Nonlinear Site Response Evaluation Procedure Under The Strong Motion (Case Study: Miyaneh-Azarbayjan Sharghi Province-Iran)

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Abstract

The Miyaneh city and its suburban areas are located in the Northwest of Iran in Azarbayjan-Sharghi province. This area is prone to high seismic risk due to the presence of several active faults. Subsurface soils subjected to strong motion exhibit significant nonlinear behavior. In this paper a case study on ground response analysis of a site in Miyaneh region during the Ardabil earthquake (28 Feb. 1997, Mw6.1) is presented. For site characterization, deep site investigations have been undertaken, and a seismic geotechnical procedure for the proposed bridge over the rivers at mentioned site which is performed for Iran railway network, subjected to earthquake provokes has been notified and, the effect of nonlinearity on site response analysis for the selected site with assumption of elastic and rigid (viscoelastic) half space bedrock by use of Standard Hyperbolic Model nonlinear approach was evaluated and the results of them were compared to each other. Test of the capability of designed computer code by authors, namely as "Abbas Converter", description and evaluating the nonlinearity of the subsurface soil conditions encountered at the sites to analyze, evaluate the obtained test, site response and quantify the site effect on the surface over a number of geotechnical areas were the targets of this study. The results clearly showed that the effect of bedrock and local soil conditions on soil behavior under the earthquake excitation is one of the main effective factors on computed response spectra in ground response prediction. The key factor in this work was to develop and use "Abbas Converter". It worked and install so quickly, operated as a logic connecter function between the used softwares and could generate the input data corresponding to defined format for them. Its output results easily can export to the other used softwares in this study. More than it can make and render the study easier than previous have done, and take over the encountered problem.

Keywords: *Miyaneh city, "Abbas Converter", Ardabil earthquake, site response, site amplification*

1. Introduction

The Miyaneh region with 47°, 30´ to 48° East longitude and 37° to 37°, 30´ North latitude is placed on Northwest of Iran in Azarbayjan-Sharghi province. This area is an active seismic belt which is located in Alborz-Azarbayjan seismotectonic province. The Ardabil earthquake with M_w 6.1, Depth of 10 Km and 38.075 N, 48.050 E epicentral coordinates, occurred at 4:27 p.m. Iran standard time and lasted for 15 seconds was a destructive earthquake that occurred on 28 Feb. 1997. The epicenter was located near the city of Ardabil in northeastern Iran. In this study by use of geological, geophysical and geotechnical data with a designed computer code by authors namely as "Abbas Converter" the response spectra, computed motion and some related parameters for the selected area were evaluated and compared.

2. Local Geology and Ground Response

The local soil conditions have profound influence on ground response during earthquakes and can not be ignored. This problem is commonly referred to as a site specific response analysis or soil amplification study. Site response analysis is commonly performed to estimate and characterize site effects by solving the dynamic equations of motion via an idealized soil profile. Use a wide database of recorded strong motions and to group accelerograms with similar source, path and site effects could be the ideal solution for such a problem, which in practice such a database is not available. An alternative way for taking over to this problem is based on computer codes, developed from the knowledge of the seismic source process and of the propagation of seismic waves, that can simulate the ground motion associated with the given earthquake scenario. Superficial deposits, topography and basin effects, ground failure and structural deficiencies, profile depth, dynamic stiffness, impedance ratio between the soil deposit and underlying bedrock, the material damping of the soil deposits, nonlinear response of a soft potentially liquefiable soil deposits, soil type, cementation and geologic age, frequency of the base motion, the geometry and material properties of both bedrock and deposited soils, horizontal extent of the soil deposits overlying bedrock, slopes of the bedding planes of the soils overlying bedrock and faults crossing the soil deposits are some of the soil conditions and local geological features affecting the ground response.

3. Analysis Method

Characterization of site based on field investigation and laboratory tests, elect and apply the rock motion (natural or synthetic acceleration time history) on soil profile column associated with seismotectonic structure as input for rigid and elastic half space bedrock to represent and compute the effect of site motion on the soil profile at the surface are the analysis method steps. Because of the limitation in software applicability, no software can reply to all requested parameters lonely and our study respectively. For this reason the authors forced to produce a computer code to generate the new data and motion for used softwares corresponding to seismotectonic of selected area and convert the primary input of them to the other. Work and installing so quickly, operating as a logic connecter link between the used softwares and ability to generate the input data correspond the defined format for them are some of the advantages of this code. More that, its output can easily export to the other used software in this study. This code make and render easy the study more than previous have done and with it, the authors could enter recorded data with different format as an input and take defined format for them. Based on the calculated hypocentral distance, the L component of Ardabil event was applied on the bottom of the soil profile as shown in figure1 and the proposed steps of this study are shown in figures 2 to 4. This procedure indicated that the designed code can work with different conditions and shows its abilities. Among a total of 28 drilled bore holes, 10 borelogs were carefully evaluated, but the results of two of them with minimum 40m depth (BH1 and BH10) were select and presented in figures 5 to 9. Soil profile as shown in table (1), for comparison must be created and modified. In view of this, no attempts were made for developing the regression correlation based on the entire dataset and N values from locations where tests were conducted. In this study 180 pairs of N value and V_s

were applied and a formula which explained V_s as a function of N value by use of “Abbas Converter” was determined as Vs=160.16+0.42N for the selected area. By comparison of the above figures the results can under take and summarize in tables (2) and (3).

4. Discussion and Conclusion

This study tried to follow in conducting a meaningful site response and amplification study thus a case study on ground response analysis of a site in Miyaneh city, during the Ardabil earthquake is presented. The study shows that the Measurement and prediction of ground vibration due to strong motion have demonstrated the predominant role of site effects in the response of infrastructure during a seismic event. Site response analysis is usually the first step of seismic geotechnical study and authors have been trying to find a practical and appropriate solution for ground response analysis under earthquake forces for the selected site. Determination of the site specific ground response analysis is the aim of this effect of local soil conditions on seismic waves amplification and hence estimating the ground response spectra for future design purposes. The amplification spectrum of the soil column is computed between the top and the bottom of this soil deposit. Borings and dynamic in situ tests with the aim to evaluate the soil profile of V_s have been performed. The results show a very detailed and stable V_s profile. The obtained V_s profile has a good comparative with other insitu tests. After evaluating the accelerograms at the bedrock, the ground response analysis at the surface, in terms of time history and response spectra, has been obtained by nonlinear standard hyperbolic model. The PGA value at the ground surface obtained from the used computer codes which ranged from 1.1g to 0.57g can use to prepare the PGA map of Miyaneh. They are not distributed uniformly due to variation in the soil profile at various locations, more that this PGA is comparable to obtained PHA values using SPT data and the shape of variation of PA with depth are similar to the SPT data. The calculated amplification factor ranged from 3.56 to 4.30 in elastic and 34.9 to 56.4 in rigid conditions can be used to prepare the amplification map of Miyaneh region.

5. References

1-Anbazhagan, P., 2007, Site characterization and seismic hazard analysis with local site effects for microzonation of Bangalore, research work at the Indian Institute of Science, Dept. of Science and Technology of the Government of India.

2- Arslan, H., Siyahi, B., 2006, A comparative study on linear and nonlinear site response analysis, Environ. Geol., 50: 1193-1200.

3- Borja, R.I., Chao, H.Y., Montas, F.J. and Lin, C.H., 1999, Nonlinear ground response at Lotung LSST site, Journal of Geotech. Geoenviron. Eng., 125(3): 187-197.

4- Boominathan, A., 2004, Seismic site characterization for nuclear structures and power plants, Curr. Sci. (87), 1384-1397.

6- Elgamal, A.W., Zeghal, M., Parra, E., Gunturi, R., Tang, H.T. and Stepp, J.C., 1996, Identification and modeling of earthquake ground response I. Site amplification, Soil Dyn. Earthquake Engg. 15, 499-522.

7- Field EH, Johnson PA, Bersenev IA and Zeng Y (1997) Nonlinear ground motion amplification by sediments during the 1994 Northridge earthquake. Nature, 390: 599-602.

8- Idriss, I.M., 1990, Response of soft soil sites during earthquakes, Proceedings of the symposium to Honor H.B. Seed, Berkeley, CA, 273-289.

9- Imai, T., Tonouchi, K., 1982, Correlation of N-value with S-wave velocity, Proc. 2nd Euro. Symp. on Penetration Testing, 67-72.

10- Joyner, W.B., Chen, A.T.F., 1975, Calculation of nonlinear ground response in earthquake, BSSA, 65: 1315-1336.

11- Lam, N., Wilson, J., Chandler, A. and Hutchinson, G., 2000, Response spectrum modeling for rock sites in low and moderate regions combining velocity, displacement and acceleration predictions, Earthquake Engineering and Structural Dynamics, 29: 1491-1525.

12- Mersi, G., Febres-Cordero, E., Sheilds, D.R., Castro, A., 1981, Shear stress-strain –time behavior of clays, Geotechinique, 31(4), 537-552.

13- Park, D. and Hashash, Y.M.A., 2004, Soil damping formulation in nonlinear time domain site response analysis, Journal of Earthquake Engineering, Vol. 8, No.2, 249-274.

14- Rodriguez-Marek, A., Bray, J.D. and Abrahamson, N.A., 2000, A geotechnical seismic site response evaluation procedure, In Proceeding of 12 WCEE, Auckland, New Zealand.

15- Rolling, K.M., Evans, M.D., Diehl, N.B., Daily, W.D., 1998, Shear modulus and damping relationships for gravel, J. Geotech. Geoenv. Engg., ASCE 124, 396-405.

16- Seed, H.B., Idriss, I.M., 1970, soil moduli and damping factors for dynamics response analysis, Report No. EERC70-10, University of California, Berkeley.

17- Seed, H.B., Murarka, R., Lysmer, J., Idriss, I.M., 1976, Relationships between maximum acceleration, maximum velocity, distance from source and local site conditions for moderately strong earthquakes, BSSA, 66 (4), 1323-1342.

18- Vucetic, M., 1990, Normalized behavior of clay under irregular cyclic loading, Canadian Geotechnical Journal, 27, 29-46.

19- Vucetic, M., Dobroy, R., 1991, Effect of soil plasticity on cyclic response, Journal of Geotechnical Engineering, 117(1), 87-107.

20- Yoshida, N. and Iai, S., 1998, Nonlinear site response analysis and its evaluation and prediction, In: 2nd international symposium on the effect of surface geology on seismic motion, Yokosuka, Japan, pp.71-90.

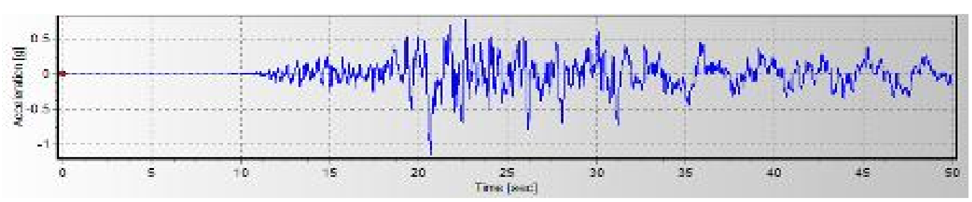

Figure1. L Component of Ardabil event (PGA=1.1447g at t=20.66s)

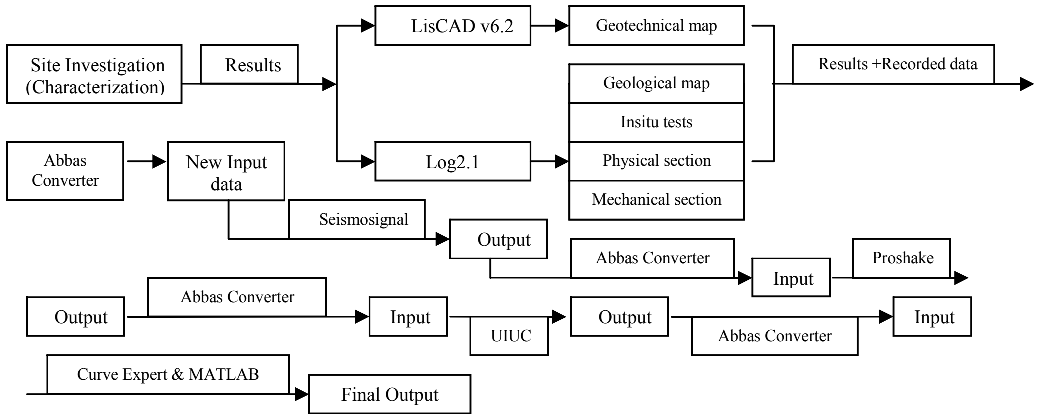

Figure2. Proposed method for this study by authors

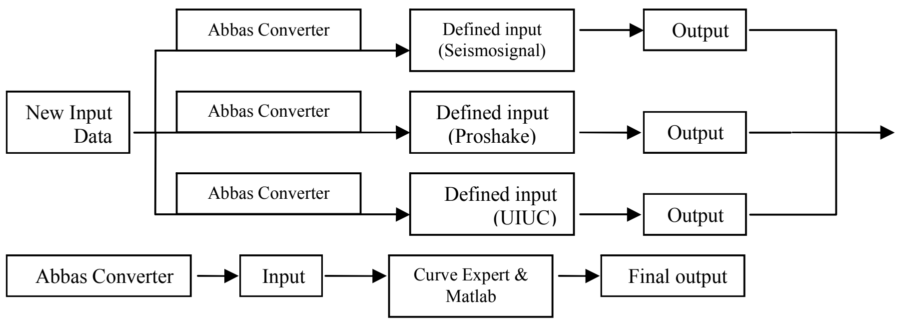

Figure3. Ability of "Abbas converter" to install in parallel condition

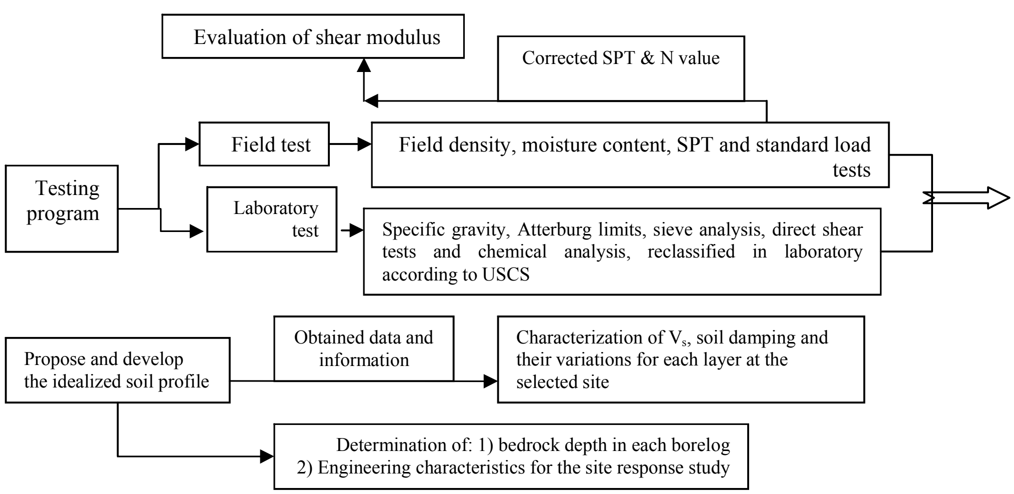

Figure4. Testing program steps

Table (1): Soil profile of BH10 and BH1

Soil type	$Depth_{(m)}$	$Thickness_{(m)}$	$\gamma_{(gr/cm3)}$	SPT	PI	$Vs_{(m/s)}$
CL	1.5	1.5	1.55	37	23	244.926
SC	1.5	1.5	1.53	29	12	230.95
SC	3.5	2	1.53	46	17	270.466
GP	3.5	2	1.77	43	---	265.603
CL	12	8.5	1.62	55	20	292.04
SP-SM	7.5	4	1.8	88	---	368.022
SM	14.5	2.5	1.7	65	---	319.19
CL	31.5	24	1.78	53	14	287.629
CL	16.5	2	1.73	59	22	300.618
CL	33.5	2	1.82	78	10	337.499
SM	18.5	2	1.71	73	30	328.326
GC	36	2.5	1.85	66	12	319.1
CL	20.5	2	1.68	60	23	305.455
CL	40	4	1.9	70	17	322.651
CH	24.5	4	1.73	58	18	298.506
MH	26.5	2	1.71	72	27	326.44
CL	30.5	4	1.81	54	25	289.849
CH	32.5	2	1.71	61	27	301.1
CL	44.5	12	1.84	73	21	368.326
BEDROCK $\gamma(2.0gr/cm^3)$, Vs=1016.125m/s (BH10)						
BEDROCK $\gamma(2.21gr/cm^3)$, Vs=1214.2m/s (BH1)						

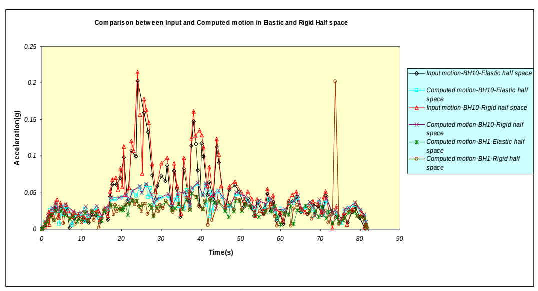

Figure5. Comparison between the Input and Computed motion in Elastic and Rigid half space (5% damping)

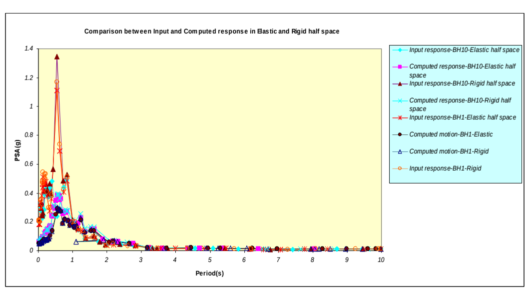

Figure6. Comparison between Input and Computed response in Elastic and rigid half space (5% damping)

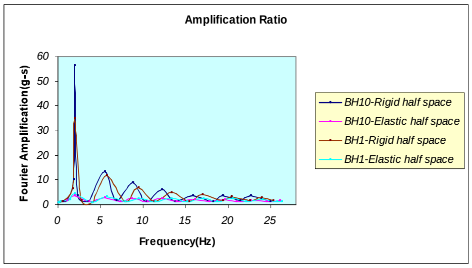

Figure7. Amplification ratio spectrum

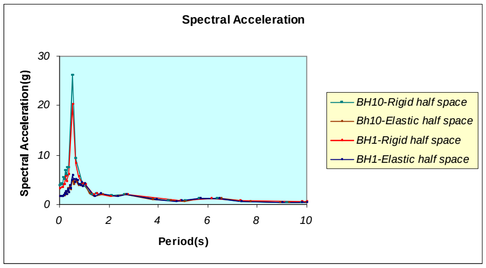

Figure8. Spectral Acceleration spectrum

Table (2): Rigid half space parameters

Location	Parameter	Maximum at…(Input)	Maximum at…(Computed)
BH-10	motion	0.2153g (t=24.1s)	0.0635g (t=39.1s)
BH-10	Response spectra	PSA=1.345 (Period 0.54s)	PSA=0.3986g (Period 0.61s)
BH-1	motion	0.2153g (t=24.1s)	0.0502 (t=37.08s)
BH-1	Response spectra	PSA=1.171g (Period 0.54s)	PSA=0.2963g (Period 0.56s)
BH-10	Amplification ratio	--------------------------	56.4 (f=1.9274Hz)
BH-1	Amplification ratio	--------------------------	34.9(f=1.9146Hz)
BH-10	Spectral Acceleration	--------------------------	26.1g (period 0.52s)
BH-1	Spectral Acceleration	--------------------------	8.22g (period 0.65s)

Table (3): Elastic half space Parameters

Location	Parameter	Maximum at…(Input)	Maximum at…(Computed)
BH-10	motion	0.2027g (t=24.1s)	0.0619g (t=39.1s)
BH-10	Response spectra	PSA=1.237g (Period 0.54s)	PSA=0.3842g (Period 0.55s)
BH-1	motion	0.2027g (t=24.1s)	0.0619g (t=39.1s)
BH-1	Response spectra	PSA=1.112 (Period 0.54s)	PSA=0.2936g (Period 0.55s)
BH-10	Amplification ratio	--------------------------	3.56 (f=1.8889Hz)
BH-1	Amplification ratio	--------------------------	4.30 (f=1.8889Hz)
BH-10	Spectral Acceleration	--------------------------	4.91g (period 0.53s)
BH-1	Spectral Acceleration	--------------------------	5.79g (period 0.52s)