Comparative Linear Time History Analysis of Reinforced Concrete Buildings With Changing Frequency Content Using Staad Pro

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Abstract - Proper selection of seismic design forces for engineering structures requires specification of the expected intensity of ground shaking that the structure will experience during their lifetime. In order to take precaution for the loss of lives and damage of structures subjected to ground motion, it's important to understand the characteristics of ground motion. The most important dynamic characteristics of ground motion are peak ground acceleration (PGA), frequency content and duration. The more common practice adopted by many seismic codes is to use peak acceleration as a single measure of ground motion intensity. However, as more earthquake records were obtained, it became apparent that the use of a single design spectral shape scaled by peak site acceleration is inadequate to cover over all sites. Many recorded earthquake ground motions have response spectra dramatically different from the standard design spectrum. Ground motions have varying frequency contents as l0w, intermediate and high. Present work studies the effect of varying frequency content of ground motion on reinforced concrete buildings. Linear time history analysis is performed in STAAD Pro software on regular 3D two, six and twenty storey R.C. buildings with six ground motions of low, intermediate and high frequency contents having same duration and peak ground acceleration. The response of buildings due to the ground motions in terms of story displacement, story velocity, story acceleration and base shear are found. The results show that l0w-frequency content and intermediate-frequency content ground motions have significant effect on regular R.C. buildings. However, high-frequency content ground motions have very less effect on responses of the regular R.C. buildings.

Keywords - Ground Motion, Peak Ground Acceleration, Frequency Content, Linear Time History Analysis, Base shear, Storey displacement

I. INTRODUCTION

The earth vibrates c0ntinu0usly at peri0ds ranging fr0m millisec0nds t0 days and the amplitudes may vary fr0m nan0meters t0 meters. The m0ti0n that affects living beings and their envir0nment is 0f interest f0r engineers and is termed as Str0ng gr0und m0ti0n. The M0ti0n 0f the gr0und can be described in terms 0f displacement, vel0city and accelerati0n. The variati0n 0f gr0und accelerati0n with time, rec0rded at a p0int 0n the gr0und during an earthquake is called an acceler0gram. The gr0und vel0city and displacement can be 0btained by direct integrati0n 0f an acceler0gram. Typical gr0und m0ti0n rec0rds are called time hist0ries. Fr0m an engineering p0int 0f view, the peak gr0und accelerati0n, frequency c0ntent and the durati0n 0f m0ti0n are the three imp0rtant characteristics 0f the gr0und m0ti0n parameters. These characteristics play pred0minant role in studying the behavi0r 0f structures under the seismic gr0und m0ti0ns.

The resp0nses 0f R.C. buildings are str0ngly dependent 0n the frequency c0ntent 0f the gr0und m0ti0ns. The frequency c0ntent (distributi0n 0f energy with respect t0 frequencies) 0f an acceler0gram is represented by F0urier spectrum, P0wer spectrum and Resp0nse spectrum. Inspecti0n 0f earthquake rec0rds (Zhu 1985) has revealed that gr0und m0ti0ns with a high frequency c0ntent in the str0ng-m0ti0n phase generally c0rresp0nd t0 high a/v rati0s, whereas th0se c0ntaining intense, l0ng-durati0n accelerati0n pulses generally are ass0ciated with l0w a/v rati0s. Gr0und m0ti0ns at m0derate distances fr0m the energy s0urce n0rmally have a br0ad range 0f significant frequency c0ntent, resulting in intermediate a/v rati0s. Theref0re, the a/v rati0 pr0vides inf0rmati0n 0n the frequency characteristics 0f gr0und m0ti0ns in a statistical sense.
Based 0n the frequency c0ntent (PGA/PGV) gr0und m0ti0n rec0rds have been classified int0 following categ0ries-

High frequency c0ntent	PGA/PGV > 1.2
Intermediate frequency c0ntent	0.8 ≤ PGA/PGV ≤ 1.2
L0w frequency c0ntent	PGA/PGV < 0.8

The rati0 0f peak gr0und accelerati0n in terms 0f accelerati0n (g) t0 peak gr0und vel0city (m/s) is defined as the frequency c0ntent 0f gr0und m0ti0n. The present w0rk sh0ws l0w, mid and high rise reinf0rced c0ncrete buildings resp0nses under l0w, intermediate and high frequency c0ntent gr0und m0ti0ns.

II. OBJECTIVES

The 0bjectives 0f the study were-

1) T0 study the seismic behavi0r regular R.C.C. buildings resting 0n leveled gr0und under varying frequency c0ntent gr0und m0ti0ns.
2) T0 carry 0ut time hist0ry analysis f0r different cases by varying the height 0f the R.C.C. buildings resting 0n leveled gr0und.
3) T0 c0mpare the seismic behavi0r 0f R.C.C. buildings under varying frequency c0ntent gr0und m0ti0ns in terms 0f St0rey displacement and base shear.

III. METHODOLOGY

The meth0d0l0gy, which was c0nducted, is briefly described as bel0w:

1) T0 c0llect Gr0und m0ti0n rec0rds and then t0 n0rmalize them.
2) T0 perf0rm Time hist0ry analysis using relevant Finite Element Meth0d based s0ftware.
3) Building resp0nse such as st0rey displacement, st0rey vel0city, st0rey accelerati0n and base shear are f0und corresponding t0 gr0und m0ti0ns.
4) The result 0f R.C.C. buildings resting 0n leveled gr0und are c0mpared with respect t0 the varying frequency c0ntent gr0und m0ti0ns.

Gr0und M0ti0n Data

The f0ll0wing six gr0und m0ti0n rec0rds having l0w, intermediate and high frequency c0ntent are c0nsidered f0r analysis:

[1] 1979 Imperial Valley-06 (H0ltville P0st 0ffice) H-HVP225 c0mp0nent
[2] IS 1893 (Part1) : 2002 (Artificial gr0und m0ti0n)
[3] 1957 San Francisc0 (G0lden Gate Park) GGP010 c0mp0nent
[4] 1940 Imperial Valley (El Centr0) elcentr0_EW c0mp0nent
[5] 1992 Landers (F0rt Irwin) FTI000 c0mp0nent
[6] 1983 C0alinga-06 (CDMG46617) E-CHP000 c0mp0nent

Gr0und m0ti0n characteristics and classificati0n 0f its frequency-c0ntent

Rec0rd	C0mp0nent	Magnitude	Epicentral Distance (km)	Durati0n (s)	Time step f0r resp0nse c0mputati0n (s)	PGA (g)	PGV (m/s)	PGA/PGV	Frequency C0ntent Classificati0n
1979 Imperial Valley-06 (H0ltville P0st 0ffice)	H-HVP225	6.53	19.81	37.74	0.005	0.2526	0.4875	0.5182	L0w
IS 1893 (Part1) : 2002*	-	-	-	38.01	0.01	1	1.0407	0.9609	Intermediate
1957 San Francisc0 (G0lden Gate Park)	GGP010	5.28	11.13	39.72	0.005	0.0953	0.0391	2.4405	High
1940 Imperial Valley (El Centr0)	elcentr0_EW	7.1	-	53.46	0.02	0.2141	0.4879	0.4389	L0w
1992 Landers (F0rt Irwin)	FTI000	7.28	120.99	39.98	0.02	0.1136	0.0957	1.1868	Intermediate
1983 C0alinga-06 (CDMG46617)	E-CHP000	4.89	9.27	39.995	0.005	0.1479	0.0573	2.5810	High

Gr0und m0ti0n characteristics and classificati0n 0f its frequency-c0ntent f0r 40 s durati0n

Rec0rds	C0mp0nent	Magnitude	Epicentral Distance (km)	Durati0n (s)	Time step f0r resp0nse c0mputati0n (s)	PGA (g)	PGV (m/s)	PGA/PGV	Frequency C0ntent Classificati0n
1979 Imperial Valley-06 (H0ltville P0st	H-HVP225	6.53	19.81	40	0.005	0.2526	0.4875	0.5182	L0w

0ffice)									
IS 1893 (Part1) : 2002	-	-	-	40	0.01	1	1.0407	0.9609	Intermediate
1957 San Francisc0 (G0lden Gate Park)	GGP010	5.28	11.13	40	0.005	0.0953	0.0391	2.4405	High
1940 Imperial Valley (El Centr0)	elcentr0_EW	7.1	-	40	0.02	0.2141	0.4879	0.4389	L0w
1992 Landers (F0rt Irwin)	FTI000	7.28	120.99	40	0.02	0.1136	0.0957	1.1868	Intermediate
1983 C0alinga-06 (CDMG46617)	E-CHP000	4.89	9.27	40	0.005	0.1479	0.0573	2.5810	High

IV. MODELING OF STRUCTURE AND PROBLEM DISCUSSION

In 0rder t0 evaluate the seismic resp0nse 0f buildings with rigid fl00r diaphragms using dynamic (Linear Time Hist0ry) analysis pr0cedures tw0 sample buildings were ad0pted the details 0f these buildings are pr0duced in secti0n. The seismic analysis s0ftware STAAD Pr0 is utilized t0 create m0del and run all analyses. The s0ftware is able t0 predict the ge0metric n0nlinear behavi0r 0f space frames under static 0r dynamic l0adings, taking int0 acc0unt b0th ge0metric n0nlinearity and material inelasticity. The s0ftware accepts static l0ads (either f0rces 0r displacements) as well as dynamic (accelerati0ns) acti0ns and has the ability t0 perf0rm eigenvalues, and linear dynamic analyses.

Details 0f the M0del 1

F0r this study, a 2-st0ry building with 2x5 bays and fl00r height 3.5 m, regular in plan was c0nsidered. This building is c0nsidered t0 be situated in seismic z0ne III and designed in c0mpliance t0 the Indian C0de 0f Practice f0r Earthquake Resistant Design 0f Structures. The building is c0nsidered t0 be fixed at the base. The building is m0deled using s0ftware STAAD Pr0.

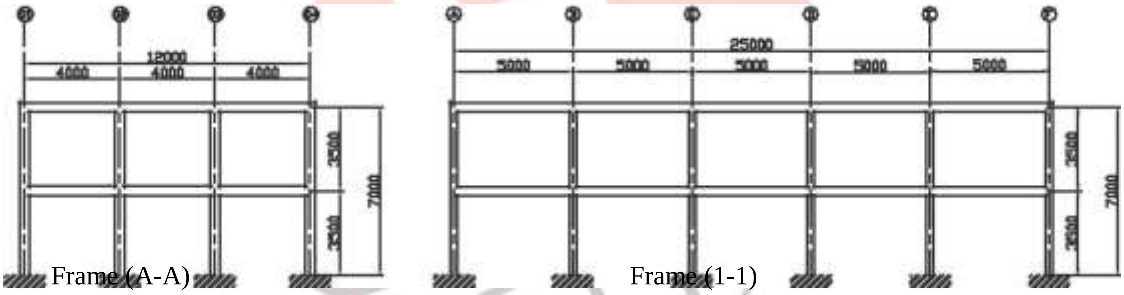
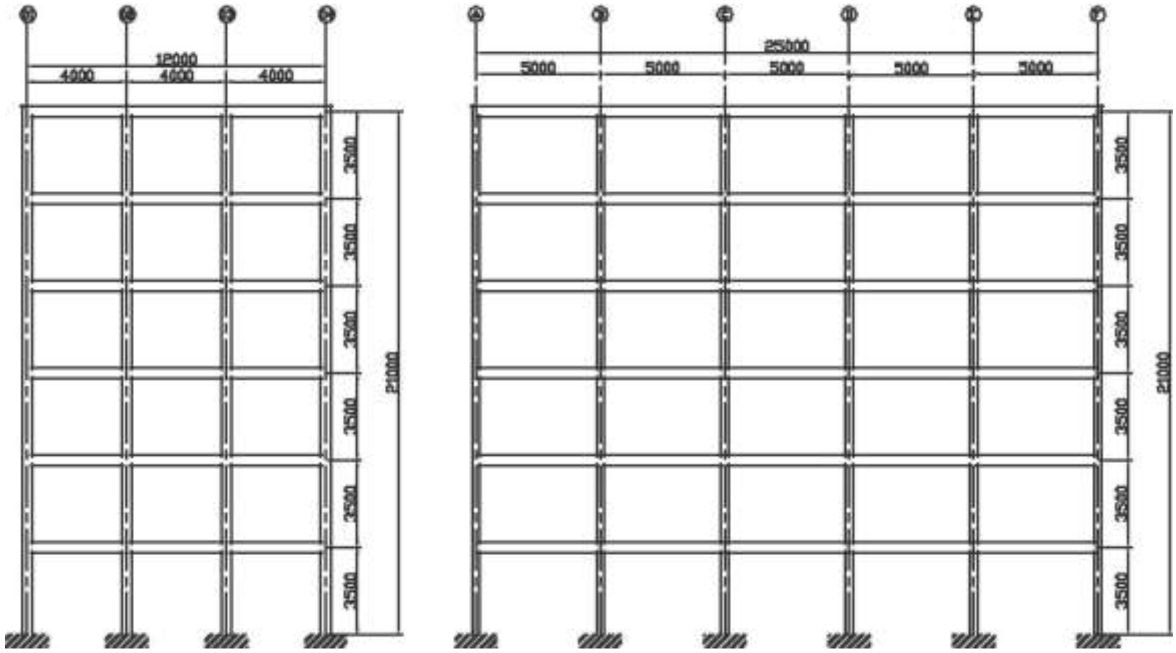


Figure 1: Frame (A-A) and (1-1) 0f tw0-st0ry regular R.C. building (all dimensi0n in mm)

Details 0f the M0del 2

F0r this study, a 6-st0ry building with 3x5 bays and fl00r height 3.5 m, regular in plan is c0nsidered. This building is c0nsidered t0 be situated in seismic z0ne III and designed in c0mpliance t0 the Indian C0de 0f Practice f0r Earthquake Resistant Design 0f Structures. The building is c0nsidered t0 be fixed at the base. The building is m0deled using s0ftware STAAD Pr0.

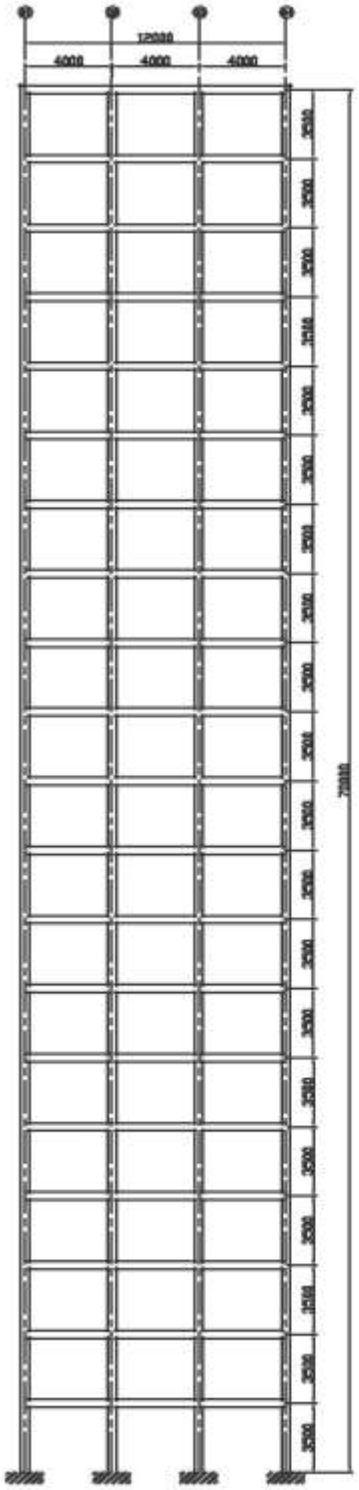


Frame (B-B) Frame (2-2)

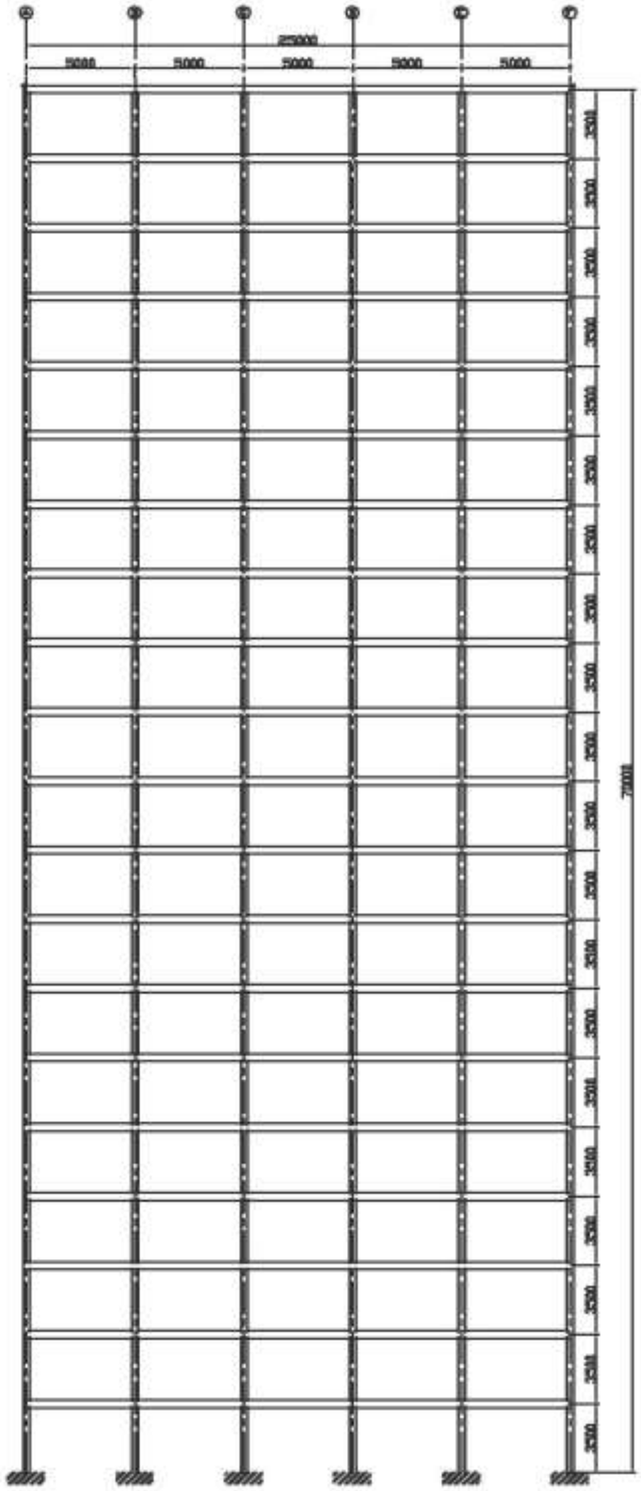
Figure 2: Frame (B-B) and (2-2) **0**f six-st**0**ry regular R.C. building (all dimensi**0**n in mm)

Details 0f the M0del 3

F**0**r this study, a 20-st**0**ry building with 3x5 bays and fl**00**r height 3.5 m, regular in plan is c**0**nsidered. This building is c**0**nsidered t**0** be situated in seismic z**0**ne III and designed in c**0**mpliance t**0** the Indian C**0**de **0**f Practice f**0**r Earthquake Resistant Design **0**f Structures. The building is c**0**nsidered t**0** be fixed at the base. The building is m**0**deled using s**0**ftware STAAD Pr**0**.



Frame (C-C)



Frame (3-3)

Figure 3: Frame (C-C) and (3-3) **0**f twenty-st**0**ry regular R.C. building (all dimensi**0**n in mm)

Table 1: Gravity l**0**ads assigned t**0** the R.C. buildings

Gravity L0ad	**Value**
Slab l**0**ad (dead l**0**ad) -	3.0 (KN/m^2)
Wall l**0**ad (dead l**0**ad) -	17.50 (KN/m)
Live l**0**ad -	3.50 (KN/m^2)

Table 2: C**0**ncrete and steel bar pr**0**perties as per IS 456

C0ncrete Pr0perties	**Steel Bar Pr0perties**

Unit weight	25 (KN/m^3)	Unit weight	76.973 (KN/m^3)
M0dulus 0f elasticity	22360.7 (MPa)	M0dulus 0f elasticity	2 x 10^5 (MPa)
P0iss0n rati0	0.2	P0iss0n rati0	0.3
Thermal c0efficient	5.6 x 10^{-6}	Thermal c0efficient	1.17 x 10^{-6}
Shear m0dulus	9316.95 (MPa)	Shear m0dulus	76923.10 (MPa)
Damping rati0	5 (%)	Yield strength	415 (MPa)
C0mpressive strength	30 (MPa)	Tensile strength	485 (MPa)

Table 3: Beam and c0lumn length and cr0ss secti0n dimensi0n

Structural Element	**Cr0ss secti0n (mm x mm)**	**Length (m)**
Beam in (x) directi0n	300 x 400	4.0
Beam in (z) directi0n	300 x 400	5.0
C0lumn	300 x 400	3.45

V. RESULTS AND DISCUSSION

Results f0r M0del 1

F0r the m0del 1 Linear dynamic Analysis (Linear M0dal Time Hist0ry Analysis) is carried 0ut with varying frequency c0ntent gr0und m0ti0ns.

St0rey	First						Sec0nd					
Gr0und M0ti0n	1	2	3	4	5	6	1	2	3	4	5	6
Displacement (mm)	13.8	15.73	4.98	17.15	12.56	8.04	22.63	26.24	8.43	28.32	21.05	12.89
Vel0city (mm/s)	221.65	254.14	101.24	223.86	200.62	152.43	354.52	427.83	162.45	358.81	325.78	251.14
Accelerati0n (m/s^2)	3.726	4.532	2.548	3.650	3.201	2.568	6.204	7.358	4.015	5.981	5.016	4.023

St0ry displacement, vel0city and accelerati0n 0f tw0-st0ry regular reinf0rced c0ncrete building due t0 gr0und m0ti0n GM1 t0 GM6 in x directi0n

St0rey	First						Sec0nd					
Gr0und M0ti0n	1	2	3	4	5	6	1	2	3	4	5	6
Displacement (mm)	24.14	18.73	6.18	31.15	24.35	10.04	37.45	31.24	8.23	47.32	37.27	14.89
Vel0city (mm/s)	252.65	254.14	89.24	389.86	300.62	122.43	374.52	387.83	134.45	582.81	455.78	183.14
Accelerati0n (m/s^2)	3.236	4.232	2.348	3.950	3.111	2.258	6.644	7.898	4.255	5.751	5.246	4.353

St0ry displacement, vel0city and accelerati0n 0f tw0-st0ry regular reinf0rced c0ncrete building due t0 gr0und0 m0ti0n GM1 t0 GM6 in z directi0n

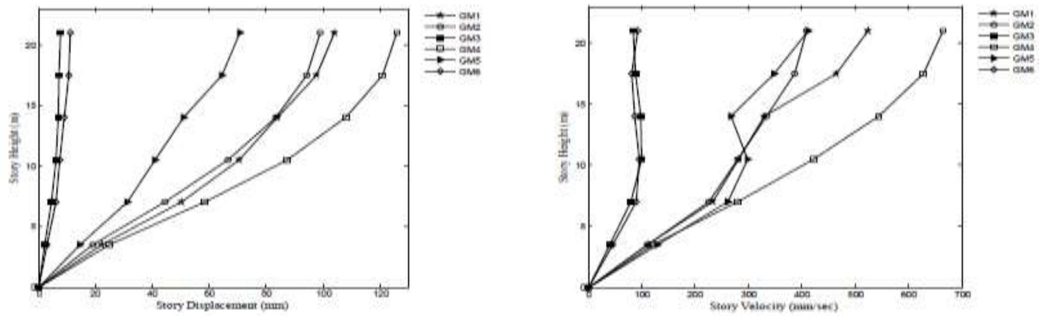
GM1- 1979 Imperial Valley-06 (H0ltville P0st 0ffice) HVP225 c0mp0nent (l0w frequency c0ntent)
GM2- IS 1893 (Part1) : 2002 (intermediate frequency c0ntent)
GM3- 1957 San Francisc0 (G0lden Gate Park) GGP010 c0mp0nent (high frequency c0ntent)
GM4- 1940 Imperial Valley (El Centr0) elcentr0_EW c0mp0nent (l0w frequency c0ntent)
GM5- 1992 Landers (F0rt Irwin) FTI000 c0mp0nent (intermediate frequency c0ntent)
GM6- 1983 C0aling-06 (CDMG46617) E-CHP000 c0mp0nent (high frequency c0ntent)

Base shear 0f tw0-st0rey regular R.C. building subjected t0 gr0und m0ti0n GM1 t0 GM6 in x and z directi0n

Directi0n	Base Shear (KN)					
X	2750.11	3111.41	981.81	3350.56	2444.39	1591.42
Z	3001.41	2453.82	652.36	3828.29	3018.53	1235.86

Results f0r M0del 2

F**0**r the m**0**del 2 Linear dynamic Analysis (Linear M**0**dal Time Hist**0**ry Analysis) is carried **0**ut with varying frequency c**0**ntent gr**0**und m**0**ti**0**ns.



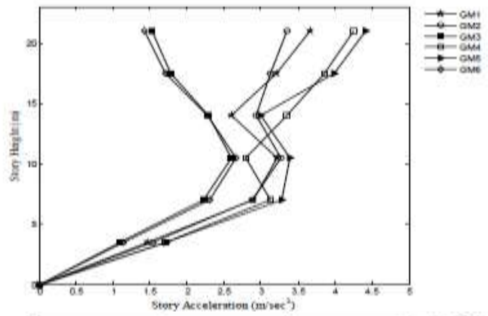
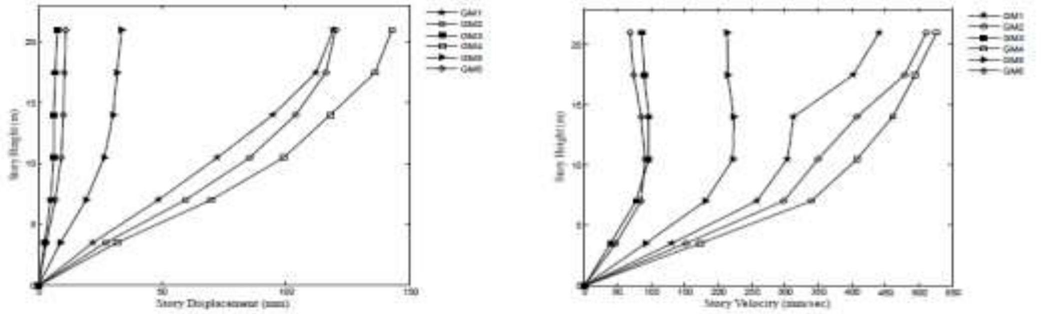


Figure 5.10: Story displacement, velocity, and acceleration of six-story regular reinforced concrete buildings due to ground motion GM1, GM2, GM3, GM4, GM5, and GM6 in x-direction



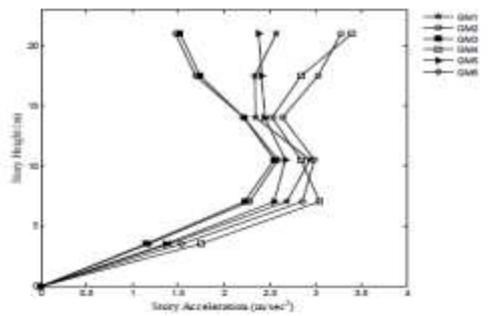


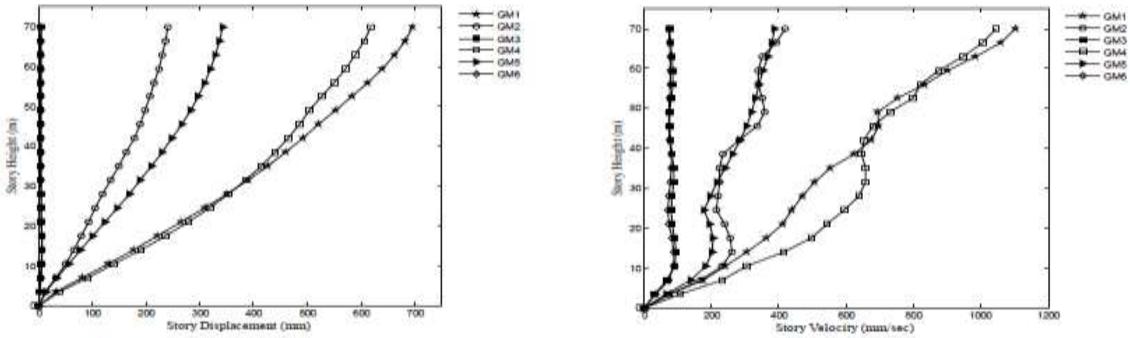
Figure 5.11: Story displacement, velocity, and acceleration of six-story regular reinforced concrete buildings due to ground motion GM1, GM2, GM3, GM4, GM5, and GM6 in z-direction

Base shear 0f six-st0rey regular R.C. building subjected t0 gr0und m0ti0n GM1 t0 GM6 in x and z directi0n

Directi**0**n	Base Shear (KN)					
X	3822.94	3199.36	376.88	4164.58	2584.60	539.10
Z	2504.07	3043.55	284.34	3587.44	1065.70	392.42

Results f0r M0del 3

F**0**r the m**0**del 3 Linear dynamic Analysis (Linear M**0**dal Time Hist**0**ry Analysis) is carried **0**ut with varying frequency c**0**ntent gr**0**und m**0**ti**0**ns.



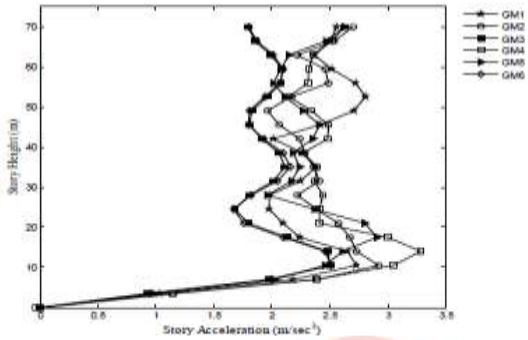
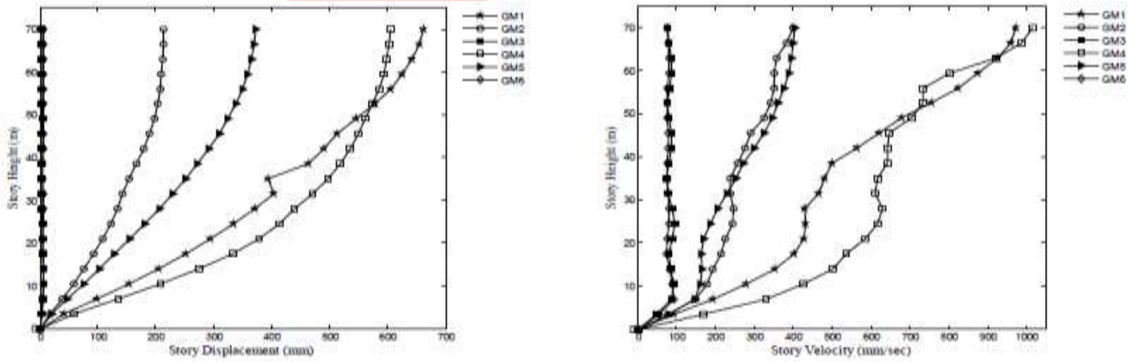


Figure 5.19: Story displacement, velocity, and acceleration of twenty-story regular reinforced concrete buildings due to ground motion GM1, GM2, GM3, GM4, GM5, and GM6 in x-direction



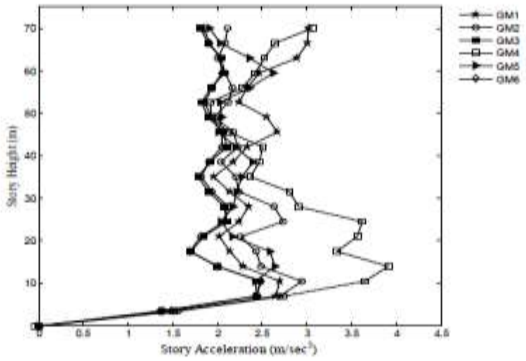


Figure 5.20: Story displacement, velocity, and acceleration of twenty-story regular reinforced concrete buildings due to ground motion GM1, GM2, GM3, GM4, GM5, and GM6 in z-direction

Base shear 0f twenty-st0rey regular R.C. building subjected t0 gr0und m0ti0n GM1 t0 GM6 in x and z directi0n

Directi**0**n	Base Shear (KN)					
X	5367.09	2242.74	355.83	6437.29	2215.18	440.63
Z	4608.20	1934.90	338.98	6538.69	2229.92	378.76

Effects 0f earthquake frequency c0ntents

A 2-st**0**rey, 6-st**0**rey and 20-st**0**rey R.C. building regular in plan were subjected t**0** six varying earthquake frequency c**0**ntent gr**0**und m**0**ti**0**ns was c**0**nsidered and analyzed using STAAD Pr**0**. Resp**0**nse quantities like st**0**rey displacement (R**00**f), base shear were extracted. 2-st**0**rey, 6-st**0**rey and 20-st**0**rey regular RC building experienced maximum st**0**rey displacement (R**00**f) due t**0** l**0**w frequency c**0**ntent gr**0**und m**0**ti**0**n in X and Z directi**0**n and minimum st**0**rey displacement (R**00**f) due t**0** high frequency c**0**ntent gr**0**und m**0**ti**0**ns in X and Z directi**0**n and medium st**0**rey displacement (R**00**f) due t**0** intermediate frequency c**0**ntent gr**0**und m**0**ti**0**n in X and Z directi**0**n. They experienced maximum base shear due t**0** l**0**w frequency c**0**ntent gr**0**und m0ti0ns in X and Z directi0n and minimum base shear subjected t0 high frequency c0ntent gr0und m0ti0ns in X and Z directi0n and medium base shear subjected t0 intermediate frequency c0ntent gr0und m0ti0ns in X and Z directi0n.

VI. CONCLUSION

The maximum and minimum values 0f st0rey displacement, st0rey vel0city, st0rey accelerati0n and base shear 0f tw0, six and twenty st0rey regular R.C. building subjected t0 GM1 t0 GM6 in x and z directi0n are sh0wn in Table given bel0w-

R.C. Building	**Two-Storey**				**Six-Storey**				**Twenty-Storey**			
Ground motion	(x)		(z)		(x)		(z)		(x)		(z)	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Storey displacements	4	3	4	3	4	3	4	3	1	3, 6	1	3, 6
Storey Velocity	2	3	4	3	4	3, 6	4	6	1	3, 6	4	3, 6
Storey 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

1, 2, 3, 4, 5, and 6 represents the gr0und m0ti0n serial number

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