Effect of Vibrating and Sieving Time on the Reliability of Test Results for Gradation Analysis of Fragile Geomaterials

Chao Yang[1,a*], Shuguang Liu[2,b], Sikai Bai[1,3,c]

[1]School of Civil Engineering and Architecture, Wuyi University, Jiangmen Guangdong 529020, P.R.China
[2]CCCC Highway Consultants Co., Ltd., Beijing 100010, P.R.China
[3]Tianjin Port & Channel Engineering Co., Ltd.Tianjin 300457, P.R.China

[a]*89733609@qq.com, [b]*158126344@qq.com, [c]*731802628@qq.com

Abstract. The vibrating and screening is easy to break the particles of brittle geomaterials, which is difficult to obtain real gradation and also brings difficulties to engineering guidance. In order to find out the reliability of the vibrating and sieving method for testing the gradation of fragile geomaterials, the vibrating and sieving test of different time was carried out with coral sands. The results show that the vibrating and sieving time has a great influence on the gradation of coral sands. And the quality of the each particle group coral sands changed considerably in the first 25 minutes, and the changes slow down after 25 minutes of vibrating and sieving. Except for coral sands with particle diameters of 10 ~ 20 mm and 1 0.25 ~ 0.5 mm, coral sands with other particle diameters shared a significant change in the vibrating and sieving test. The characteristic particle diameters of coral sands also change most greatly in the first 25 minutes of of vibrating and sieving. The non-uniformity coefficient C_u and curvature coefficient C_c are changed the most in the first 10 minutes of vibrating and sieving, and then the non-uniformity coefficient C_u continues to increase, but the curvature coefficient C_c is basically unchanged. Vibrating and sieving continually change the particle size of coral sands, which will cause its gradation to constantly recombine and its properties to constantly change. The reliability of the test results decreases with the vibrating and sieving time.

Keywords: fragile geomaterials; vibrating and sieving; particle breakage; gradation analysis; reliability

1 INTRODUCTION

The gradation has an important effect on the engineering properties of geomaterials. It is also one of the important contents of the analysis of engineering properties of geomaterials. Particle gradation has an important effect on the permeability properties[1-3], compression properties[4-6], mechanical properties[7-10] and other aspects of geomaterials[11-15]. The deformation and destruction of soil are caused by the sliding, tumbling,

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embedding, pulling out and breaking of contact points among particles[1]. Vibrating and sieving is one of the common means to test the particle gradation in the geotechnical test, especially in particle analysis testing of coarse-grained soils. When vibrating and sieving is used to test the particle gradation of friable geomaterials, sliding, tumbling and collision of the particles in the sieve mesh will inevitably lead to the occurrence of such phenomena as particle abrasion, fracture of the particles tip, and even the overall crushing of the particles, etc. The particle breakage that occurs during the testing will reduce the size of the larger particle and increase the content of the small particle. It will affect the particle composition of the friable geomaterial. The particle breakage in the vibrating and sieving test will affect the accuracy of the test results. The reliability of test results and the accuracy of test indexes are affected. If the gradation of crushed geomaterials is used to analyze its engineering properties such as permeability, compression and mechanical properties, there will be some errors in the results and wrong conclusions may be drawn. It may incorrectly guide the construction of geotechnical engineering, especially the construction of filling engineering. And it may further cause serious consequences to the safety and use of the engineering. In addition, the gradation of aggregates is also an important factor affecting the design of concrete mix proportion. Improper aggregate gradation will affect the mix proportion of concrete with friable aggregate, which affect the filling effect and mechanical properties of concrete with friable aggregate. It is of great significance to find out the influence of vibrating and sieving on the particle composition of fragile geomaterials, which is conducive to improving the reliability of the particle gradation test results and to correctly analyze and evaluate the engineering properties of fragile geomaterials and guide the project filled and tamped with fragile geomaterials.

In this paper, the characteristics of particle breakage may occur in the vibrating and sieving of fragile geomaterials. The distribution characteristics of each particle group during particle gradation are obtained by analyzing the vibrating and sieving method. And according to this, it is analyzed the characteristics of particle breakage and gradation changes of various particle sizes during the vibrating and sieving. The influencing factors of particle gradation can be obtained by vibrating and sieving method, and the appropriate vibrating and sieving time is proposed for specific projects. It is beneficial to obtain a suitable particle gradation analysis method for fragile geomaterials. And it is of great significance for how to correctly obtain the distribution and gradation index of fragile geomaterials in specific projects and guiding the engineering construction.

2 EXPERIMENTAL MATERIALS AND METHODS

It is necessary to select the easily available and common geomaterials as the test objects to find out the effect of vibrating and sieving on the reliability of the test results of the grading analysis of brittle geomaterials. Coral sands with high $CaCO_3$ content was selected as the experimental material to find out the effect of the vibrating and sieving method on the test results of the particle composition of fragile geomaterials.

Coral sands is a material with special properties such as porous, irregular shape, easy to break and easy to cement[16, 17]. It is widely distributed in the continental shelf and along the coastline in tropical or subtropical climates between 30° N and 30° S latitude; and it is a common geomaterial in there. Coral sands is a typical friable geomaterial. It is very appropriate to use coral sands to analyze the effect of vibrating and sieving on the results of gradation analysis tests of brittle geomaterials. The vibrating and sieving experiments were carried out by a standard geotechnical sieve with a diameter of 300mm and electric vibrating sieve. The electric vibrating sieve has a sieving frequency of 221 times per minute and a vibrating frequency of 147 times per minute. And the analysis of the test results of coral sands particle gradation by vibrating and sieving method is beneficial to find out the effect of vibrating and sieving method on the particle gradation results of fragile geomaterials.

2.1 Experimental Materials

The $CaCO_3$ content of the coral sands selected in this vibrating and sieving experiment is as high as 80%, and the maximum grain length is not more than 20cm, but it's less abundant. The shape of the coral sands particles is irregular and sharp(Figure 1). Their forms are mainly in block, dendritic, flat and so on. The specific gravity of coral sands is 2.772; the maximum pore ratio is 1.31; the minimum pore ratio is 0.82. The limited particle diameter D_{60}, average particle diameter D_{50}, median particle diameter D_{30} and effective particle diameter D_{10} are as follows: 2.75mm, 2.23mm, 0.57mm and 0.13mm. Particle analysis test results show that the non-uniformity coefficient C_u is 21.15; and the curvature coefficient C_c is 0.91.

Fig. 1. Coral sands particle shape in vibrating and sieving experiments

2.2 Experimental Methods

In order to analyze the effect of different vibrating and sieving time on the distribution characteristics of grain group, 14 vibrating and sieving times were used in this experiment. The vibrating and sieving time was as follows: 5min, 10min, 15min, 20min, 25min, 30min, 35min, 40min, 45min, 50min, 55min, 60min, 65min, 70min. Coral sands sample was 506.49g in this experiment. Firstly, the samples were manually sieved with the geotechnical sieve, and the action should be light to prevent particle fragmentation. Standard geotechnical sieves were stacked from top to bottom according to 10mm, 5mm, 2mm, 1mm, 0.5mm, 0.25mm, 0.075mm sieve holes. After the manual sieving was completed, the coral sands in the sieve with each aperture was weighed; It was taken as the initial grain group content to facilitate the later comparative analysis. Then, the coral sands from each grain group was carefully and lightly placed back into the original geotechnical sieve. After 5 minutes of each vibrating and sieving, the sieve was removed successively, and the quantity of coral sands on the sieve with each aperture was weighed to obtain out the characteristics of the particle grade distribution of coral sands with different vibrating and sieving time. Coral sands is vibrated and sieved until the total vibrating and sieving time reaches 70 minutes. Loss of coral sands due to manual handling should be avoided each time， when the coral sands was weighed and loaded into the geotechnical sieves.

3 ANALYSIS RESULTS OF CALCULATIONS

3.1 Gradation Curves at Different Vibrating and Sieving Times

The gradation curves of the coral sands were obtained after undergoing different vibrating and sieving times (Figure 2). Coral sands quality of the intermediate particle diameter *D*50 changed obviously as the vibrating and sieving time increased. Particle collisions during vibrating and sieving result in the realignment of the particle gradation of coral sands. The characteristic particle diameter of coral sands changes greatly due to particle fragmentation. The changes of gradation characteristics of coral sands will cause the changes of the permeability characteristics, compression characteristics, mechanical properties and other aspects of geomaterial characteristics of coral sands.

Overall, the shape of coral sands gradation curves of each vibrating and sieving time are basically the same. Particle collisions during vibrating and sieving result in fracture and abrasion of coral sands particles tip and particle surfaces, and the particle diameter changes slightly. The qualities of coral sands particles with larger particle diameter have little change as the vibrating and sieving time increased, but the qualities of coral sands with smaller particle diameter varies greatly. For example, the qualities of coral sands with particle diameters of 1-2mm, 0.5-1mm, 0.25-0.5mm, and 0.075-0.2mm varies greatly in different vibrating and sieving time. Particle crushing caused by vibrating and sieving mainly affected the coral sands content of the intermediate particle diameter group. Characteristic particle diameters of coral sands are greatly affected by particle breakage.

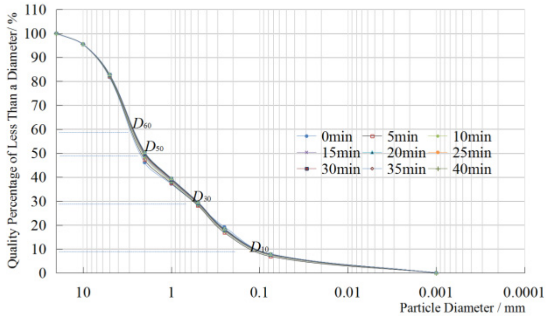
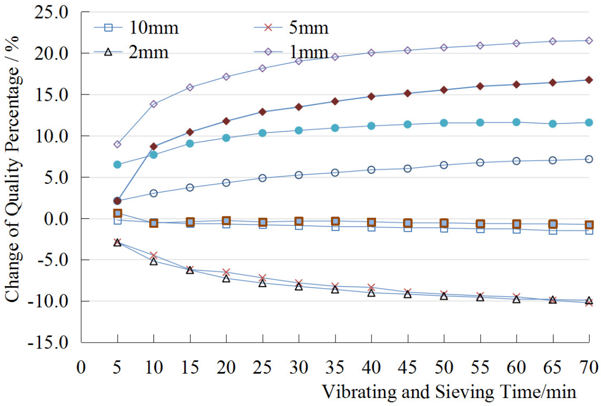


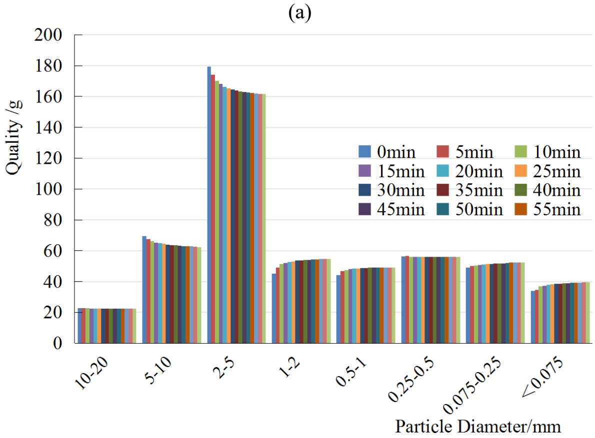
Fig. 2. Gradation curves of coral sands with different vibrating and sieving time

3.2 Effect of Vibrating and Sieving Time on the Quality of Particle Group

In order to analyze the effect of vibrating and sieving time on the gradation of coral sands, the quality change characteristics of each particle group coral sands with vibrating and sieving time were analyzed. The effects of vibrating and sieving time on coral sands of different particle groups are very different, and the effect times are different. Throughout the first 25 minutes of the vibrating and sieving process, the quality of the coral sands changed considerably in each particle group, especially in the coral sands with particle diameters of 5-10 mm, 2-5 mm, and 1-2 mm, 0.5-1 mm, 0.75-0.25 mm, less than 0.75 mm.



(a)



(b)

Fig. 3. The changes of coral sands quality in each particle group with different vibrating and sieving time

After 25 minutes of vibrating and sieving, the quality of coral sands of each particle group continued to change, but the amount of change gradually diminished. Therefore, the particle breakage of coral sands is most intense in the first 25 minutes of the vibrating and sieving process. The violent collision of coral sands particles in the first 25 minutes caused the particles tip of the coral sands to break, and then the collision mainly caused abrasion of coral sands particles. The characteristics of quality change of coral sands in each particle diameter group show that the quality of smaller coral sands increases due to the fragmentation of coral sands particle with larger diameter. The qualities of coral sands with particle diameters of 10-20 mm, 5-10 mm, 2-5 mm, 0.25-0.5 mm are decreased, while the qualities of coral sands with particle diameter of 1-2 mm, 0.5-1 mm, 0.75-0.25 mm, less than 0.75 mm are increased.

The main reason is that the coral sands particles in the initial form are irregular and multi-pointed, and the strength of the particles is low and easy to break, so the vibration collision in the early stage of vibrating and sieving causes the particles tip of the particles to break. The breakage of coral sands particles at the tip reduces the particles diameter and transfers it into other particle groups. This results the coral sands quantity of the original particle group decreased, and other particle groups increased. Larger diameter particles have a heavier quality. The amount of coral sands with particle diameter of 10-20 mm is small, and the collision can not break the coral sands particles. The overall amount of coral sands broken in the vibrating and sieving test for this particle diameter is small. Particle quantity of coral sands with particle diameter of 10-20 mm has little change in the vibrating and sieving test.The quality change of coral sands with this particle diameter mainly occurred in the first 10 minutes of vibrating and sieving (Figure 3). The particle quantity of coral sands with particle diameter of 0.25-0.5mm also has little change in the vibrating and sieving test. The reason is that the particles tip of the large particle diameter coral sands are broken and transferred into this particle group, and the coral sands particles of this particle group are broken or abrased and transferred into the smaller diameter particle group.

3.3 Effect of Vibrating and Sieving Time on the Characteristic Particle Diameters

Gradation curves have shown that the characteristic particle diameters of coral sands change with the increase of vibrating and sieving time (Figure 2). The particle breakage of coral sands results in the change of its characteristic particle diameter. The particle breakage of coral sands is most intense in the first 25 minutes of vibrating and sieving. This also causes the characteristic particle diameter of coral sands to change greatly (Figure 4).

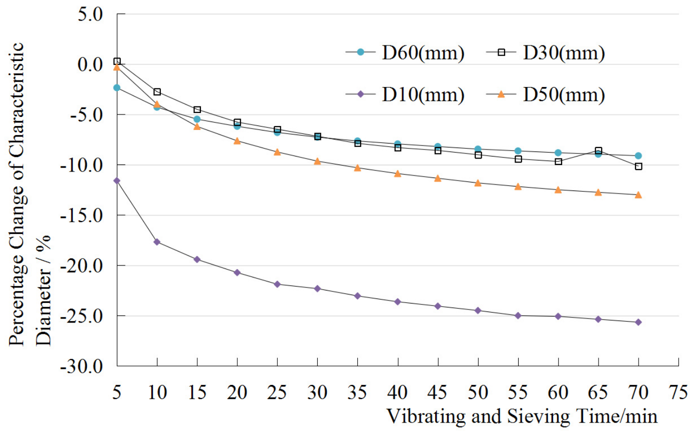


Fig. 4. The changes of characteristic particle diameter with different vibrating and sieving time

After 25 minutes of vibrating and sieving, the percentage change in the diameter of each characteristic particle tended to slow down. The percentage change of the diameter of each characteristic particle is quadratic function with the vibrating and sieving time, and the change trends are basically the same.The effective particle diameter *D*10 changes most significantly; the limiting particle diameter *D*60 changes least; and the median particle diameter *D*30 changes close to the limiting particle diameter *D*60, especially after 25 minutes of vibration. Characteristic particle diameters have a great effect on the engineering properties of soils.

Particle crushing during vibrating and sieving resulted in a recombination of the coral sands particle gradation and the change of the characteristic particle diameter, which affected the physical properties of it. For example, the effective particle diameter *D*10 is directly related to the permeability of soil[18-22], and it also has a great influence on the adsorption capacity of TOC, TN and TP[23] .The effective particle diameter *D*10 of coral sands changes the most in the vibrating and sieving tests, which also directly affects its permeability and other properties.

Table 1. Predictive calculation of the coefficient of permeability of sandy soils[18-22]

Method	Amer	Hazen	Terzaghi	Qian Kun	Zhu Conghui
Predictive calculation	$k = 3.5\times10^{-4}\dfrac{e^3\gamma_w}{(1+e)\eta_T}d_{10}^{2.32}C_u^{0.6}$	$k = Cd_{10}^2$	$k = 2d_{10}^2e^2$	$k = R\dfrac{\eta_{20}}{\eta_T}\cdot 10^e C_cC_ud_{10}^2$	$k = 4eC_cC_ud_{10}^2$

e is the pore ratio; γ_w is he heaviness of the water (kN/m^3); μ_T and μ_{20} are the coefficient of dynamic viscosity of water at T°C and 20°C (kPa·s×10^{-6}); C is the empirical coefficient.

In addition to the fine particle content affecting the properties of sandy soils, the coarse particle content also affects the mechanical and other properties of sands. The coarse particles constitute the skeleton of the soil in sands with a high content of coarse particles, and the fine particles fill in between the interstices of the skeleton. The mechanical and deformation properties of the sands are mainly characterized by the mechanical properties of the skeleton composed of coarse particles. The increase in the content of fine particles causes the fine particles from filling the gaps to filling full the gaps and even wrapped the coarse particles. When coarse particles are covered by fine particles, coarse particles cannot contact directly to form the main force skeleton. So the influence of coarse particles on the mechanical and deformation characteristics of sands is also weakened. Although vibrating and sieving causes less particle breakage in the coarse particles of coral sands than that in the fine particles, its particle diameter still decreases with the continuous vibrating and sieving. Therefore, the reliability of evaluating the engineering properties of coral sands is weakened by the crushed coral sands particle gradation, and it may even lead to false conclusions.

3.4 Effect of Vibrating and Sieving Time on the Gradation Indexs

Gradation index is an important method to evaluate the engineering properties of sands. It is affected by the diameter of the characteristic particle. It is different from the previous analysis results. The non-uniformity coefficient C_u and curvature coefficient C_c are changed the most in the first 10 minutes of vibrating and sieving, and then the non-uniformity coefficient C_u continues to increase, but the curvature coefficient C_c is basically unchanged(Figure 5).

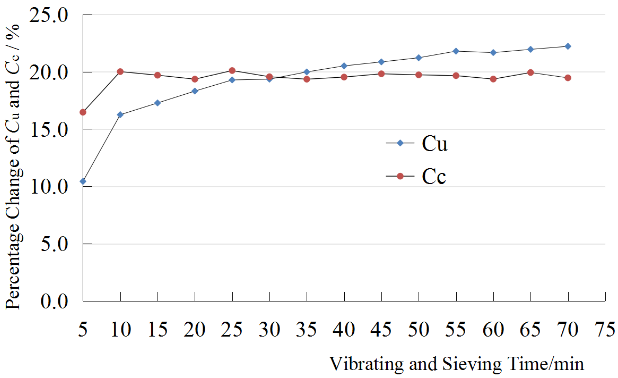


Fig. 5. The changes of gradation indexs with different vibrating and sieving time

The non-uniformity coefficient C_u can reflect the particle diameter distribution of soil. In generally, the non-uniformity coefficient C_u is larger for the wider distribution of particle diameters; and it has the better the engineering properties. Therefore, the particle breakage in the vibrating and sieving continues causes the change of the non-uniformity coefficient C_u, and the permeability properties(Table 1), mechanical properties[24], and other engineering properties of coral sands continue change too. If the results of particle analysis test are used to analyze the engineering properties of coral sands, the analytical conclusions will be wrong. And the error will become more and more serious with the increase of vibrating and sieving time.

4 CONCLUSION

(1)The collision of coral sands particles caused by vibrating and sieving results in the coral sands with smaller particle diameters increased due to fracture of the particles tip and abrasion of the particles surfaces of coral sands with larger particle diameter, and continuous change of the sample gradation curve and gradation characteristics. The shape of coral sands gradation curves of each vibrating and sieving time are basically the same.

(2)The violent collision of coral sands particles in the first 25 minutes caused the particles tip of the coral sands to break, and then the collision mainly caused abrasion of coral sands particles. And the quality of the each particle group coral sands changed considerably in the first 25 minutes. But particle quantity of coral sands with particle diameter of 10-20 mm and 0.25-0.5mm have little change in the vibrating and sieving test. Therefore, when the particle group composition of fragile geomaterials such as coral sands is tested by vibrating and sieving, the content of large particle group is smaller, and the content of small particle group is larger. The reliability of the results is poor.

(3)The particle breakage of coral sands results in the change of its characteristic particle diameter. The characteristic particle diameter of coral sands changes most greatly in the first 25 minutes of of vibrating and sieving. The percentage change of the diameter of each characteristic particle is quadratic function with the vibrating and sieving time, and the change trends are basically the same. The effective particle diameter $D10$ changes most significantly, the limiting particle diameter $D60$ changes least, and the median particle diameter $D30$ changes close to the limiting particle diameter $D60$, especially after 25 minutes of vibration. Therefore, in order to correctly guide the project filled and tamped with fragile geomaterials such as coral sands and to ensure the quality of that, the vibrating and sieving should be adequate, and the vibrating and sieving time should not be less than 25 minutes.

(4)The non-uniformity coefficient C_u and curvature coefficient C_c are changed the most in the first 10 minutes of vibrating and sieving, and then the non-uniformity coefficient C_u continues to increase, but the curvature coefficient C_c is basically unchanged.

(5)Gradation index is an important method to evaluate the engineering properties of sands. Particle breakage changes the particle composition of geomaterials, which affects its permeability, compressibility, mechanical properties and other engineering properties. The combination of crushed geomaterials reduces the reliability of evaluating its engineering properties and it may even lead to erroneous conclusions. Therefore, it is necessary to adopt the appropriate particle composition test method for specific projects in order to correctly guide the construction and evaluate the engineering properties of fragile geomaterials.

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