Preliminary Study on In-Situ Test for Testing Operation Error for Shear Wave Velocity at Class III Site

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Abstract. A special in-situ test for shear wave velocity at class III site is conducted in the given borehole by three professional groups using the same suspension logging apparatus. Testing operation error for shear wave velocity and its effect on ground motion with different intensity are investigated. The main conclusions are as follows: (1) the testing operation error for shear wave velocity exists objectively. The testing data in this paper indicate the error is independent on burying depth and the maximum value of error is less than 20%; (2) when the amplitude of input acceleration is not more than 0.2g, the effect for testing operation error on ground motion can be ignored. However, when the input acceleration is larger, this effect becomes larger and should be recognized and examined carefully.

1. Introduction

Shear wave velocity is an important parameter of soils on the site. In situ shear-wave velocity test has become one of the most common tests in civil and environment engineering. Because the testing results are intuitive and convenient to use, shear wave velocity is popularly applied to solve practical engineering problems.

For any physical quantity, there is a certain degree of deviation in the test results. For the physical quantity of shear wave velocity for soils, though all the tests are carried out according to the testing code, the workers and apparatus, method, etc. used in the tests are different. Those factors can still lead to shear wave velocity testing errors. In geotechnical earthquake engineering, shear wave velocity is not an isolated parameter, therefore testing errors for shear wave velocity of soils can directly influent some analysis results relate to ground motion. Furthermore, currently, the testing results of shear wave velocity for soil layers at a given field are used to judge site classification or evaluate site effects in a determinate way rather than considering to the uncertainty of shear wave velocity. When a field's conditions are critical, the uncertainty of the testing results can enlarge the influence on the evaluation results that are based on shear wave velocity. Therefore, testing errors for shear wave velocity are important branch in geotechnical engineering. At present, researchers at home and aboard have some accomplishments on discretization for shear wave velocity [1-5]. The main findings are focused on the relationship between shear wave velocity and burying depth or soil classification, which can evaluated the shear wave velocity of soil layers that are difficult to directly carry out the tests in-situ. CHEN [4] designed the special experiment of shear-wave velocity testing error, then systematically analyzed the results and got some new findings. He carried out the distribution of the testing error and made an evaluation on it. By using the real test error of the shear wave velocity, the impact on ground motion at different intensity had also been figured out.

Though previous studies on discretization for shear wave velocity have been accomplished, few investigations on testing operation errors and its effect on ground motion have been reported. Testing operation error is recognized as part of testing error for shear wave velocity in this paper. Influence of operation factor is inherent during the tests for shear wave velocity, which is a domain source to produce testing errors. For a given field and testing conditions (such as given workers, measuring apparatus, environments, etc.), testing operation error is a large part of testing errors, which has more influence on the accuracy and reliability of shear wave velocity. In addition, previous studies on effect of testing errors for shear wave velocity on ground motion had used artificial error, rather than using testing data obtained from real parallel tests. Those assumed cases are different from the real ones. Therefore, it is necessary and important to carry out special in situ tests for shear wave velocity testing operation errors, and analyze its effect on ground motion.

In this paper, a special in-situ test for shear wave velocity at class Ⅲ site is conducted in the given borehole by three professional groups using the same suspension logging apparatus. On the basis of the triplicate testing results, distribution laws of testing operation error for shear wave velocity, relationship between testing operation error and burying depth are analyzed. In addition, the effect for this error on ground motion under different intensity is investigated. This work can provide the experimental basis and new understandings on testing operation error for shear wave velocity, which is also an important part of further study on testing error for shear wave velocity and its effect on ground motion in advance.

2. Test design

At present, it is the fact that more and more buildings are constructed at class Ⅲ site, however, few investigations on shear wave velocity at class Ⅲ site has been reported. Otherwise, limited by the costs, in-situ conditions, measure apparatus, etc., single-borehole based method is the most popular and sophisticated approach for measuring shear wave velocity of soils in practice engineering. Consider to the mentioned above, the in-situ test is designed and carried out at class Ⅲ site ,and the shear wave velocity is measured by single-borehole based method

The shear wave velocity in-situ test is carried out in a class Ⅲ site in southwest plain area of Shandong province, east of China. In this area, having deep quaternary system strata, the main overlying geological layers include holocene(Q_4) and part of pliocene, miocene series(Q_{2+3}) sediments. The designed depth of the survey hole is 80m. In the range of survey depth, the soil layers mainly consist of clay, silt clay, sand, etc., which are the common soils by engineering classification standard. Single-hole based method is used to test shear wave velocity of soil layers in situ. The apparatus of measurement for shear wave velocity is XG-I typed suspension logging instruments, made in china. In this method, the probe in which the seismic source and the geophone are incorporated in a series serves to exert pressure on the borehole wall via the borehole water; furthermore this innovative system functions to measure the propagation velocities of P wave and S wave by detecting the behavior of the borehole water through the geophone of floating type. In the in-situ test, to avoid possible influents on the shear wave measurements, strict operation and quality-controlled measures are carried out to improve the quality of borehole. After the borehole constructions, three groups use the same apparatus (XG-I typed suspension logging instruments), test the shear wave velocity of soil layers in the given borehole (i.e. having the same testing environments and conditions) respectively. In the groups, all the testing workers are professionally trained and do the test according to the code and user's manual for shear wave velocity measurements. So, the testing results can reflect the influence on the testing operation error. Three testing results in the in-situ test for shear wave velocity are respectively named 1st test, 2nd test, and 3rd test in this paper.

3. Test analysis

3.1 Testing results

In this in-situ test, three testing results of shear wave velocity are illustrated in Fig.1, which all indicate that the shear wave velocity increase with depth gradually. The dependence tangencies of velocity and burying depth are similar and consist with the current knowledge of shear wave velocity of soils. These primary data analyses also indicate that the test is successful and reliable, which can be used to do further research on testing operation error.

It is found that when the depth is 70m, the shear wave velocity has reached 500m/s. This result means that the soil become hard enough and is recognized as rock in the view of engineering. Furthermore, we found that, in every test, the values of shear wave velocity are lightly different from each other at the given depth measuring point. Triplicate testing results are similar, which also illustrate that the test is successful and reliable. Because the three tests are carried out in the same borehole and using the same apparatus by different professional workers, triplicate testing data indicate that the testing operation error of shear wave velocity exists objectively.

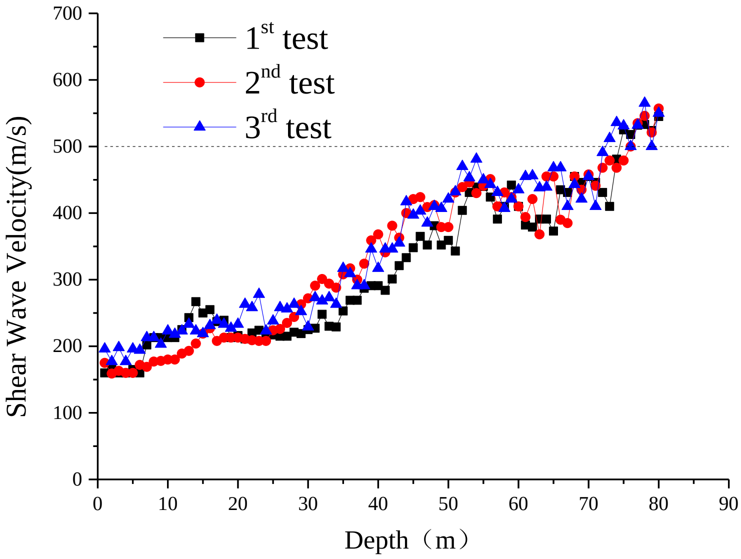


FIGURE1. Triplicate testing results for shear wave velocity in the in-situ test

3.2 Analysis for testing operation error

The value of shear wave velocity of soil layers are obtained from the arithmetic mean value of triplicate testing results. In every case, the testing operation error at the give depth is defined as formulas 1 in the paper.

$$e = \frac{\left|v_{s,i} - v_{s,mean}\right|}{v_{s,mean}} \qquad (1)$$

Where, e: testing operation error of shear wave velocity at the given depth; $v_{s,i}$: shear wave velocity of soil layer at the given depth in the test; $v_{s,mean}$: the mean shear wave velocity of soil layer at the given depth.

The calculated testing operation errors for the triplicate tests are showed in Fig.2. Compared with the relationship of depth and shear wave velocity, we found that the testing operation error is random and independent with burying depth. In addition, the range of the testing operation error value is 0~20%, which consist with the findings of other researchers [4].

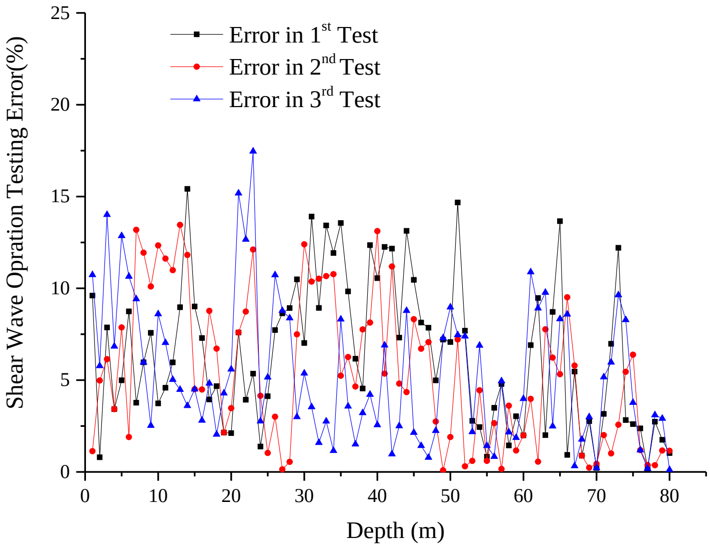
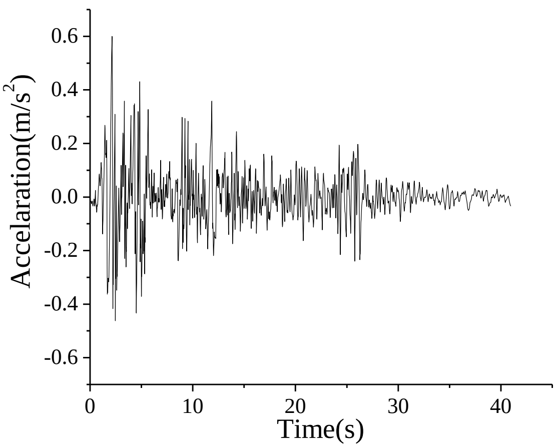


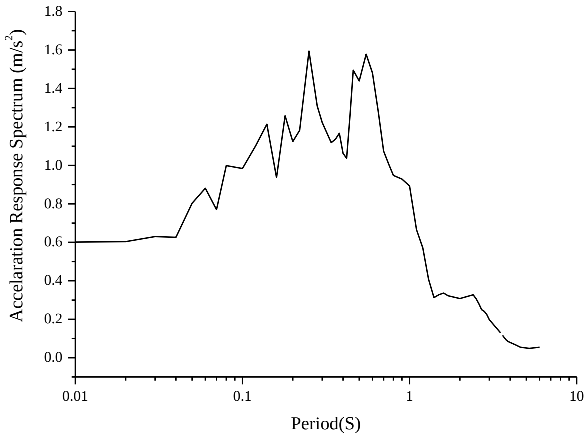
FIGURE2. Testing operation error for shear wave velocity in the in-situ test

3.3 Analysis for testing operation error effects on ground motion

As mentioned above, shear wave velocity is not an isolated parameter in earthquake engineering, which is an important parameter in seismic response analysis of soil layers. It is necessary to analyse the effect of testing operation error for shear wave velocity on ground motion. At present, LSSRL-1 is the most popular Program used in seismic response analysis of soil layers in China mainland, which is also the proposed program for seismic safety evaluations [6]. Therefore, this program is selected to calculate effect of testing operation error on ground motion. In any simulated case, the dynamic shear modulus ratio and damping ratio should be fixed, so the results can only reflect the effect of shear wave velocity for testing operation error on ground motion. EI-Centro earthquake wave, shown in Fig.3 (a), is commonly applied in earthquake engineering. The acceleration response spectrum of this earthquake wave, illustrated in Fig.3 (b), indicates a wide range of frequency. Obviously, EI-Centro earthquake wave is an ideal selection of input acceleration in the analysis for effect of testing operation error on ground motion. In order to satisfy the different intensity of ground motion, in the seismic response analysis, the maximum amplitude of the acceleration is modified in proportion as 0.05g, 0.10g, 0.20g, 0.40g, which are corresponding to VI, VII, VIII, IX anti-seismic design intensity respectively in Chinese code for seismic design of buildings[7].



（a）EI-Centro earthquake wave



（b）Acceleration response spectrum

FIGURE 3. EI-Centro earthquake wave and its acceleration response spectrum

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Based on the testing results for shear wave velocity, three different one-dimensioned models for seismic response analysis of soil layers are established. The calculated results of seismic response analysis of soil layers, expressed in acceleration spectrum, under input acceleration with amplitude of 0.05g, 0.10g, 0.20g and 0.4g, are illustrated in Fig.4. Some findings are obtained as follows: (1) under the same input acceleration, the calculated results based on the three models are different from each other, which indicate the testing operation errors can produce effect on ground motion. (2)The difference between the calculated results based on the three models becomes larger with the increasing amplitude of input acceleration. (3) When the amplitudes of acceleration are 0.05g，0.10g and 0.20g, the effect of testing operation error for shear velocity on ground motion can be ignored. However, when the amplitude of input acceleration is 0.40g，this effect is too large to be ignored. Though the method of seismic response analysis of soil layers can influent the final simulated results, the method is a deterministic one in the evaluation of local site effect for a given field. Therefore, when the input acceleration is strong, the effect of testing operation errors for shear velocity on ground motion should be recognized and examined carefully.

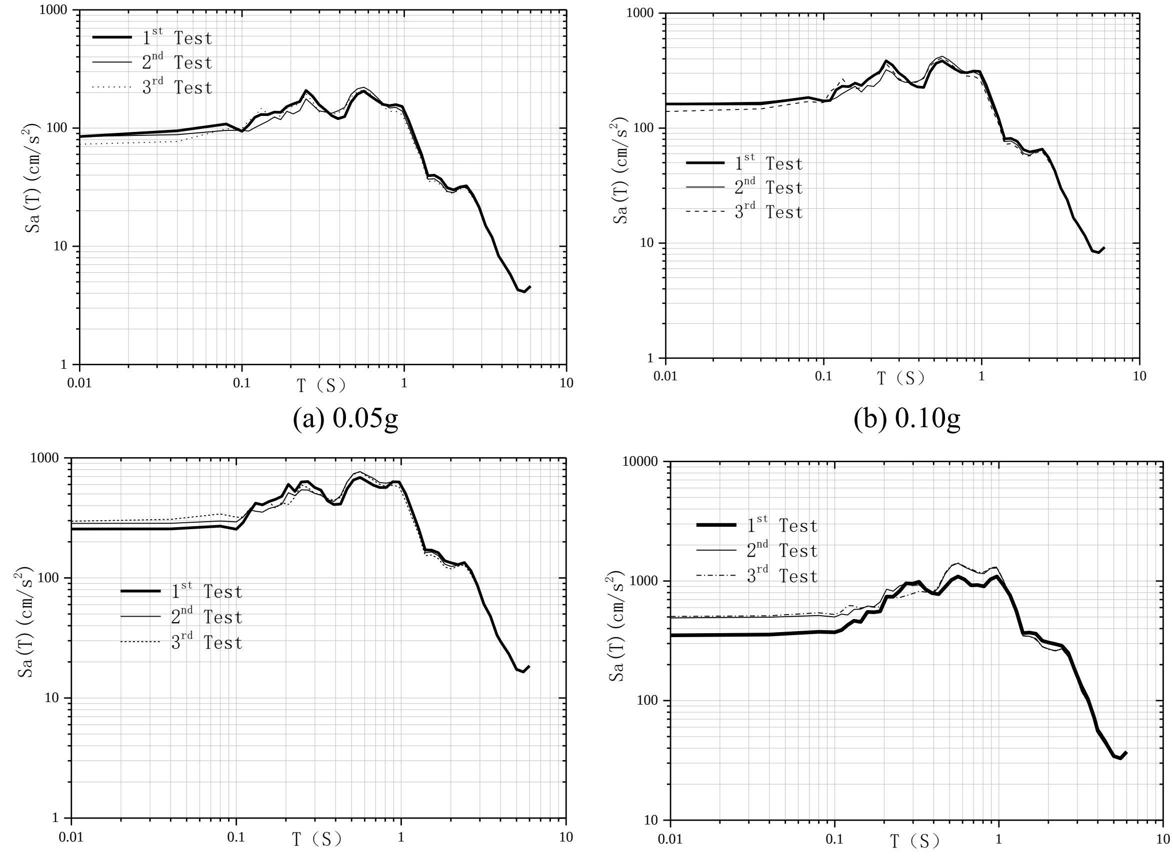

FIGURE 4. Effects for testing operation error on ground motion under different intensity of input acceleration

4. Conclusion

A special shear wave velocity in-situ test at class III site was conducted in the given borehole by three professional groups using the same suspension logging apparatus. On the basis of the testing results, investigations on testing operation errors and its effect on ground motion have been done. The main conclusions are as follows: (1) the testing operation error for shear wave velocity exists objectively. This error is independent on burying depth and the maximum value of error is less than 20%; (2) when the intensity of input acceleration is not more than 0.2g, the effect for testing operation error on ground motion can be ignored. However, when the input acceleration is larger, this effect becomes larger and should be recognized and examined carefully. (3) In the future study, more in situ tests for shear wave velocity should be designed and conducted to improve the investigations on testing operation error and its effect on ground motion in this paper.

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