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A STUDY TO FIND THE MOST SIMILAR REAL EARTHQUAKE RESPONSE SPECTRUM TO THE RESPONSE SPECTRUM DEVELOPED FROM BNBC 2006 NORMALIZED RESPONSE SPECTRUM

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ABSTRACT
Earthquake is a natural phenomenon which has an adverse effect on human lives and natural resources. It is now a growing concern of our structural engineer to design an earthquake resisting structure. In this study, the comparison has been made between earthquake response spectra with our national building code provided response spectra. BNBC 2006 has provided us with a normalized response spectrum for 5% damping ratio. This is used in this study to develop a response spectrum for rock and stiff soil (soil type S1) and earthquake zone 2. With the help of Pacific Earthquake Engineering Research Centre (PEER) we have selected 5 earthquake response spectra named Friuli earthquake Italy, Gazli earthquake Uzbekistan, Imperial Valley 2 earthquake USA, Imperial Valley 6 earthquake USA, and Tabas earthquake Iran for the comparison. The analysis has been done by using SAP2000 on a steel structure. With some modification, the model structure has been developed from Federal Emergency Management Agency (FEMA) 355C report Appendix B which is a 9 storied building, square in plan and with 5 bays in each direction with one underground basement. The structural response like base reaction, joint reaction, and joint displacement has been considered for the comparison. Finally, it is found out that the response spectrum for earthquake Gazli of Uzbekistan which is a magnitude of 7.0 provides response close to BNBC response spectrum for soil type S1.
Keywords: Response Spectrum; BNBC 2006, PEER; FEMA; SAP2000

INTRODUCTION
Dhaka is the capital of Bangladesh which is a developing country facing the problem of overpopulation, environmental degradation, open space loss, and socio-economic tension. Dew to centralization Dhaka controls the major portion of the Bangladesh economy. This growing economy leads to industrialization, which demands quicker and sustainable development of infrastructure to ensure accommodation and employment for new residents. Steel structures are now gaining more concentration due to its advantages over RCC structure. So almost every industry are now constructed by steel. Also, residential buildings are constructed using steel frame and RCC which we called composite structure. Though steel structure has many advantages over RCC structure it is not free from the risk of an earthquake. As Bangladesh is not free from the danger of earthquake so whatever the

building type is it should be sustainable and can withstand any danger posed by the earthquake. There are lots of techniques to study a building response when it is faced by earthquake and response spectrum analysis is one of them which is a fine tool to understand building behavior under earthquake.

In this study, response spectrum analysis has been done on a standard steel structure which is described in FEMA 355C article (FEMA 355C, 2000). For response spectrum analysis, BNBC provided normalized response spectrum has been used to develop response spectra for Dhaka city which is located at zone 2 according to BNBC 2006 earthquake zooning (BNBC, 2006). After that, this developed response spectrum has been used to find similar response spectrum of some real earthquake. Finally, the comparison has been made between the developed response spectrum and response spectrum of the different earthquake to find the most suitable response spectrum of an earthquake based on the structural response which can be used for future analysis.

The objectives of the study are:

1. To find some similar earthquake response spectrum to developed earthquake.
2. To compare the developed response spectrum with different earthquake response spectrum to find the most similar earthquake response spectrum based on structural response like base reaction, joint reaction, and joint displacement.

METHODOLOGY

Development of Response Spectrum for rock and stiff soil and zone 2 from the normalized response spectrum:

The ground acceleration Sa graph has been developed based on the normalized response spectrum provided in the BNBC 2006 (Shafi et al., 2015). Two conditions have been considered in order to calculate the ground acceleration. They are:

1. Zone 2 has been considered (where, z=0.15)
2. Ordinary Moment Resisting Frame OMRF for steel has been considered (where, R=6)

Calculation:

$$Sa/gZ = 2.48 \qquad (1)$$

$$Or,\ Sa = 2.48 * g * Z$$

$$Or,\ Sa = 2.48 * 32.2 * 0.15$$

$$Or,\ Sa = 11.98$$

$$Now,\ Sa\ for\ OMRF = 11.98/6 = 1.9964$$

Based on the above calculation following table has been prepared.

Table 1: Ground acceleration for different soil.

Time Period	Sa		
	Soil I	**Soil II**	**Soil III**
0.0	1.9964	1.9964	1.9964
0.4	1.9964	1.9964	1.9964
0.5	1.6020	1.9964	1.9964
0.9	0.9660	1.2880	1.9964
1.0	0.8855	1.1914	1.8515
1.5	0.5635	0.7970	1.2075
2.0	0.4347	0.6440	0.8855
2.5	0.3542	0.4830	0.6762
3.0	0.2737	0.4025	0.5796

Based on the above table following graph has been prepared which can be used for response spectrum analysis.

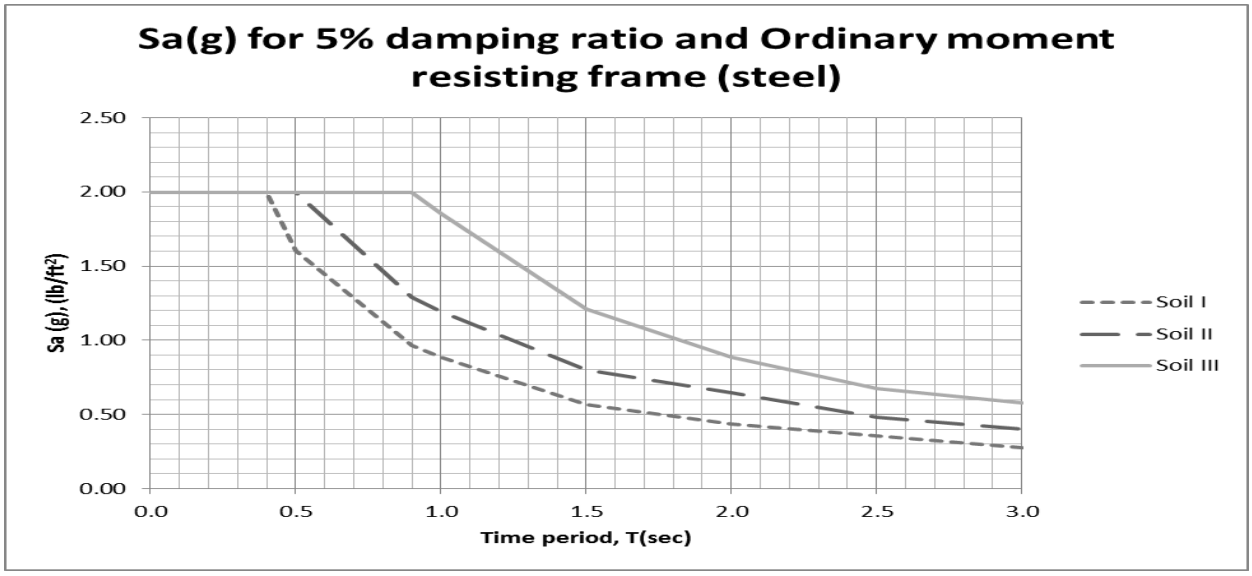
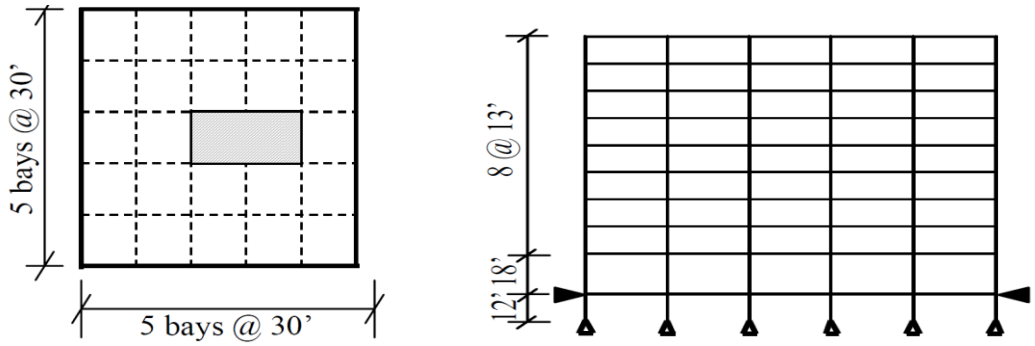


Fig 1: Response spectrum developed from BNBC normalized response spectrum.

A brief description of the development of building model in Etabs:

We have used the 9 stories SAC building for the analysis. The detail of the building has been described in FEMA 355C report appendix B. A brief summary has been described in this section.



(a) (b)

Fig 2: (a) plan view (b) elevation view

The orientation of the frame elements of the structures is given in the following table.

Table 2: Orientation of frame elements.

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

The joint restraint has been defined as fixed support. The joint constraint has been provided as a rigid diaphragm. For this study auto meshed has been used. Mesh has been done by 5X5 area meshes. A mass

source has been defined as “From loads” where only the dead and super dead loads have been included. For modal load case, we have considered a maximum of 12 modes and minimum of 01 mode and the other parameters are as default. The response spectrum has been defined as RS1, RS Friuli, Italy RS Gazli, RS Imperial Valley 2, RS Imperial Valley 6 & RS Tabas.

Finding similar earthquake response spectrum using PEER (Pacific Earthquake Engineering Research Centre):

At first, the developed response spectrum data should be written file where one column contains the time period and another column contains the soil acceleration. After that, the file should be saved as CSV (Comma delimited). Then we logged into the PEER website and enter NGA west 2 database. Here we select user-defined spectrum model and use the previously developed CSV file to generate the spectrum. After that, we search the record to find the most suitable response spectrum that matched our response spectrum. The criteria’s has been shown in the following figure.

Fig 3: Search criteria for finding similar spectrum to developed spectrum.

Here spectral ordinate has been selected as H1 so that we could use the raw data of the earthquake in one direction. Finally, from the search result, we have selected 5 earthquake spectrums. The values for time period 0.01 sec to 0.032 sec have been shown in the following table.

Table 3: Response spectrum data of five earthquakes.

Period (sec)	Friuli_ Italy-01 pSa (g)	Period (sec)	Gazli pSa (g)	Period (sec)	Imperial Valley 2 pSa (g)	Period (sec)	Imperial Valley-06 pSa (g)	Period (sec)	Tabas_ Iran pSa (g)
0.01	0.4782703	0.01	1.2206390	0.01	0.352449	0.01	0.416275	0.01	0.531173
0.02	0.4874193	0.02	1.4793732	0.02	0.351271	0.02	0.455293	0.02	0.533529
0.022	0.4949621	0.022	1.4445406	0.022	0.351456	0.022	0.474753	0.022	0.562051
0.025	0.4928253	0.025	1.7216740	0.025	0.351738	0.025	0.541016	0.025	0.574011
0.029	0.4936260	0.029	2.0473408	0.029	0.352179	0.029	0.663627	0.029	0.569074
0.03	0.4996952	0.03	2.0434354	0.03	0.352315	0.03	0.6916	0.03	0.565956
0.032	0.5151942	0.032	2.0354354	0.032	0.352623	0.032	0.691264	0.032	0.541983

RESULTS AND DISCUSSIONS

The comparison has been discussed made on three outputs. They are base reaction, joint reaction, and joint displacement.

Comparison based on base reaction:

To perform the comparison based on base reaction two reactions have been considered. They are reaction force in global X direction and moment about global Y direction.

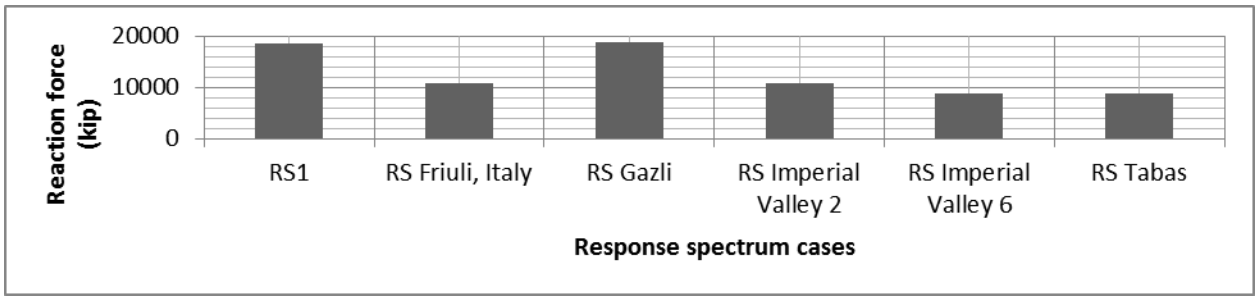


Fig 4: Base reaction force in the global x-direction for different earthquake response spectra.

The [Fig. 4] compare different earthquake response spectrum with BNBC response spectrum for soil type 1. The horizontal axis represents different response spectra cases and in the vertical direction, it represents the reaction force in kip. The RS Gazli has maximum reaction followed by RS1. Here the base reaction of RS1 is 18516.74 kip and of RS Gazli is 18846.58 kip. The least reaction was found for RS Tabas which is 8691.903 kip.

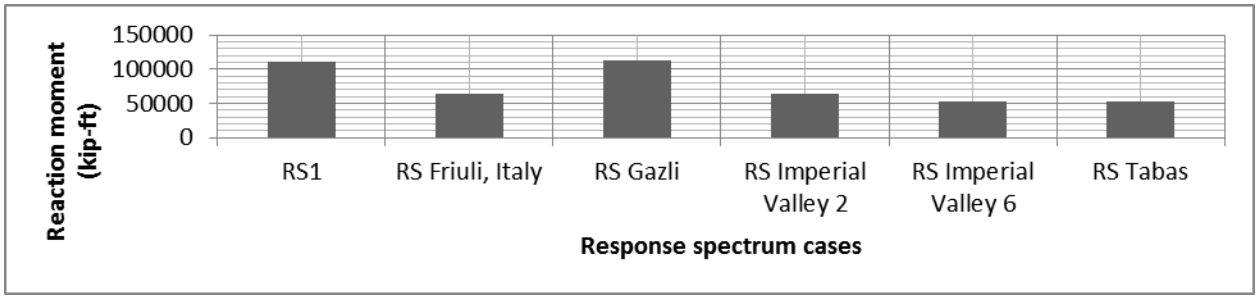


Fig 5: Base reaction moment about global Y direction for different earthquake response spectra.

The [Fig. 5] compare different earthquake response spectrum with BNBC response spectrum for soil type 1. The horizontal axis represents different response spectra cases and in the vertical direction, it represents the reaction moment in kip-ft. The RS Gazli has maximum reaction followed by RS1. Here, the base reaction moment of RS1 is 111100.42 kip-ft and of RS Gazli is 113079.49 kip-ft. The least reaction was found for RS Tabas which is 52151.41 kip-ft.

Comparison based on Joint reaction:

Joints of the bottom-most floor have been considered since it will provide maximum reaction.

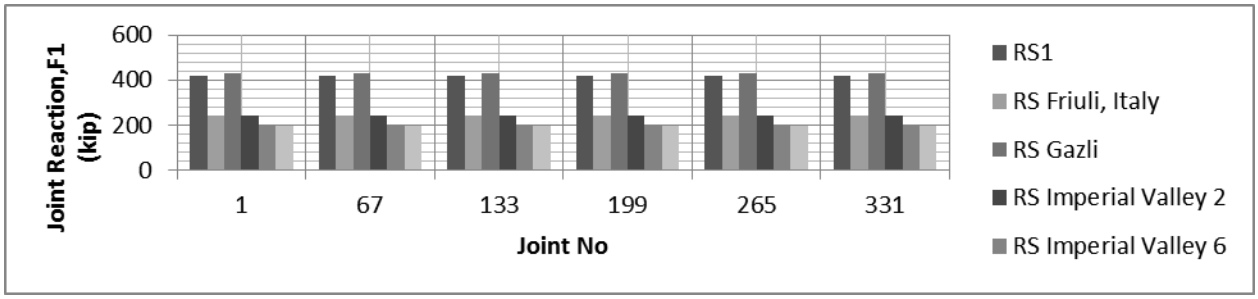


Fig 6: Joint reaction force about local 1(red) direction for different earthquake response spectra.

The [Fig. 6] represents the comparison between different response spectra based on joint reaction force in local 1 direction. Since the structure is symmetric and the joints are in the same plane so the reaction

of each joint is similar. The joint reaction of RS Gazli is maximum followed by RS1 which is 429.05 kip and 421.54 kips respectively.

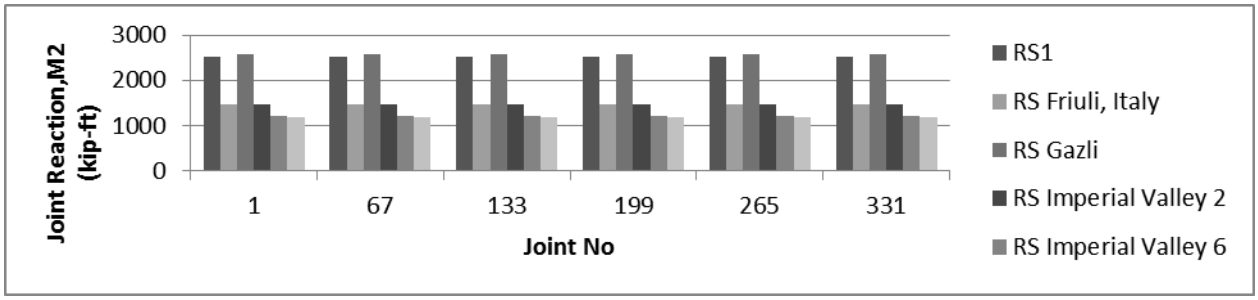


Fig 7: Joint reaction moment about local 2 (white) direction for different earthquake response spectra.

The [Fig. 7] represents the comparison between different response spectra based on joint reaction moment in local 2 direction. Since the structure is symmetric and the joints are in the same plane so the reaction of each joint is similar. Like the previous chart, it showed that the joint reaction of RS Gazli is maximum followed by RS1 and the value is 2574.33 kip-ft and 2529.27 kip-ft respectively.

Comparison based on joint displacement:

From left third column, joints have been selected for analysis.

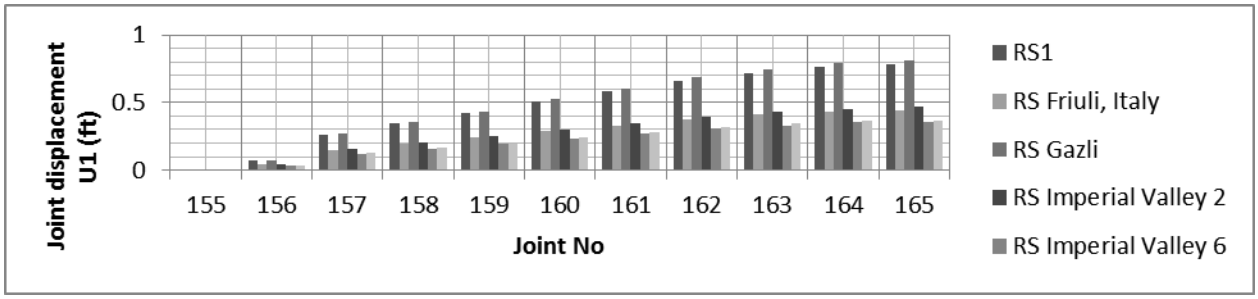


Fig 8: Joint displacement in U_1 direction for different earthquake response spectra.

The [Fig. 8] represents the comparison between different response spectra based on joint displacement in U1 direction. in the horizontal axis, it represents joint number and in the vertical axis, it represents joint displacement in ft. the joint number 155 is at the base so it has no displacement and joint number 165 is at the top so it has maximum displacement. In every case except for the joint no 155, RS Gazli provide maximum displacement followed by RS1 and the values are almost the same.

CONCLUSIONS

Finally, it can be concluded that the response spectrum of Gazli earthquake which has a magnitude of 7.0 is the most identical to the response spectrum developed from BNBC normalized response spectrum. We can use this study to find more similar real earthquake response spectrum in order to analyze our structure against earthquake. Though this study only considers rock and stiff soil we can also use this study for the other two types of soil condition provided in the BNBC 2006.

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