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Classification of soil types described in BNBC 2006 by analyzing Los Angeles SAC model under BNBC response Spectrums.

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Abstract:*Dhaka is the most densely populated city and the risk poses due to earthquake is more compare to any other cities in Bangladesh.Before any construction in Dhaka, it is essential to understand the soil characteristics and its response to earthquake loading. To understand the soil behavior this study includes the response spectrum analysis of Los Angeles 9 story SACsteel building under Pre-Northridge design condition.BNBCresponse spectrums of Zone-2 for three different types of soils are considered for response spectrum analysis.Here,response spectrum RS1, RS2 & RS3 is developed for soil type 1, 2 & 3. The model is developed by using SAP 2000version 14.2.0. After performing response spectrum analysisthis study has found a relation between the results due to RS1, RS2 & RS3.It is found that, the structural output for RS3 is 1.57 & 2.07 times greater than the output due to RS2 & RS1 respectively. Output for RS2 is 1.31 times greater than the output for RS1.*

Key word:*BNBC 2006, Pre-Northridge design, Response Spectrum, SAC model, Static and Dynamic.*

I. Introduction

Bangladesh is positioned at the junction of several active tectonic plate boundaries. Moreover, it sits atop the world's largest river delta at close to sea level, facing both the risk posed by a quake and secondary risks of tsunamis and flooding in the quake's aftermath[1].After the massive quake that killed more than 3,000 people in Nepal, two tremors have hit Bangladesh. The country was jolted by a massive 7.5 quake causing panic among the people in the capital and parts of the country [2]. There are lists of the major earthquakes that have affected besides and in between Bangladesh [3]Furthermore micro-seismicity data has shown that at least four earthquake sources is present in and around Dhaka city [4][5]. According to earthquake disaster risk index, Dhaka is placed in 20 most vulnerable cities in the world [6].Based on the earthquake severity, this country is divided into three different seismic zones namely zone 1, 2, 3 being least to most severe gradually [7]. Again based on the physical characteristics, BNBC [8]has classified the soil in four groups 1, 2, 3 & 4. Generally soil type 4 does not consider so, only three types soil is included in this study. This study is conducted over the standard SAC[9]steel model of Los Angeles to understand the response of steel structure.Since Dhaka is located in zone 2 so, the response spectrum is developed for zone 2 soil types.

II. BNBC Soil Characteristics:

Before describing BNBC response spectrum, it is important to understand the soil characteristics [10] provided in the code. The general characteristics of the soils can be known from the following figure.

Site Soil Characteristics		Coefficient, S
Type	Description	
S_1	A soil profile with either : a) A rock-like material characterized by a shear-wave velocity greater than 762 m/s or by other suitable means of classification, or b) Stiff or dense soil condition where the soil depth is less than 61 metres	1.0
S_2	A soil profile with dense or stiff soil conditions, where the soil depth exceeds 61 metres	1.2
S_3	A soil profile 21 metres or more in depth and containing more than 6 metres of soft to medium stiff clay but not more than 12 metres of soft clay	1.5
S_4	A soil profile containing more than 12 metres of soft clay characterized by a shear wave velocity less than 152 m/s	2.0
Note : (1)	The site coefficient shall be established from properly substantiated geotechnical data. In locations where the soil properties are not known in sufficient detail to determine the soil profile type, soil profile S_3 shall be used. Soil profile S_4 need not be assumed unless the building official determines that soil profile S_4 may be present at the site, or in the event that soil profile S_4 is established by geotechnical data.	

Figure 1: BNBC soil characteristics (Source: BNBC 2006 table 6.2.25, p-10633)

III. Development Of BNBC Response Spectrum:

For general condition, the normalized response spectra [11] given in the following figure is considered for response spectrum. The response spectra provided in the Fig 2. is developed for 5 % damping and used when site specific response spectrum is absent.

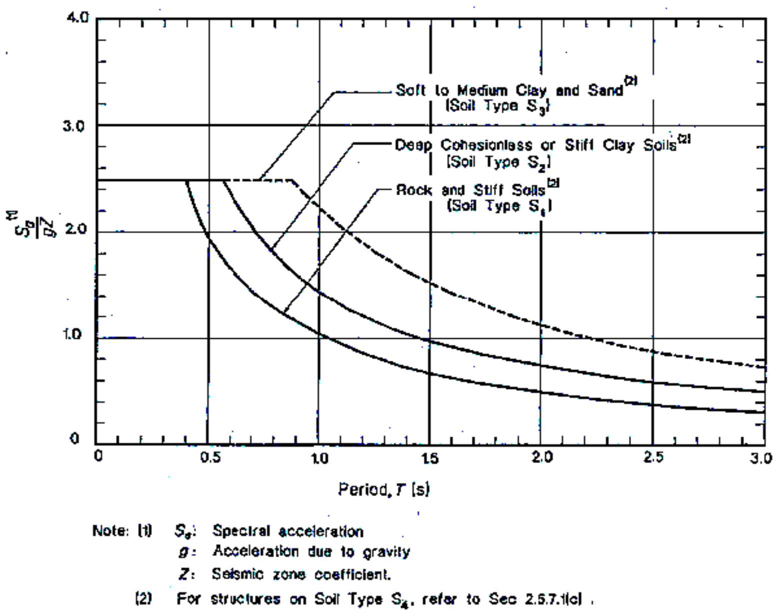


Fig 2: BNBC 2006 Normalized response spectra (Source: BNBC 2006, fig 6.2.11)

In the above graph X axis represent the fundamental period of vibration in second and Y axis represent (S_a/gZ) where, S_a stands for spectral acceleration, g stands for acceleration due to gravity and Z stands for seismic zone coefficient. For every 5 seconds interval the corresponding Y axis value is determined for each types of soil. Considering ordinary moment resisting frame, the values are then divided by response modification coefficient, R=6. Finally the values obtained are represented in the table below.

Table I:*BNBC response spectrum data for Ordinary Moment Resisting frame structure.*

Time period	Soil type 1	Soil type 2	Soil type 3
0	2.0125	2.0125	2.0125
0.5	1.61	2.0125	2.0125
1	0.966	1.127	1.771
1.5	0.4991	0.805	1.2719
2	0.4508	0.6279	0.95795
2.5	0.322	0.483	0.7245
3	0.2415	0.4025	0.5635

IV. Methodology

The model is developed in SAP 2000 version 14.2.0 [12]according to the report FEMA 355C. Slight modification is done in case of loading. This study does not include the pent house loading. The metal slab is provided as uniformly distributed load and the concrete slab is provided as shell thick slab in the software.Other than this, all the design condition is maintained as per FEMA 355C report. Fig 3. shows the plan view of the model whereas Fig 4. shows the elevation view of the model.

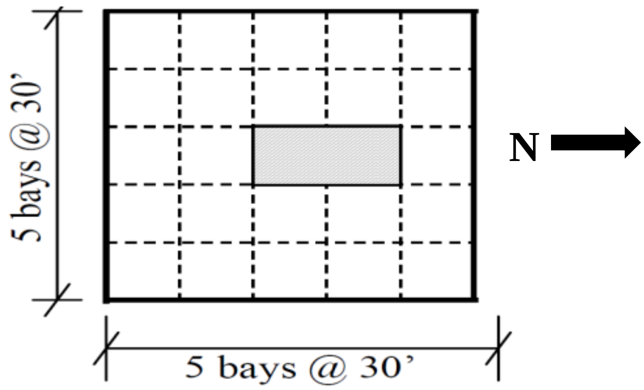


Figure 3: Plan view of LA building (Source: FEMA 355c, Appendix B)

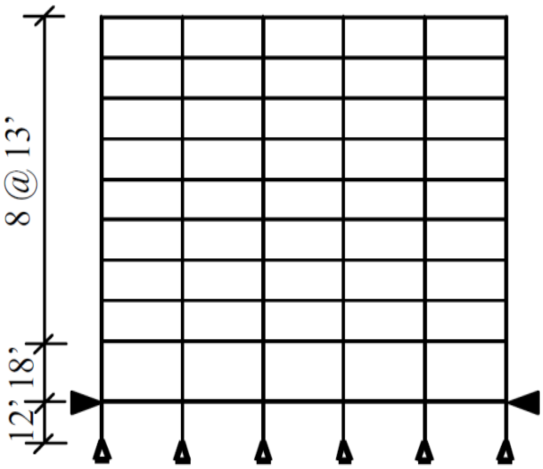


Figure 4: Elevation view of LA building (Source: FEMA 355c, Appendix B)

The 9 story building has one basement of 12 ft height. Columns are arranged as exterior column and interior column. The arrangement of the frame elements are shown in Fig 5.

9-story Building

Story/Floor	COLUMNS		DOUBLER PLATES (in)	GIRDER
	Exterior	Interior		
-1/1	W14X370	W14X500	0,0	W36X160
1/2	W14X370	W14X500	0,0	W36X160
2/3	W14X370, W14X370	W14X500, W14X455	0,0	W36X160
3/4	W14X370	W14X455	0,0	W36X135
4/5	W14X370, W14X283	W14X455, W14X370	0,0	W36X135
5/6	W14X283	W14X370	0,0	W36X135
6/7	W14X283, W14X257	W14X370, W14X283	0,0	W36X135
7/8	W14X257	W14X283	0,0	W30X99
8/9	W14X257, W14X233	W14X283, W14X257	0,0	W27X84
9/Roof	W14X233	W14X257	0,0	W24X68

Figure 5: Frame elements of 9 story LA building (Source: FEMA 355c, Appendix B)

Materials are different for column and girder. For column section strength of the material is F_y=50 ksi and for girder is A36 (F_y =36 ksi).The loads are applied on the structure as per following tables. Here, loading conditions are different for floor and roof.

Table II:*Loads on different floors.*

Load Name	Unit	Amount
Flooring	psf	3
Partitions	psf	10
Exterior wall	psf	25
Live load	psf	50
Mech. /Elect.	psf	7
Metal Deck	psf	122.5

Table III:*Loads on roof.*

Load Name	Unit	Amount
Roofing	psf	7
Parapet	plf	175
Metal Deck	psf	122.5

From the table, metal deck is the metal slab which we have provided as uniformly distributed load.In case of lateral loading, auto load definition has been used for both seismic and wind load. The lateral loads provided in the design criteria are as follows.

Table IV:*Lateral Load*

Name	Load
Seismic	UBC 94 definition
Wind	UBC 94 definition

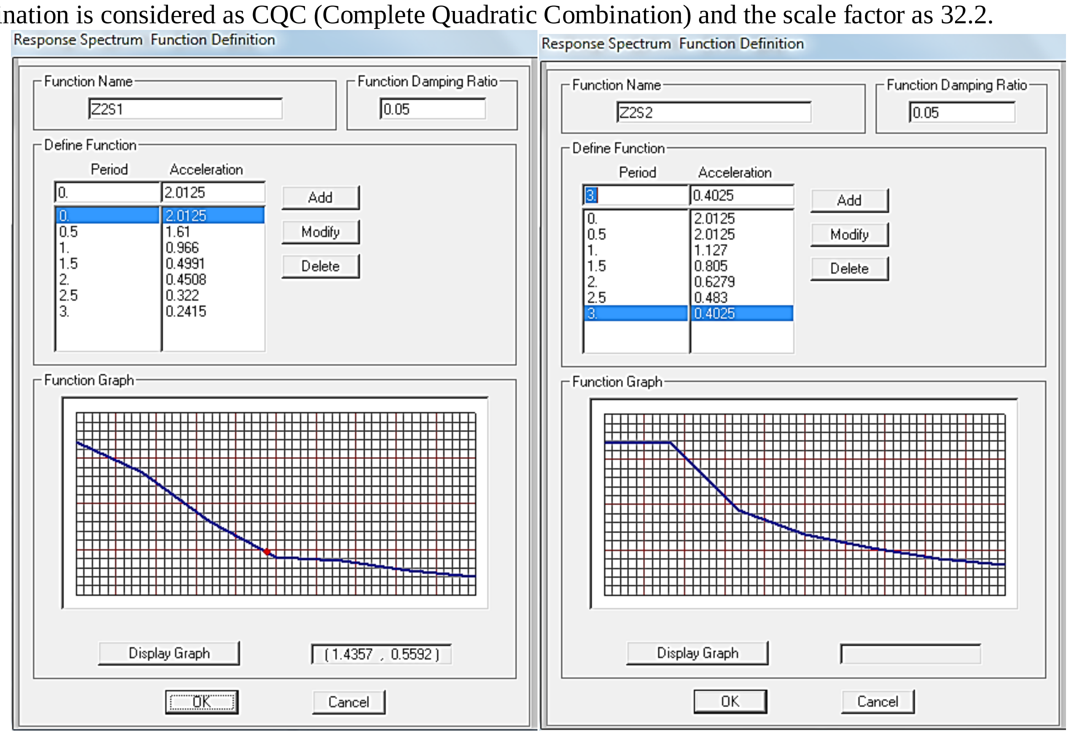
For lateral load calculation diaphragms are provided as joint constraint. We have considered all the dead (Dead, Super dead) load as mass source. The load combination inputted in the software is UBC 94 ASD load combinations. They are as follows:

- DL+LL
- DL+LL+WL
- DL+LL-WL
- DL+LL+0.5WL
- DL+LL-0.5WL
- DL+LL+EQ-X
- DL+LL- EQ-X
- DL+LL- EQ-Y
- DL+LL- EQ-Y
- ENVELOPE

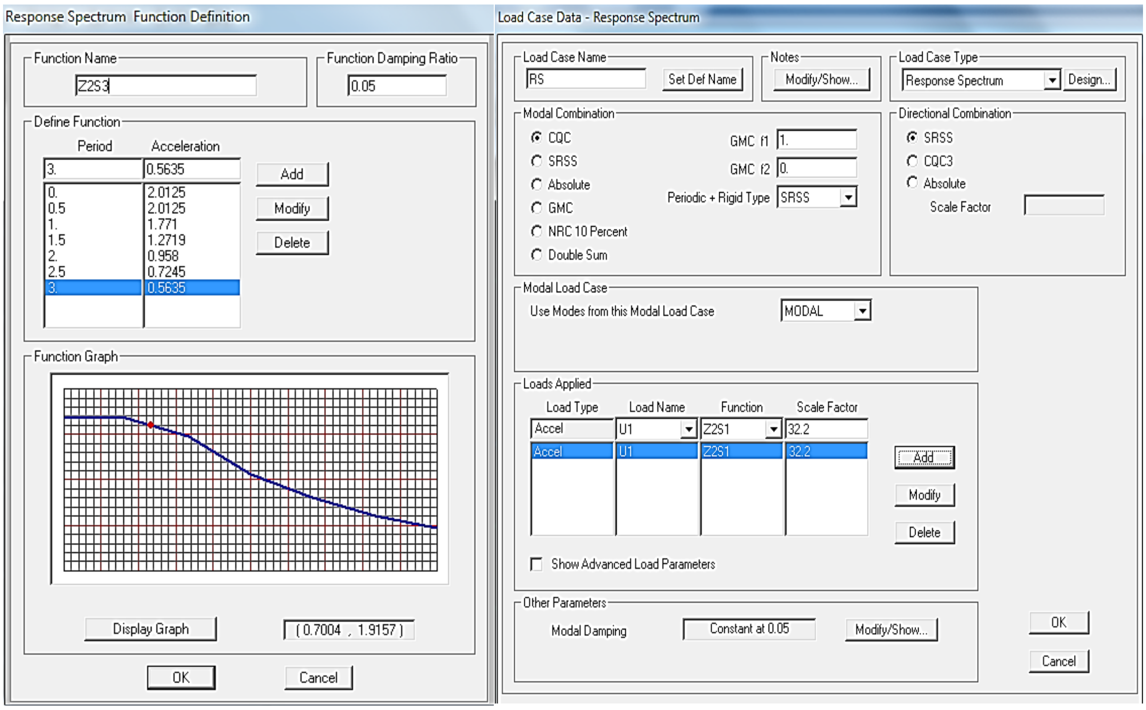
Here,
DL= Dead Load
LL= Live Load
WL= Wind Load
EQ-X= Earthquake load in X direction
EQ-Y= Earthquake load in Y direction
ENVELOPE= Combination of all load combinations

4.1. Defining Response Spectrum Function:

In the software response spectrum is defined as function. For each type of soil we have to define each response spectrum function individually. Three response spectrum functions defined in this study are shown in the Fig 6. While defining the response spectrum load cases we have considered 12 modes. The modal combination is considered as CQC (Complete Quadratic Combination) and the scale factor as 32.2.



(a) (b)



(c) (d)

Figure 6:(a) Response spectrum function for zone-2 soil type 1 (b) Response spectrum function for zone-2 soil type 2 (c) Response spectrum function for zone-2 soil type 3 (d) response spectrum load case.

V. Data Collection

Beam bending moment and shear force data has been collected for the beam A1-B1. For column axial force and bending moment we have considered column A1. The location of beam & column chosen for this study is clearly visualized by the Fig 7.

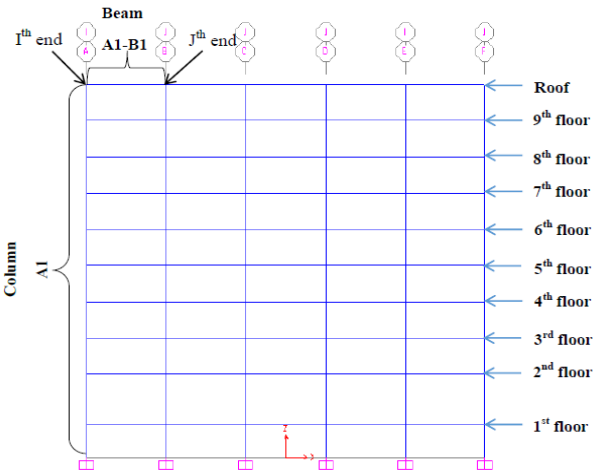


Figure 7: Location of beam column selected for data collection.

5.1 Beam Analysis:

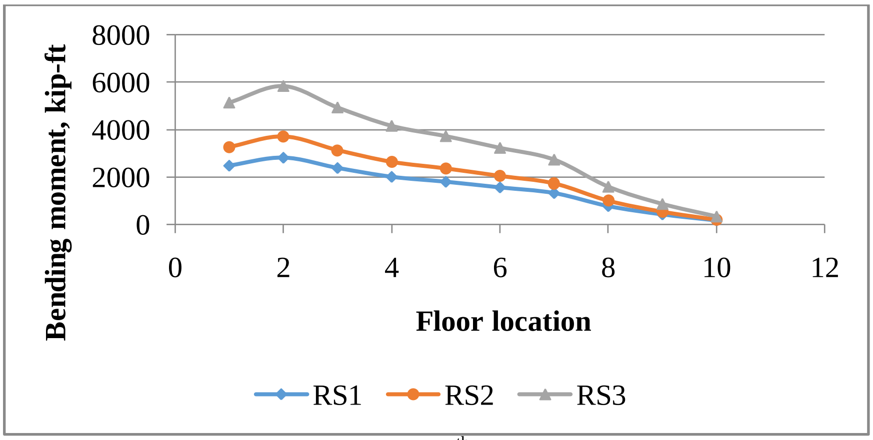


Figure8: Moment distributions of beam A1-B1 at I[th] end in different floor due to RS1, RS2 &RS3.

Beam bending moment data has been synchronized from 1[st] floor to roof level. Data has been represented for both I[th]& J[th] end of the beam. At I[th] end, the values are varied from 160.52 kip-ft to 2826.75 kip-ft for RS1, 210.83 kip-ft to 3712.60 kip-ft for RS2 and 332.03 kip-ft to 5147.52 kip-ft for RS3. From Fig 8.maximum bending moment obtained for RS1, RS2 and RS3 is 2826.75 kip-ft, 3712.60 kip-ft and 5846.93 kip-ft respectively.

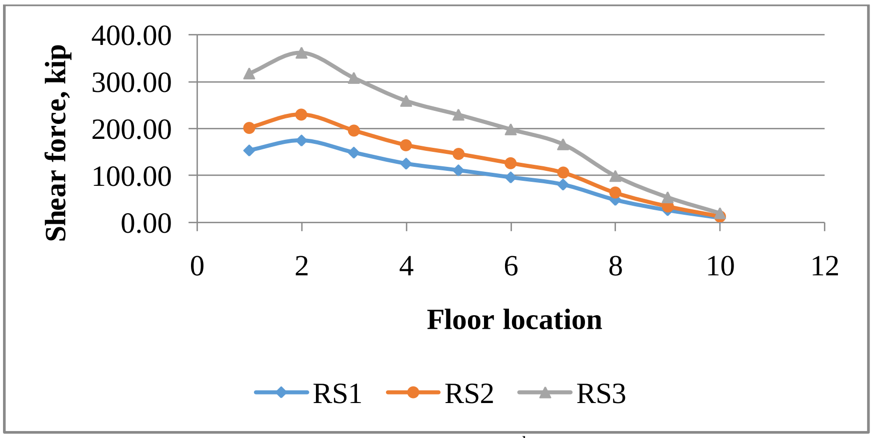


Figure 9: Shear force distribution in between beam A1-B1 at I[th] end in different floor level due to RS1, RS2 & RS3.

In Fig 9. shear force values are varied from 9.97 kip-ft to 175.17 kip-ft for RS1, 13.10 kip-ft to 230.06 kip-ft for RS2 and 20.63 kip-ft to 362.32 kip-ft for RS3 at I[th] end. Maximum shear force obtained for RS1, RS2 and RS3 is 175.17 kip-ft, 230.06 kip-ft and 362.32 kip-ft respectively.

5.2 Column Analysis:

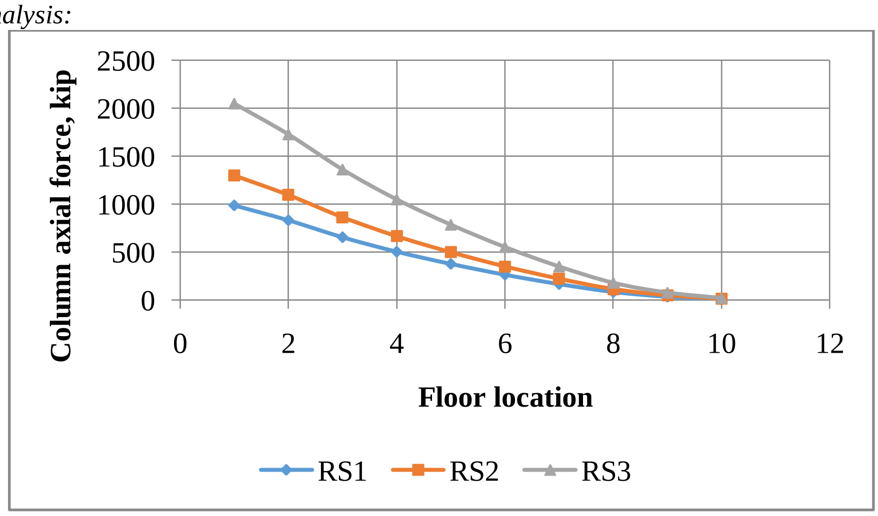


Figure 10: Distribution of axial force of column A-1 in different floor level due to RS1, RS2 & RS3.

Column axial forces data are synchronized from 1st floor to roof level. In Fig 10.the values are varied from 10.5 kip-ft to 990.88 kip-ft for RS1, 13.79 kip-ft to 1301.41 kip-ft for RS2 and 21.72 kip-ft to 2049.58 kip-ft for RS3. Maximum axial force obtained for RS1, RS2 and RS3 is 990.88 kip-ft, 1301.41 kip-ft and 2049.58 kip-ft respectively.

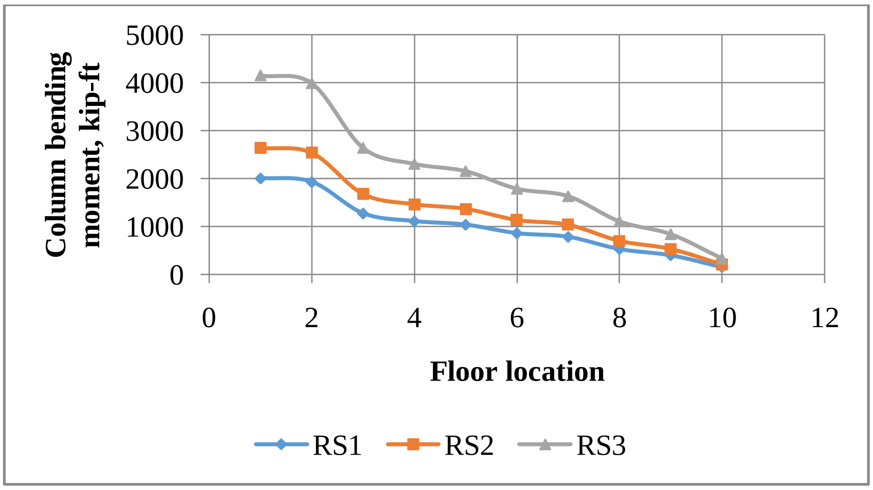


Figure 11: Distribution of column bending moment of column A-1 in different floor level due to RS1, RS2 & RS3.

In case of column bending moment, data has been represented from 1st floor to roof level. In Fig 11.the values are varied from 162.2 kip-ft to 2009.56 kip-ft for RS1, 213.03 kip-ft to 2639.32 kip-ft for RS2 and 335.5 kip-ft to 4156.64 kip-ft for RS3. Maximum bending moment obtained for RS1, RS2 and RS3 is 2009.56 kip-ft, 2639.32 kip-ft and 4156.64 kip-ft respectively.

5.3 Joint Displacement & Story Drift:

Joint displacement data has been collected for wind load. According to Fig 12.the maximum joint displacement is occurred at the roof and the value is 0.39″. From the joint displacement data story drift has been calculated. Story drift is the displacement of one level relative to the level above or below due to design lateral forces. According to FEMA 355C the maximum permissible story drift is "h/400" where, h is the story height. So the maximum allowable story drift for story 1 is (12x12)/400=0.36 in, for story 2 is (18x12)/400=0.54 in and for the rest of the stories are (13x12)/400=0.39 in. From Fig 13.it is found that,the maximum value of story drift is 4.17 E-4 in which is less than the minimum story drift calculated for the structure.

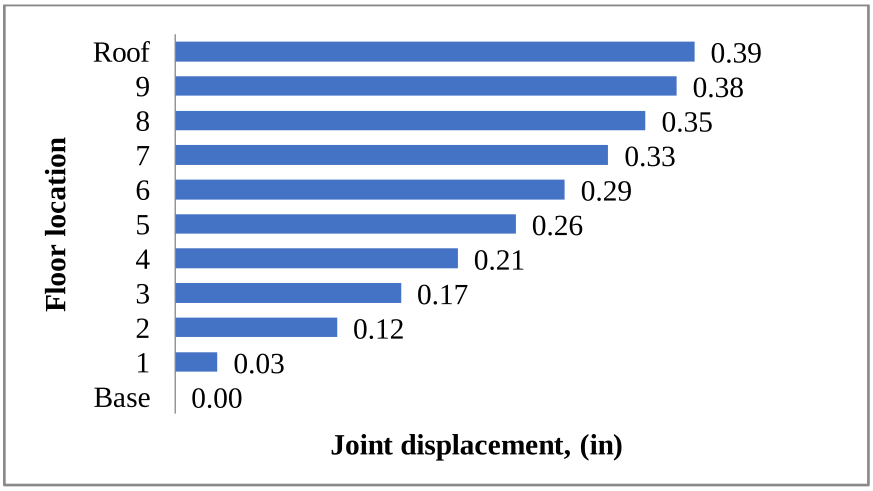


Figure 12: Joint displacement for wind load in different floor

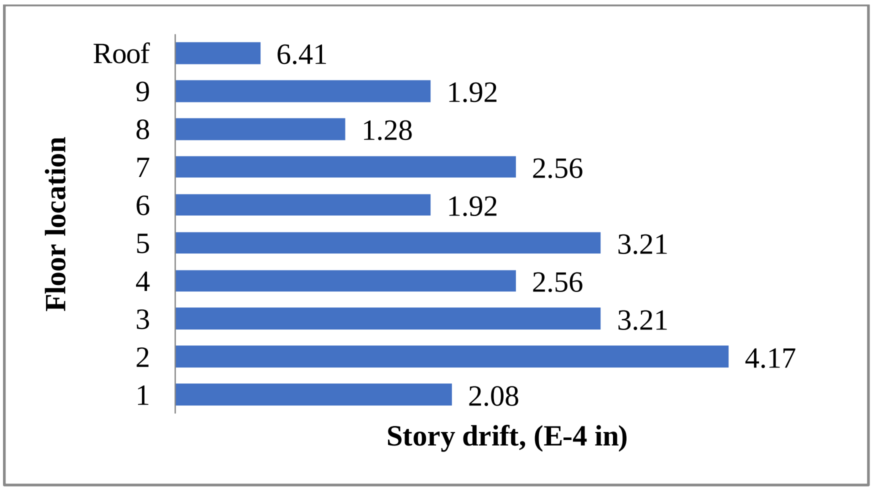


Figure 13: Story drifts due to wind loading

5.4 Base Reaction:

The base reaction data obtained in this study is presented in the following table.

Table V:*Base Reaction:*

Type	RS1	RS2	RS3
Global F_X	11160.83	14658.561	23085.616
Global M_Y	998354.2	1311231.744	2065045.394

6. RESULT:

Table VI:*Relationships observed in beam bending moment at Ith end.*

Type	Value(kip-ft)	Result		
		(RS3/RS1)	(RS3/RS2)	(RS2/RS1)
RS1	2826.75	2.068428	1.574888	1.313381
RS2	3712.6			
RS3	5846.93			

Table VII:*Relationshipsobserved in beam shear force at Ith end.*

Type	Value (kip)	Result		
		(RS3/RS1)	(RS3/RS2)	(RS2/RS1)
RS1	175.17	2.068391	1.574894	`1.313353
RS2	230.06			
RS3	362.32			

Table VIII:*Relationshipsobserved in column axial force.*

Type	Value (kip)	Result		
		(RS3/RS1)	(RS3/RS2)	(RS2/RS1)
RS1	990.88	2.068444	1.574892	1.313388
RS2	1301.41			
RS3	2049.58			

Table IX:*Relationships observed in column bending moment.*

Type	Value (kip-ft)	Result		
		(RS3/RS1)	(RS3/RS2)	(RS2/RS1)
RS1	2009.56	2.068433	1.574891	1.313382
RS2	2639.32			
RS3	4156.64			

Table X:*Relationshipsobserved in base reaction force.*

Type	Value (kip)	Result		
		(RS3/RS1)	(RS3/RS2)	(RS2/RS1)
RS1	11160.8	2.06845	1.57489	1.313393
RS2	14658.6			
RS3	23085.6			

Table XI:*Relationships observed in base reaction moment.*

Type	Value (kip-ft)	Result		
		(RS3/RS1)	(RS3/RS2)	(RS2/RS1)
RS1	998354	2.06845	1.57489	1.313393
RS2	1311232			
RS3	2065045			

VI. Conclusion

From the above tables it is clearly seen that, the output of RS3 is 2.07 times greater than the output for RS1 and 1.57 times greater than RS2. The output of RS2 is 1.31 times greater than the output of RS1. So it can be concluded that soil type 3 will produce 2.07 & 1.57 times more response than the soil types 1 & 2 respectively. Soil type 2 will give 1.31 times more response than the soil type 1. In case of vulnerability, soil type 3 is more vulnerable to earthquake loading than the other two types of soil.

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