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Influences of S-Wave Velocity to the Seismic Response of Silt Ground

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ABSTRACT

By using of one-dimension equivalent linearzation seismic response analysis method, the study is performed to the different silt grounds. The influences of s-wave velocity uncertainty to the seismic acceleration peak, duration, response spectrum of silt ground are discussed in the paper. Following conclusions will be expected. (1) The relationship between the difference of seismic peak acceleration and the difference of s-wave velocity is in linear distribution approximately. The seismic peak acceleration is changed with the S-wave velocity. The seismic peak acceleration is much effected by the uncertainty of S-wave velocity. (2) The uncertainty of shear wave velocity has little influence on the seismic duration. (3) The long-period seismic response spectrum is much effected by the decreasing of shear wave velocity. Conversely, the moderate-period and short-period seismic response spectrum is much effected by the increasing of shear wave velocity. With the depth of silt layers extended, the seismic response spectrum is greater influenced by the uncertainty of shear wave velocity.

1 INTRODUCTION

There are three uncertainties in the soil seismic response analyses, namely the input seismic waves, methods of calculation and soil dynamic parameters. These uncertainties were studied previous by some researchers. Some reasonable advice was proposed. After Housner (1947)[1] firstly took random pulse superposition to simulate time history of seismic acceleration, artificially synthetic seismic wave as the input rock seismic wave is generally used. Towhata (1996)[2] adopted analytic method, Batta (1996)[3] et al used Boundary method and FEM-Boundary mixed method in seismic response analyses. Li tian (1994)[4] proposed to use emulation technology in seismic response calculation with random parameters according to the real uncertainty factors of projects. Due to the close relationship between s-wave velocity and the strength, deformation property of foundation, and also because s-wave can be easily measured by simple apparatus and method, so it is widely used in seismic response analyses, seismic zoning study, machine foundation design, soil and structure interaction analyses, bridges of railway and highway anti-seismic analyses, soft soil foundation identification and improvement, and underground pipe anti-seismic design. S-wave velocity is an important soil dynamic parameter. It can be easily got by in-situ measurements. The uncertainty can not be avoided due to the difference in the measuring method and apparatus, and 30 percent or even more uncertainty may present. Silt is widely distributed, but the study on the influence of s-wave velocity uncertainty on the seismic parameters of silt ground is short. In this article, the influence of s-wave velocity uncertainty on the seismic parameters of silt ground is studied in detail through researching silt region. The gained conclusions have important reference value for earthquake resistant in silt region.

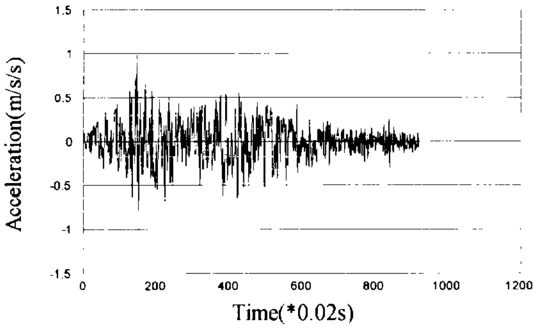
2 DATA INPUT OF SOIL SEISMIC RESPONSE CALCULATION

2.1 Seismic Wave on Rock

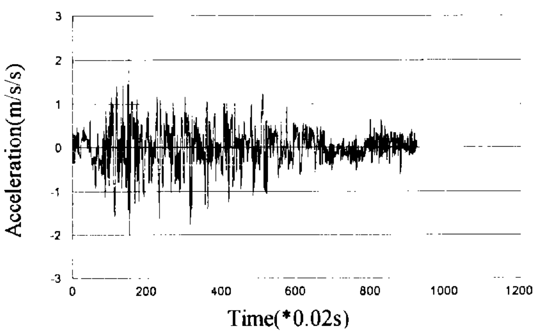
In order to investigate the influences of uncertainty in s-wave velocity at different intensity on the soil seismic response, an artificially synthetic seismic wave method was applied to obtain three typical waves: The acceleration peak of the three artificial waves are $0.98 m/s^2$ for wave No.1, $1.96\ m/s^2$ for wave No. 2 and $3.92\ m/s^2$ for wave No. 3. The amplification peak of the response spectrum is 2.24; the characteristic period takes 0.25s and the duration takes 10s(see fig.1).

2.2 Relationship among Shear modulus Ratio, Damping Ratio and Shear strain of Silt

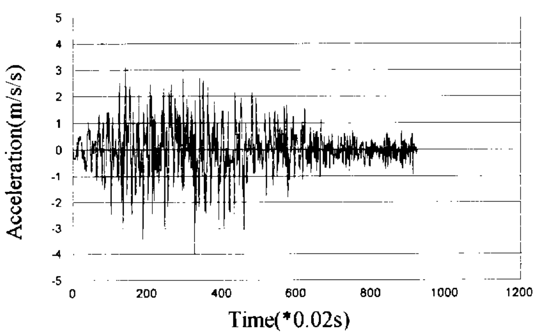
The data of the shear modulus ratio, damping ratio and shear strain of silt are taken from the data recommended in " The Chinese norm of seismic safety evaluation for projects"[5] (see Table 1).



(a) Seismic wave No.1



(b) Seismic wave No.2



(c) Seismic wave No.3

Fig.1 Input seismic waves on rock

Table 1 Shear modulus ratio, damping ratio and shear strain of silt

1-a

Parameter	Shear strain(10^{-4})			
	0.05	0.1	0.5	1.0
Shear modulus ratio	0.965	0.935	0.775	0.660
Damping ratio	0.006	0.010	0.030	0.045

1-b

Parameter	Shear strain(10^{-4})			
	5.0	10.0	50.0	100.0
Shear modulus ratio	0.300	0.250	0.105	0.090
Damping ratio	0.088	0.103	0.124	0.130

2.3 Variety Law of Shear-wave Speed to Depth

The variety law of shear-wave speed to the depth takes the statistic result of Zhou Xiyuan etc.[6]:

$$V_s = 242.5(1+h)^{0.291} / H^{0.217} \qquad (1)$$

Where H is the mantle thickness, h is the depth of the silt response to wave velocity V_s.

On the above assumptions, the shear wave velocity vary as $\pm 10\%$, $\pm 20\%$, $\pm 30\%$ $\pm 40\%$

3 INFLUENCE OF SHEAR WAVE SPEED UNCERTAINTY ON SILT SEISMIC PARAMETERS

The thickness of the silt is supposed to be 10, 30, 50, and 70m, and density ρ=1900kg/m^3. By inputting the rock seismic wave, the shear wave velocity and the relation between shear modulus ratio, damping ratio and shear strain, the seismic response is calculated through the equivalent linear solution[7] for one dimensional soil seismic response. The influences of uncertainty of the shear wave velocity on the silt seismic parameters are studied through the calculating results.

3.1 Influence on Acceleration Peak

The influences of the shear wave uncertainty, corresponding to different input seismic wave and thickness of silt, on the acceleration peak are shown in Table 2 and Figure 2.

From the table and the figure, we can see that:

(1) Except the case for the 10m thick silt, the greater the difference between the shear wave velocities are, the larger the difference in the acceleration peaks are, vice versa, which behaviors almost as a linear law. When there is a -40% discrepancy between the shear wave velocities, there is a –5.7% to -75.0% variety in the acceleration peaks with average variety of –48.1%. When there is a -30% discrepancy between the shear wave velocities, there is a –4.8% to –65.7% variety in the acceleration peaks with average variety of –32.2%. When there is a -20% discrepancy between the shear wave velocities, there is a –10.2% to –35.4% variety in the acceleration peaks with average variety of –23.5%. When there is a -10% discrepancy between the shear wave velocities, there is a –3.1% to –20.9% variety in the acceleration peaks with average variety of -11.1%. When there is a 10% discrepancy between the shear wave velocities, there is a 6.2% to 19.0% variety in the acceleration peaks with average variety of 12.4%. When there is a 20% discrepancy between the shear wave velocities, there is an 11.9% to 45.6% variety in the acceleration peaks with average variety of 21.6%. When there is a 30% discrepancy between the shear wave velocities, there is a 1.4% to 50.7% variety in the acceleration peaks with average variety of 24.8%. When there is a 40% discrepancy between the shear wave velocities, there is an 8.8% to 54.1% variety in the acceleration peaks with average variety of 29.3%. Comparing the effects of the discrepancy in shear wave speeds, the negative discrepancies have greater effect on the acceleration peaks than the positive ones do.

(2) Except the case for the 10m thick silt, the negative

discrepancies of the shear wave velocities cause declines in the acceleration peaks (-3.1% -75.0%) and the positive discrepancies will produce increases in the accelerations (1.4% 54.1%). This shows that the shear wave velocities present a similar law as the acceleration peaks.

(3) The uncertainty cause a variety in the acceleration peak from −3.1% to -75.0% with an average of -28.7% and an increase from 1.4% to 54.1% and average to 22.0%. Of all the varieties, there are 80.6 percent are greater than 10%. Therefore a common uncertainty may cause a 10 percent variety in peak value acceleration.

(4) To different seismic input the influence of s-wave velocity uncertainty on the acceleration peak present a similar law.

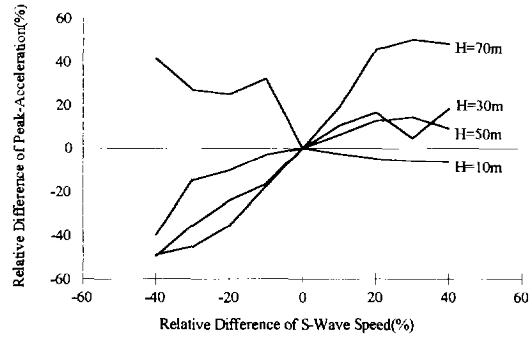
Table 2 Comparison results of seismic acceleration peak to that is gained according to norm s-wave velocity

2-a

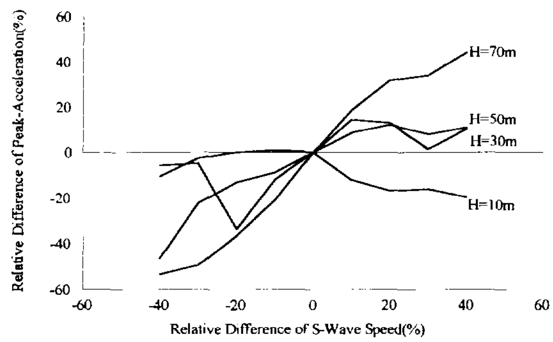
Seismic wave	Depth (m)	Relative difference of s-wave velocity(%) -40	-30	-20	-10
	10	41.4	27.1	25.0	32.1
	30	-39.8	-14.8	-10.2	-3.1
1	50	-48.7	-45.1	-35.4	-17.7
	70	-49.4	-35.4	-24.1	-16.5
	10	-10.5	-2.4	0.0	1.0
	30	-46.3	-22.2	-13.0	-8.8
2	50	-5.7	-4.8	-33.5	-11.9
	70	-53.5	-49.6	-36.4	-20.9
	10	-24.2	-16.1	0.0	12.3
3	30	-47.8	-28.8	-25.9	-8.4
	50	-67.0	-23.7	-19.5	-9.3
	70	-75.0	-65.7	-13.4	-3.5

2-b

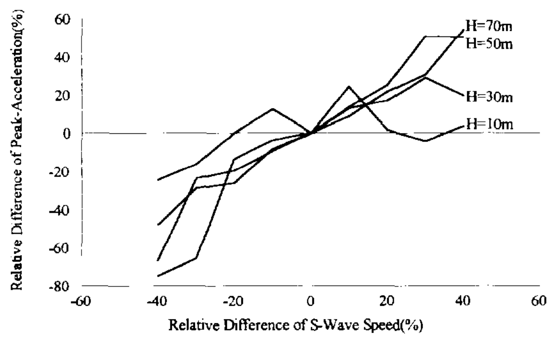
Seismic wave	Depth (m)	Relative difference of s-wave velocity(%) 10	20	30	40
	10	-2.9	-5.0	-5.7	-6.4
	30	10.2	16.4	4.7	18.0
1	50	6.2	12.4	14.2	8.8
	70	19.0	45.6	50.1	48.1
	10	-11.9	-16.7	-16.0	-19.7
	30	14.4	13.0	1.4	10.2
2	50	8.5	11.9	8.0	10.8
	70	18.6	31.8	34.1	44.2
	10	24.4	1.7	-3.8	3.6
3	30	12.8	16.9	29.1	19.7
	50	13.5	25.1	50.7	50.2
	70	8.7	21.5	30.8	54.1



(a) Seismic wave No.1



(b) Seismic wave No.2



(c) Seismic wave No.3

Fig.2 Influence curves of s-wave uncertainty on seismic acceleration peak

3.2 Influence on the Seismic Duration

The influences of the shear wave uncertainty, corresponding to different input seismic wave and thickness of silt, on the duration are shown in Table 3.

From the table, we can see that:

(1) Any change in the s-wave velocity can make the seismic duration increased or decreased randomly. When the s-wave velocity diminishes, the increase probability, the decrease probability and the unchanged probability in the seismic duration are 50.0%, 43.7% and 6.3% respectively. When the s-wave velocity rises, the increase probability, the decrease probability and the unchanged probability in the seismic duration are 33.3%, 56.3% and 10.4% respectively.

(2) The s-wave velocity uncertainty can make the seismic

duration decreased within the range of -0.2% to –30.4% (average –12.3%) and increased within the range of 0.8% to 77.1% (average 21.0%). The probability is 71.0% that the overall varying range is less than 20.0%(including positive and negative values). Therefore, the decreased range of seismic duration is a bit closer to the increase range, mostly less than 20.0%.

(3) To different seismic input the influence of s-wave velocity uncertainty on duration present a similar law.

Table 3 Comparison results of seismic duration with that is gained according to norm s-wave velocity

3-a

Seismic wave	Depth (m)	Relative difference of s-wave velocity(%) -40	-30	-20	-10
1	10	-22.1	-3.8	0.0	-28.5
	30	10.0	-3.7	0.0	-8.8
	50	37.5	36.6	23.9	33.0
	70	8.2	24.0	11.2	10.0
2	10	-14.4	-15.2	-11.7	-11.3
	30	10.3	-11.1	-7.1	-3.8
	50	59.0	35.4	37.3	10.6
	70	53.2	30.9	27.7	10.4
3	10	1.3	-6.8	-10.4	-28.7
	30	-20.0	0.8	4.0	-20.0
	50	-1.0	-28.4	-20.7	11.7
	70	77.1	41.6	-10.0	0.0

3-b

Seismic wave	Depth (m)	Relative difference of s-wave velocity(%) 10	20	30	40
1	10	-4.6	-5.9	-5.9	-6.9
	30	-15.1	-14.2	0.0	-30.4
	50	21.4	10.7	10.7	10.7
	70	-0.5	-16.9	-16.9	-1.6
2	10	-0.2	0.0	0.0	0.0
	30	-18.8	-17.6	3.2	-14.2
	50	15.7	15.5	19.7	19.7
	70	-9.8	-18.3	-5.7	-5.7
3	10	-28.7	-10.4	-7.2	-10.6
	30	-16.6	1.9	-20.2	0.0
	50	2.7	2.5	-0.8	-0.8
	70	41.1	26.1	29.5	25.3

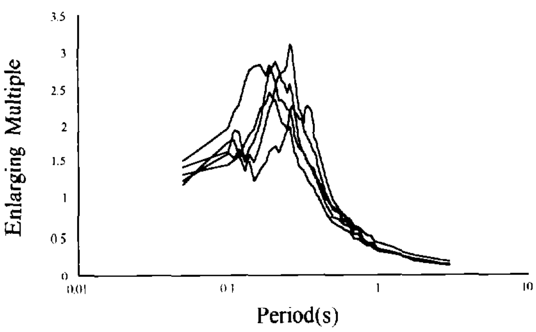
3.3Influence on the seismic spectrum

The influences of the shear wave uncertainty, corresponding to different input seismic wave and thickness of silt, on the seismic spectrum are as follows (as shown in fig.3):

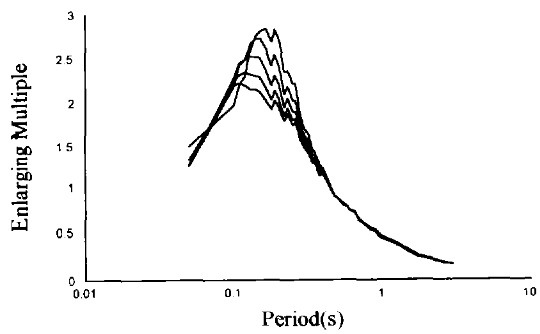
(1) The decrease in the s-wave velocity has considerable influence on the long-period seismic response spectrum. The increase in the s-wave velocity has considerable influence on the moderate-period and short-period seismic response spectrum, but with the depth of silt layers increased, it imposes on the long-period seismic response spectrum gradually. By comparison the decrease in the s-wave velocity have greater effect on the seismic spectrum than the increase in the s-wave velocity.

(2) With the depth of silt layers increased, the s-wave velocity uncertainty imposes on the entire seismic response spectrum gradually.

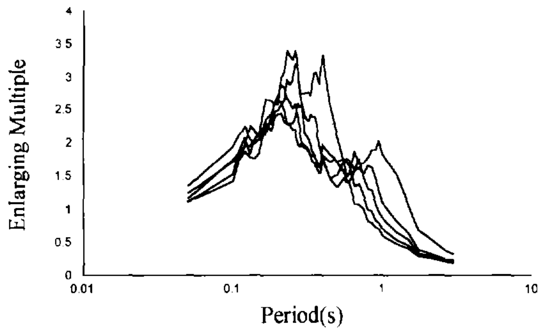
(3) To different seismic input the influence of s-wave velocity uncertain on the seismic response spectrum present a similar law.



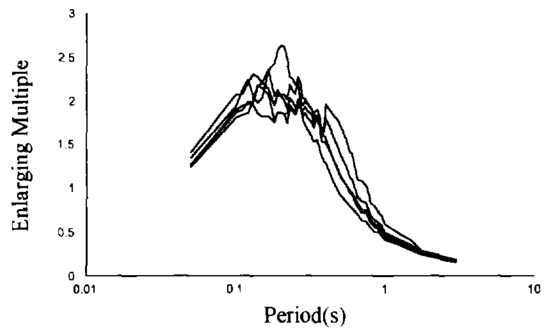
(a) Wave No.1, H=10m,negative s-wave difference



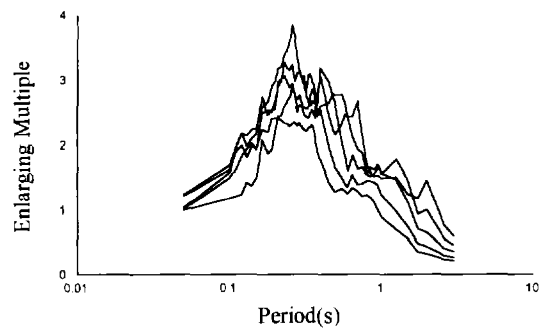
(b) Wave No.1, H=10m,positive s-wave difference



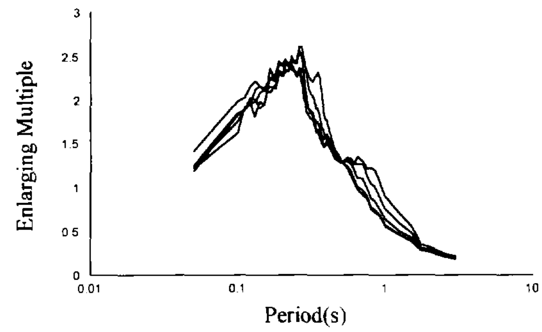
(c) Wave No.1, H=30m,negative s-wave difference



(d) Wave No.1, H=30m,positive s-wave difference



(e) Wave No.2, H=30m,positive s-wave difference



(f) Wave No.3, H=30m,positive s-wave difference

Fig.3 Influence curves of the s-wave velocity speed uncertainty on the seismic response spectrum

4 CONCLUSION

Shear wave velocity is an important dynamic parameter. It can be obtained by in situ measurement. However, due to the difference of measuring method and apparatus there exist evident uncertainty. To different seismic input, the standard shear modulus ratio, damping ratio and variety law of s-wave in depth are taken. The influence of shear wave velocity uncertainty, corresponding to different depth, on the silt seismic response based on the silt ground seismic response calculation are as follows:

(1)The relationship between the difference of seismic acceleration peak and the difference of s-wave velocity is linear approximately. The seismic acceleration peak is also decreasing with the s-wave velocity decreasing, and vice versa.

(2) The seismic acceleration peak varies with the s-wave velocity uncertainty generally in the range of more than 10.0%. The seismic duration varies with the s-wave velocity uncertainty generally in the range of less than 20.0%.

(3)The decrease in the s-wave velocity has considerable influences on the long-period seismic response spectrum. Conversely, the increase in the s-wave velocity has considerable influences on the moderate-period and short-period seismic response spectrum. As the depth of silt layers increased, the influence of the s-wave velocity uncertainty on the seismic response spectrum rises.

(4) To different intensity seismic region, the influences of s-wave uncertainty on the seismic response present the similar law.

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