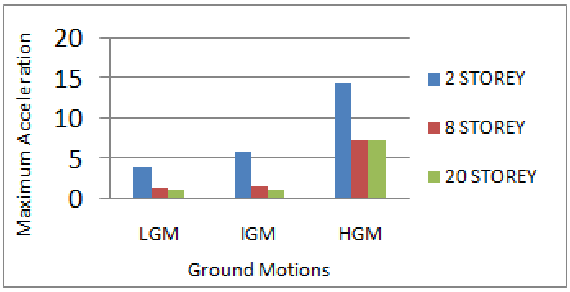
Table 2: The response of two, eight and twenty storey RC building due to LGM, IGM and HGM in (x) longitudinal and (y) transverse direction

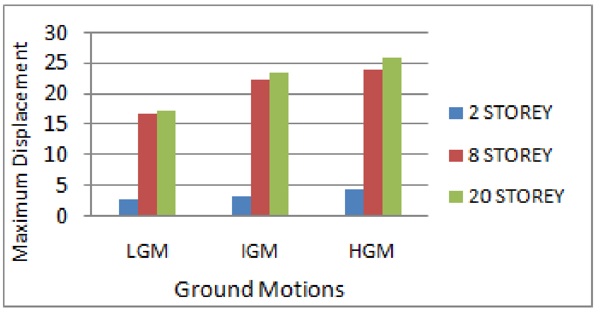
RC Building	Two Storey				Eight Storey				Twenty Storey			
GM (x, y)	GM (x)		GM (y)		GM (x)		GM (y)		GM(x)		GM (y)	
Maximum/ Minimum	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Floor Acceleration	HGM	LGM	HGM	LGM	HGM	LGM	HGM	LGM	HGM	LGM	HGM	LGM
Floor Displacement	HGM	LGM	HGM	LGM	HGM	LGM	HGM	LGM	HGM	LGM	HGM	LGM
Storey Drift	HGM	LGM	HGM	LGM	HGM	LGM	IGM	LGM	HGM	LGM	HGM	LGM

The comparative study for the above responses is graphically represented with the help of bar charts as shown in Fig 6(a) to Fig 6(b).

Maximum Response in longitudinal direction

Bar charts have been drawn for each type of ground motions i.e. low, intermediate and high frequency content ground motions with varying height of the RC building. Maximum Responses in longitudinal direction are shown in fig 6(a).





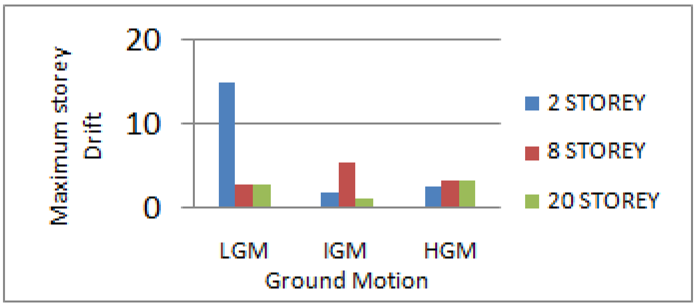


Figure 6(a): Maximum Responses longitudinal direction for Acceleration, Displacement and Storey Drift

As seen from the figures above it is observed that a low frequency content ground motion produces less acceleration as compared to high frequency and intermediate frequency content ground motion. It is also observed that as the height of the building increases, the acceleration response of the building goes on decreasing.

From displacement responses it is observed that a low frequency content ground motion produces less displacement as compared to high frequency content ground motion ground. Further as the height of the building increases, the displacement response of the building goes on increasing. This is obvious because at top storeys the displacements are larger as compared to lower storeys.

Maximum Response in transverse direction

Bar charts have been drawn for each type of ground motions i.e. low, intermediate and high frequency content ground motions with varying height of the RC building. Maximum responses in transverse direction are shown in fig 6(b).

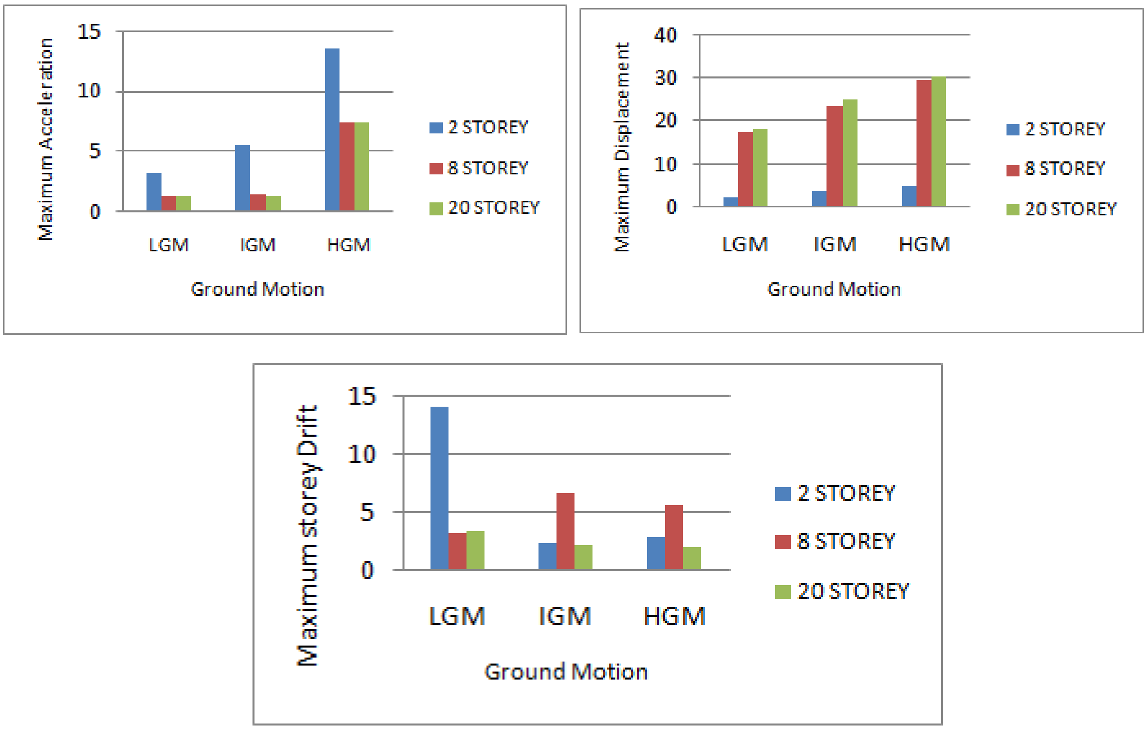


Figure 6(b): Maximum Responses transverse direction for Acceleration, Displacement and Storey Drift

As seen from the figures above it is observed that a low frequency content ground motion produces less acceleration as compared to high frequency and intermediate frequency content ground motion. It is also observed that as the height of the building increases, the acceleration response of the building goes on decreasing.

From displacement responses it is observed that a low frequency content ground motion produces less displacement as compared to high frequency content ground motion ground. Further as the height of the building increases, the displacement response of the building goes on increasing. This is obvious because at top storeys the displacements are larger as compared to lower storeys.

V. CONCLUSION

It is concluded that as the height of the building goes on increasing, acceleration response goes on decreasing. On the other hand, displacement response goes on increasing. Hence higher storey level is subjected to higher values of displacement responses and lower values of acceleration responses, for all considered frequency content ground motion excitations. The amount of earthquake forces reduces as the height of the building increases. Low rise buildings are subjected to higher rate of acceleration and hence higher earthquake forces as compared to mid – rise and high – rise buildings. Hence low – rise buildings are susceptible to higher damages due to earthquake as compared to high rise buildings. All considered responses such as acceleration and displacement are observed to be higher for high frequency content ground motion as compared to low frequency content ground motion. Acceleration responses are observed to be higher for high frequency content ground motion as compared to low frequency content ground motion. Contrary to this, displacement responses are observed to be higher for low frequency content ground motion as compared to high frequency content ground motion. Hence a low rise building subjected to high frequency ground motion is assumed to be the worst case for earthquake damage while a high rise building subjected to low frequency content ground motion is assumed to be the safest situation. It can be summarized that high-frequency content ground motion has significant effect on RC buildings responses. However, low-frequency content ground motion has very less effect on responses of RC buildings. It is found that the intermediate-frequency content ground motion has less effect than high-frequency content ground motion and more effect than low-frequency content ground motion on the RC buildings. High frequency content ground motion has significant effect RC buildings responses. However, Intermediate frequency content ground motion has very less effect on responses of RC buildings. It is found that the low frequency content ground motion has less effect than high frequency content ground motion and more effect than Intermediate frequency content ground motion on the RC buildings.

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