STUDY ON THE VARIATION OF GROUND MOTION PARAMETER ALONG DEPTH

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ABSTRACT :

A soil layer seismic response test is applied in an engineering profile. El-centro wave is chosen as the input wave in the test, its peak acceration is adjusted as 10gal、20gal、30gal、50gal、75gal、100gal、150gal、200gal、250gal、300gal、350gal、400gal during calculating. The peak accelerations and the maximal shear strains of the profile in different depth are calculated, the peak accelerations and their amplification coefficients on the surface and nearby the base are also calculated. Conclusions can be drawn from the calculation results: firstly, with the input wave becoming more and more stronger, the amplification coefficients become more and more smaller and even less than 1, the ones nearby the base become more and more lager, and the peak accelerations appear a saturation state when input wave is lager. Secondly, the peak accelerations become smaller and smaller first and then larger and larger from the base to the surface on the whole. Thirdly, the maximal shear strains become lager fastly nearby the surface with the depth increasing, when the input wave increase to a certain degree. The maximal shear strains and their curve figure along the depth do not change even if the input wave changes.

KEYWORDS: ground motion paramter, depth, varition

1. INTRODUCTION

With the developing of the economy, the exploration of underground space is set a high value on. Underground structure is applied more and more widely in water resources and hydropower projects, nuclear power stations, highway and railway transportation, important long life lines, national defence, urban development. When earthquake happens, underground structure's security and reliability is very important to protect the lives and property of the people and to keep the cities' normal state. As we all known, in 1995 Kobe Earthquake, many underground structures are defiled in Honshu city, Japan, and the subway station and the tunnel are defiled especially badly. In Taiwan Chi-Chi Earthquake and in Turkey Kocaeli Earthquake，there are also some underground structures being destroyed in varying degree, and then the seismic design study of underground structure is begin to be given emphasis. In general, underground structures has small effect on foundation around it, while underground structure is restrained clearly by the around rock an soil medium, and the properties of the foundation's motion have main effect on the response of underground structure. So it has a noticeable meaning to study the motion properties in soil body under earthquake. The study in the paper is based on a real engineering, and the trend of peak acceleration and the maximal shear strain varying along the depth is put the main emphasis on, the the peak acceleration and the amplification of the gruond surface are compared with these near the bedrock.

2. ENGINEERING SITE CONDITION

The engineering the site located is a tunnel that goes through Yellow River and connect N.O. 309 carriageway and Jile Road. The physiognomy of the site is a alluvial plain of Yellow River. The whole landscape along the tunnel lookes as flat as a pancake. So it is appropriate to use one dimension method of seismic response analysis of horizontal soil layer.

3. SELECTION OF CALCULATION PROFILE AND CALCULATION PARAMETERS

The NO. 4 hole's profile is selected as calculation profile, the hole is 103.5 meters deep, the site profile is consisted mainly of backfilled soil, silt, clay and silty clay. The data of the profile is shown in table 1, table 2 and table 3.

Table 1 Site condition

No.	Depth of layer bottom/m	Thickness of layer/m	Description of soil	Density/ g • cm^{-3}	Sample number and its overlying depth
1	1.3	1.3	Backfilled Soil: dense; wet	1.81	
2	2.7	1.4	Silt: dense; very wet	2..02	
3	4.4	1.7	Silty Clay: brown-gray; soft-plastic	2.04	
4	5.6	1.2	Silt: dense; very wet	2.02	S1:5.0-5.2
5	17.8	12.2	Silty Clay: brown-gray; soft-plastic	2.04	S2:16.4-16.6
6	33.5	15.7	Silty Clay: brown-yellow; soft-plastic	2.02 2.03	S3:21.0-21.2 S4:29.6-29.8
7	46.3	12.8	Silty Clay: brown-yellow; plastic	2.05	S5:39.8-40.0
8	48.5	2.2	Fine Sand: brown-yellow; dense; saturated;	1.97	S6:47.0-47.2
9	67.8	19.3	Silty Clay: brown-yellow; plastic; wet	2.01	
10	71.5	3.7	Clay: brown-yellow; plastic; very wet	2.03	S7:70.0-70.2
11	86.3	14.8	Silty Clay: brown-yellow; plastic; wet	2.01	S9:79.0-79.2
12	96.3	10.0	Silty Clay: gray-green; plastic; wet	1.96	S10:88.0-88.2
13	103.5	7.2	Clay: gray-green; hard- plastic; very wet	2.2	

Table 2 Shear velocity

No.	Depth/m	Shear velocity/m • s^{-1}	No.	Depth/m	Shear velocity/m • s^{-1}	No.	Depth/m	Shear velocity/m • s^{-1}
1	2	155.4	18	36	273.2	35	70	388.6
2	4	163.1	19	38	281	36	72	367.7
3	6	168.6	20	40	285.1	37	74	374.8
4	8	173.8	21	42	289.3	38	76	375.4
5	10	178.4	22	44	297.9	39	78	380.3
6	12	186.7	23	46	316.9	40	80	378.5
7	14	191.4	24	48	362.9	41	82	385.5
8	16	199.7	25	50	344.2	42	84	387.2
9	18	208.6	26	52	350.3	43	86	390.1
10	20	215.7	27	54	356.6	44	87	412.4
11	22	220.8	28	56	363.1	45	89	415.2
12	24	223.5	29	58	369.9	46	91	425.7
13	26	248.7	30	60	376.9	47	93	467.4
14	28	252	31	62	348.3	48	95	509.6
15	30	258.7	32	64	353.5	49	97	512.8

16	32	265.7	33	66	362.1
17	34	288.9	34	68	385.7

Table 3 Shear velocity

No.	G/G_{max} and λ	Shear strain γ (10^{-4})							
		0.05	0.1	0.5	1	5	10	50	100
Backfilled Soil	G/G_{max}	0.9600	0.9500	0.8000	0.7000	0.3000	0.2000	0.1500	0.1000
	λ	0.0250	0.0280	0.0300	0.0350	0.0800	0.1000	0.1100	0.1200
S1	G/G_{max}	0.9917	0.9816	0.9074	0.8291	0.4905	0.3247	0.0877	0.0458
	λ	0.0058	0.0098	0.0320	0.0509	0.1173	0.1455	0.1833	0.1898
S2	G/G_{max}	0.9911	0.9802	0.9009	0.8182	0.4716	0.3084	0.0818	0.0426
	λ	0.0094	0.0146	0.0387	0.0567	0.1116	0.1325	0.1588	0.1630
S3	G/G_{max}	0.9929	0.9842	0.9197	0.8501	0.5294	0.3598	0.1010	0.0532
	λ	0.0054	0.0088	0.0272	0.0425	0.0975	0.1219	0.1561	0.1621
S4	G/G_{max}	0.9957	0.9904	0.9498	0.9036	0.6503	0.4816	0.1566	0.0849
	λ	0.0103	0.0140	0.0284	0.0379	0.0673	0.0804	0.1000	0.1037
S5	G/G_{max}	0.9960	0.9911	0.9532	0.9098	0.6667	0.4998	0.1664	0.0908
	λ	0.0224	0.0287	0.0506	0.0638	0.1019	0.1179	0.1416	0.1461
S6	G/G_{max}	0.9963	0.9902	0.9505	0.9075	0.6782	0.5089	0.1519	0.0941
	λ	0.0042	0.0063	0.0185	0.0301	0.0825	0.1042	0.1383	0.1437
S7	G/G_{max}	0.9954	0.9898	0.9468	0.8980	0.6359	0.4659	0.1484	0.0802
	λ	0.0035	0.0067	0.0275	0.0477	0.1263	0.1612	0.2081	0.2161
S8	G/G_{max}	0.9913	0.9807	0.9034	0.8224	0.4788	0.3145	0.0840	0.0438
	λ	0.0068	0.0108	0.0315	0.0484	0.1079	0.1346	0.1727	0.1795
S9	G/G_{max}	0.9946	0.9879	0.9373	0.8810	0.5950	0.4232	0.1279	0.0683
	λ	0.0370	0.0427	0.0593	0.0677	0.0874	0.0941	0.1026	0.1040
Bedrock	G/G_{max}	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	λ	0.0040	0.0080	0.0100	0.0150	0.0210	0.0300	0.0360	0.0460

4. ANALYSIS AND CALCULATION OF GROUND MOTION PARAMETER

4.1. Input motion

The N-S acceleration recoder of El-centro wave in 1940 is choosen as input ground motion, its peak acceleration is 341.7 gal, the original acceleration time history is shown as figure 1. it is magnified pro rata so as to a series of new waves which have peal accelerations as 10gal, 20gal, 30gal, 50gal, 75gal, 100gal, 150gal, 200gal, 250gal, 300gal, 350gal, 400gal, and each of all the new waves has 2688 scatter dots and has a 0.02s time step. The new waves are the input wave in calculation.

4.2. Analysis of calcultaion results

One dimension equivalent linear method of seismic responses for soil layers is used to calculate the soil profile above. Some results are obtained under different input motions. The results include peak accelerations and the amplification coefficients at the surface and at the bottom(88m depth), peak acceleration and the maximal shear strains of the body along depth .Here amplification coefficient is defined as the calculated peak acceleration somewhere divided by the corresponding input peark acceleration. The results is shown as table 4, figure2 and figure 3.

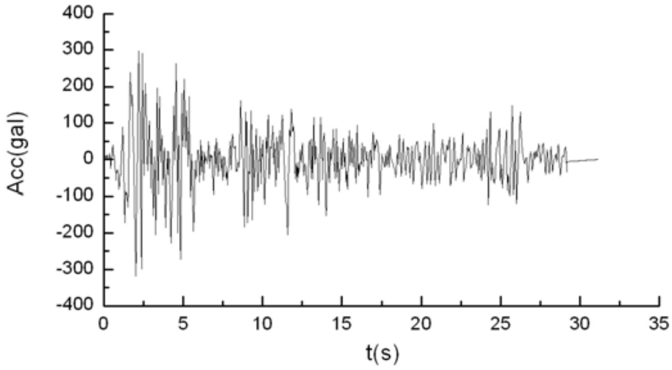

Figure. 1 Time history curve of acceleration

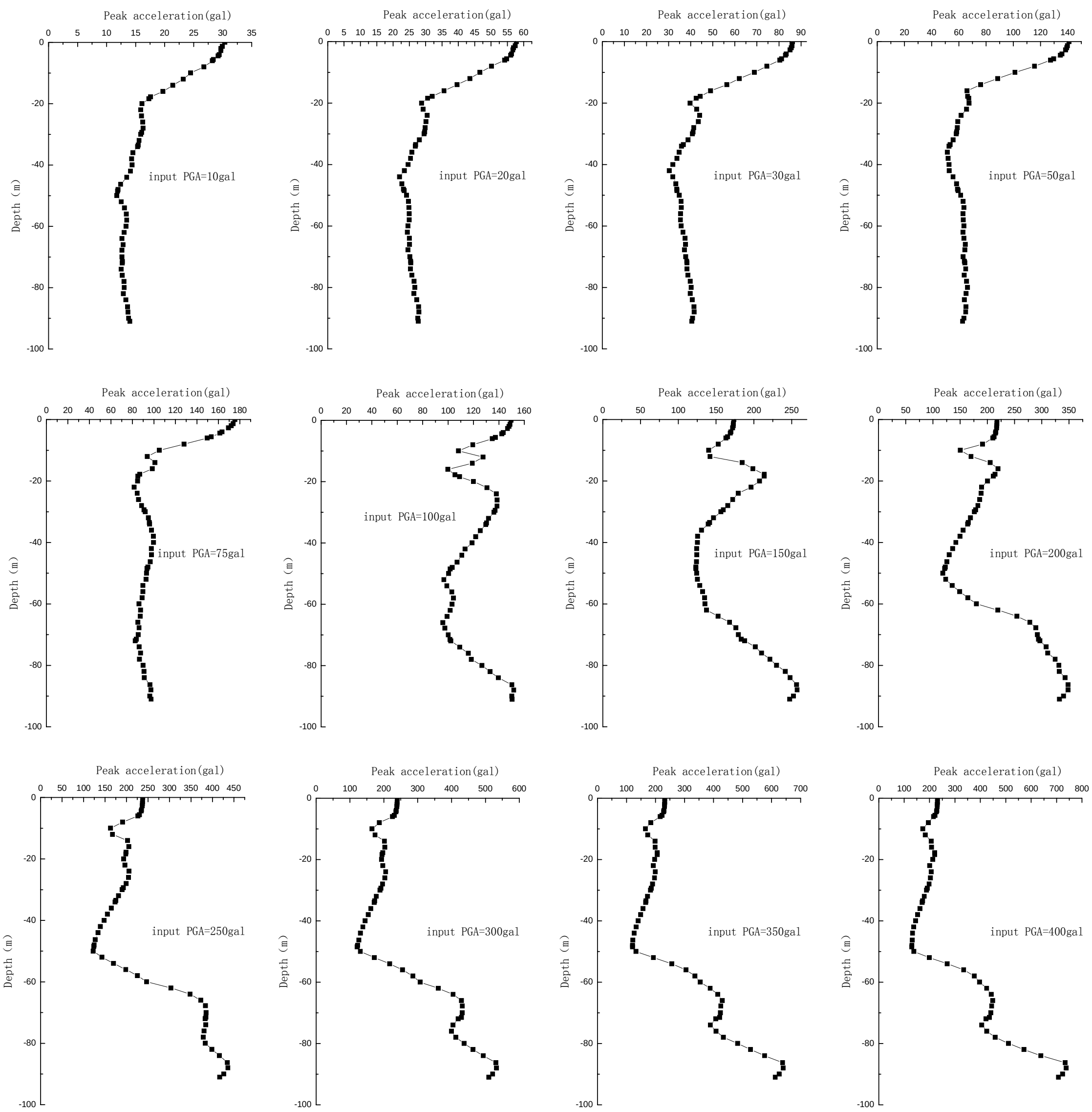

Figure 2 Peak accelerations varying along depth under different input motion

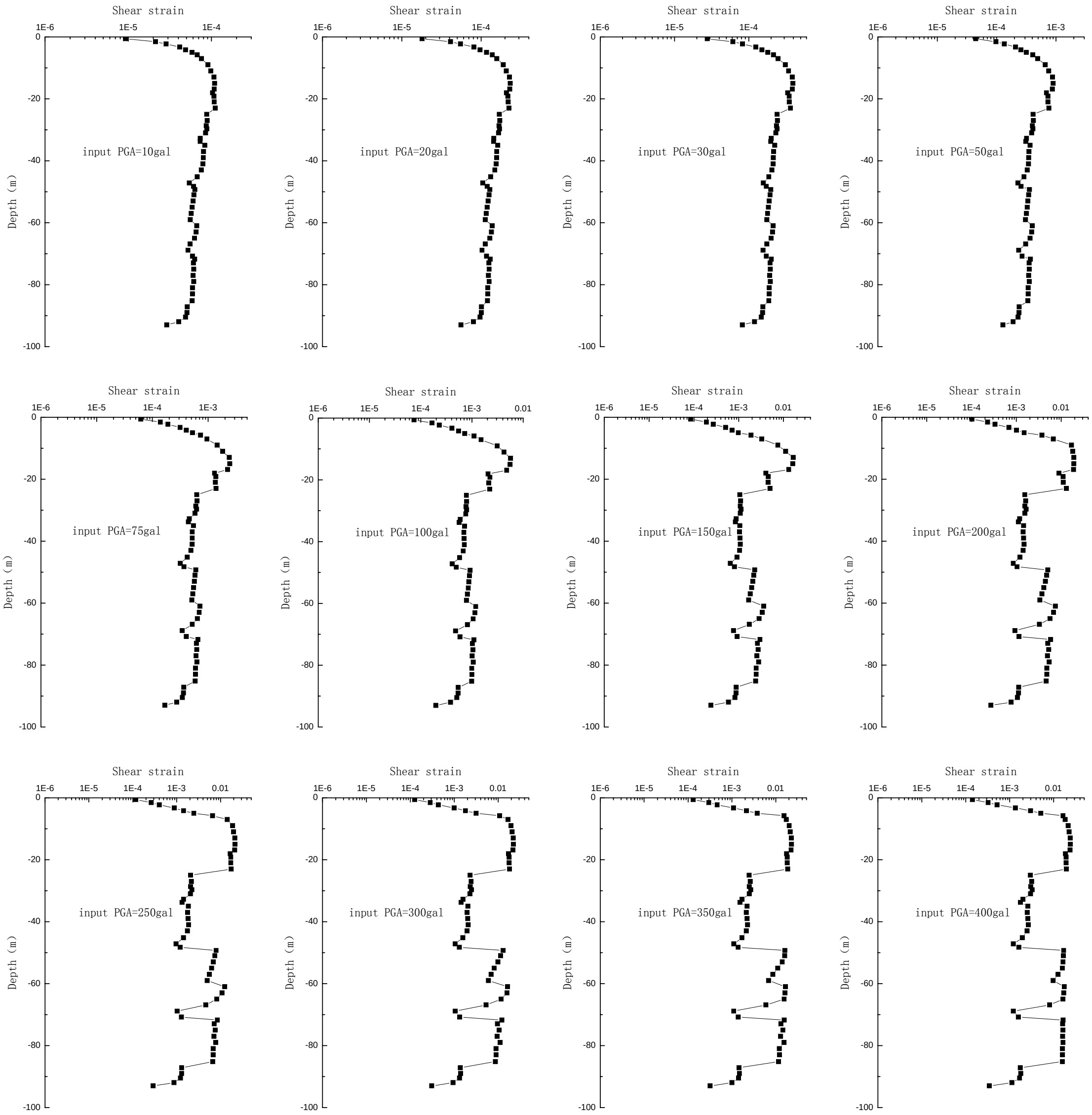

Figure 3 The Shear strain varying along depth under different input motion

Table 4 Peak accelerations and amplification coefficients
at the surface and near the bedrock(88 m underground)

Input PGA/gal	10	20	30	50	75	100	150	200	250	300	350	400
A1	30.37	57.78	86.2	141	175.4	149.6	173.5	217.7	237.8	239.8	232.2	231.6
B1	3.04	2.89	2.87	2.82	2.34	1.5	1.16	1.09	0.95	0.8	0.66	0.58
A2	13.7	27.95	41.6	65.09	97.2	151.7	257.3	348.3	436.1	532.8	640.1	738.2
B2	1.37	1.4	1.39	1.3	1.3	1.52	1.72	1.74	1.74	1.78	1.83	1.85

Here some shortened form ands symbols shoud be explained in the paper, *input PGA* stands for the peak acceleration of input motion in Figure 2, Figure 3 and Table4. *A1* and *A2* stand for peak accelerations at the surface and near the bedrock respectively, *B1* and *B2* stand for the amplification coefficients at the surface and near the bedrock respectively.

Some conclusions can be drawn by analyzing Table 4, Figure2 and Figure 3.
Firstly, when the input motion becomes stronger and stronger, the peak accelerations at the surface and near the bedrock become also lager and lager. After the peak acceleration increases a certain value, the input motion peak accelerations at the surface become no more larger, and keep a fixed value.
Secondly, when the input motion becomes stronger and stronger, the amplification coefficients at the surface vary from 3 to a value less than 1, while the amplification coefficients near the bedrock become larger and lager all along.
Thirdly, when the input motion is not strong, i.e. it less than 100 gal, the magnifying effection of the soil body is more and more distinct from 20 m underground to the surface, and the nearer to the surface the soil layer is, the more distinct the magnifying effection will be. When the peak acceleration of the input motion exceeds 100 gal, the magnifying effection of the soil from 50 m to the bottom is more distinct than that near the surface, further more, the nearer to the bedrock the soil layer is, the more distinct the magnifying effection will be.
Finally, the shear strain becomes larger and larger from the surface to about 20 m underground. When the input mothion is not strong, all the shear strain curve shaps are the same. When the input motion becomes strong, the part soil layer' shear strain is clearly different from the near layers's shear strain. When the input motion exceeds 200 gal, all the shear strain curves have same shapes by and large.

5. CONCLUSION

This paper primarily discusses peak acceleration and the maximal shear strain varying trend along the depth, and compares the amplification coefficients at the surface with that near the bedrock. And some conclusions we drawn could be some referrence meaning. In this paper, only one profile is studied, and the input motion is also one type, it's not enough to do the work above for study ground motion parameter varying along depth. There are many work to do for the future, i.e. many different type of profiles should to be studies, and different type of input motions are also choosen. Further more, equivalent linear method of seismic responses is not suitable for soft soil, it is worthy to develop method of seismic response analysis suitable for soft soil so as to study ground motion parameter varying along depth in soft soil body.

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