The effect of conglomerations gradation on engineering properties of loess

Efecto de la gradación de conglomerados en las propiedades de ingeniería de loess

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Abstract

Loess is a kind of common and important building materials in civil engineering. Particle size distribution has a significant effect on loess engineering properties and there are many studies in this filed. Due to the chemical cementation and the molecular attraction in the loess, the particles are usually gathered together and appear in the form of conglomerations. The conglomeration is much larger than the particle and easy to crush. The study on the influence of conglomeration gradation on the engineering properties of loess is relatively less and needs to be enriched. In view of this, the loess samples with different conglomeration gradations are prepared, and the compaction test, compression test and direct shear test are carried out. The test results show that the conglomeration gradation has a certain effect on the maximum dry density and shear strength of loess. But the effect on compression test is not significant. The better loess conglomeration gradation is, the better its engineering properties are. The engineering properties of loess with larger conglomerations are better than those with smaller conglomerations. The reason is related to the breakage of loess conglomerations after loading. The test samples are also observed by stereomicroscope, and the results of mesoscopic observation are consistent with the macroscopic phenomena. Therefore, reasonable adjustment of loess conglomeration gradation is beneficial to obtain better engineering properties.

Keywords: Loess, conglomeration gradation, compressive deformation, shear strength, mesoscopic observation.

Resumen

Loess es un tipo de materiales de construcción comunes e importantes en la ingeniería civil. La distribución del tamaño de partícula tiene un efecto significativo en las propiedades de ingeniería de loess y hay muchos estudios en este terreno. Debido a la cementación química y la atracción molecular en el loess, generalmente las partículas se reúnen y se aparecen en forma de conglomerados. El conglomerado es mucho más grande que la partícula y también más fácil de triturar. El estudio sobre la influencia de la gradación de conglomerados en las propiedades de ingeniería de loess es relativamente menor y es necesario enriquecer. En vista de esto, se prepara las muestras de loess con diferentes graduaciones de conglomeración, y se lleva a cabo la prueba de compactación, la prueba de compresión y la prueba de corte directo. Los resultados de las pruebas muestran que la gradación de conglomeración tiene un cierto efecto sobre la densidad seca máxima y la resistencia al corte de loess. Sin embargo, el efecto en la prueba de compresión no es tan significativo. Cuanto mejor sea la clasificación de la aglomeración de loess, mejor será el rendimiento de ingeniería. Las propiedades de ingeniería de loess con agregados más grandes son mejores que aquellas con agregados más pequeños. La razón está relacionada con la ruptura de los agregados de loess después de la carga. La muestra de prueba se observó con un microscopio estereoscópico, y los resultados de la observación mesoscópica fueron consistentes con el fenómeno macroscópico. Por lo tanto, un ajuste razonable de la clasificación de aglomeración de loess es propicio para un mejor rendimiento de ingeniería.

Palabras clave: Loess, conglomerado gradación, deformación en compresión, resistencia a la cizalladura, observación mesoscópica.

Introduction

It is generally known that soil is a soft material composed of mineral or rock fragments. Because soil is formed under various environmental conditions, its engineering characteristics are complex and changeable. In the engineering construction, back and dredger fill soil will be often encountered. In order to improve engineering properties, the soil is usually compacted to make it forming density frame. The strength of compacted soil can be increased with the increases of maximum dry density, and the settlement and permeability of the soil can be decreased at the same time. Mitchell, Hooper, & Campenella (1965) studied the effects of molding water content, density, degree of saturation, method of compaction, and thixotropic hardening on the permeability of compacted silty clay. Hao, Wang, & Wang (2019) investigated the structural properties of compacted loess by focusing on the influence of structural changes incurred by varying sample moisture content on stress-strain characteristics of unsaturated compacted loess and is of great significance for evaluating the engineering quality of compacted loess. In laboratory study, the compaction test is usually conducted to investigate compaction characteristics and simulate compaction conditions at the construction site. The compaction effect is affected by many factors, including water content, compaction energy and soil properties. Seed, Mitchell, & Chan (1961) pointed out that the soil composition has a primary influence upon the strength of compacted clays. From the properties of soil, compaction effect is related to soil particle size, gradation, mineral composition and so on. In these factors, the particle size distribution of soil has great influence on the compaction performance (Zeng, 2009). At the same time, the particle size distribution of soil also affects its compression and shear performance, which has an important impact on the settlement of building foundation, the stability of retaining wall and other related practical projects (Lemus, Moraga, & Lemus-Mondaca, 2017).

The particle size distribution refers to the relative content of each fraction contained in the soil, as a percentage of the total weight of particles. For the sake of intuition, the particle distribution curve is usually used to represent the distribution of particles. The uniformity of particle size in soil can be evaluated by curve shape. In engineering construction, uniformity coefficient and coefficient of gradation are used to reflect the uneven degree of the particle size distribution of soil. The uniformity coefficient reflects the distribution of different particle groups, and the coefficient of gradation describes the overall shape of the particle size distribution curve of soil, indicating whether there is a missing particle group.

Many scholars have studied the impact of material particle size on its engineering performance. Li, Wu, Liang, Xu, & Zhao (2018) found that the microscopic characteristics of soil samples (such as pore size distribution, particle size, inter-particle spacing, connection mode and density) have great influence on the macroscopic behaviors of loess. Guo (1998) found that the engineering properties of coarse-grained soils depend on the percentage of coarse and fine materials. The influence of fine grain content and dry density of two kinds of coarse-grained soil on the shear strength parameters and the variation of shear strength parameters were studied by direct shear test by Li & Xing (2006). Tao, Peng, Xiao, Wu, & Chen (2019) studied the changes of microscopic pore of numerical simulation and that of physical experiment during compression of clay. Ling, Fu, Han, & Wang (2010) studied the effects of particle size distribution and particle breakage on the static and dynamic characteristics of rockfill. Mitchell, Singh, & Campanella (1969) supported the hypothesis that the interparticle contact is the only significant region between soil grains where effective normal and shear stresses can be transmitted. Thus a more accurate micro explanation is given. This helps to better explain the macroscopic mechanical laws of loess from a microscopic perspective. Cai, Li, Han, & Guan (2016) studied the critical state of rockfill in consideration of gradation and particle breakage. Marachi, Chan, & Seed (1972) have studied the influence of different scales of gradation on the strength of rockfill. Marsal (1973) & Hardin (1985) respectively put forward the index parameters to describe the degree of particle breakage. Kokusho, Hara, & Hiraoka (2004) studies the undrained shear strength of soils with different particle sizes. The effects of particle size matching on shear strength of unsaturated sand were reviewed by Bayat, & Bayat (2013). Hu, Yeung, Lee, & Wang (2001) found that the variation of shear strength is directly related to the alteration of microstructure. The shear strength of loess is basically controlled by its growing particle size heterogeneity. Xu, Chen, & Jiang (2015) studied the compaction characteristics and particle breakage of soil aggregates. Saberi, Annan, & Konrad (2017) established an interface constitutive model of sandy gravel soil considering particle breakage. Zhu, Guo, Wen, Yin, & Zhou (2018) proposed a new gradation equation, and discussed the applicability of different soil particle size distributions.

Description of the Problem

However, the above studies mainly focus on coarse-grained soil. The loess is a fine-grained soil. When carrying out the particle size analysis test, the loess needs to be dispersed to the smallest size. The size of loess particles in China is mainly distributed in the range of 0.05 mm to 0.005 mm, which accounts for 52% to 72% of the total mass. Natural loess is a kind of under-consolidated and unsaturated loose granulates (silts) with its microstructure characterized with large voids and inter-particle cementation (Jiang, Li, Hu, & Thornton, 2014). But due to the chemical cementation and the molecular attraction in the natural loess, the particles are gathered together and appear in the form of conglomerations. These loess conglomerations are much larger in size than the loess particles and the compacted soil is actually a mixture of various conglomeration sizes in practical engineering. Whether the presence of conglomerations gradation has an effect on the compaction performance is less studied. In addition, when other conditions are same, whether loess conglomerations can affect compression deformation and shear strength is also relatively rare and worth to be discussed.

In view of this, the original loess has been sieved and the loess conglomerations with different sizes have been obtained. Then, different conglomerations gradation schemes were designed and four kinds of soil samples were prepared. The compaction test, compression test and direct shear test were carried out for these soil samples, and the micro observation is also taking for soil samples in order to explore the effect of loess aggregate on the engineering properties.

Materials and methods

Test materials preparation

The loess used in the test is taken from a construction site in the southern suburbs of Xi'an. The loess is Q_3 of late Pleistocene, which is homogeneous, with macropores, loose structure, and columnar jointing. As mentioned above, the loess particles are gathered together and appear in the form of conglomerations because of the chemical cementation and the molecular attraction. The picture of the loess conglomerations is shown in Figure 1.

Figure 1. Loess conglomerations Source. (Self-Elaboration).

The physical properties of loess including particle size distribution, natural moisture content, natural density, void ratio, degree of saturation, specific gravity and consistency limits were determined in accordance with Nanjing Hydraulic Research Institute (1999). The particle size distribution curve of original loess is shown in Figure 2 and the basic physical parameters are summarized in Table 1. The mass of the soil particles whose size are greater than 0.075 mm is not more than 50% of the total mass, and the plasticity index is between 10 and 17, so the soil for the test is silty clay.

Figure 2. Particle size distribution curve of original loess. (Self-Elaboration).

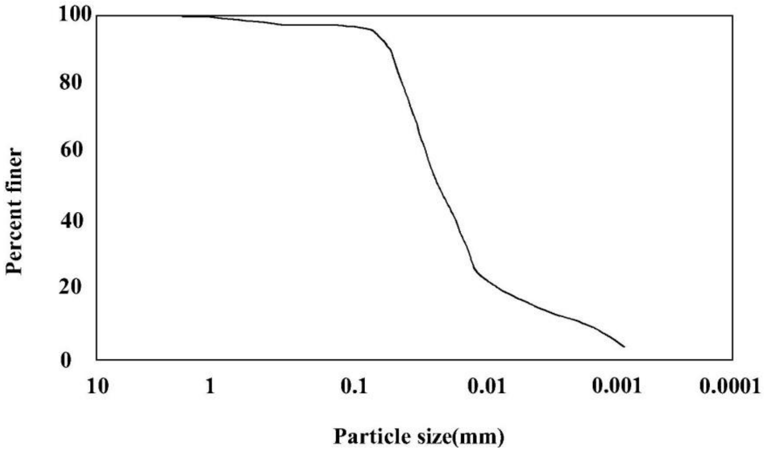


Table 1. The physical parameters of original loess. (Self-Elaboration).

Index	Moisture content (%)	Natural density (g/cm³)	void ratio	Saturation degree (%)	Specific gravity	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
Values	17.8	1.56	1.05	46	2.71	30.5	16.7	13.8

The original loess is sifted into different conglomerations grain sizes. The sizes are 5, 2, 1, 0.5, 0.25 and 0.075 mm, respectively. In order to compare and analyze the effect of conglomeration gradation on the engineering properties of loess, three types of samples with different conglomeration gradation were artificially arranged in addition to original loess samples.

Uniformity coefficient and gradation coefficient are two indices generally used for judging whether the coarse-grained soil gradation is good, such as sand. Loess is fine-grained soil with small particle sizes, but the loess conglomeration size is generally larger, similar to sand particles. Therefore, this paper uses these two indices to judge whether the conglomeration gradation of loess is good. In engineering, if the uniformity coefficient is greater than 5 and the coefficient of gradation is between 1-3, the soil gradation is good, otherwise the gradation is bad (Nanjing Hydraulic Research Institute, 1999; China Planning Press, 1999).

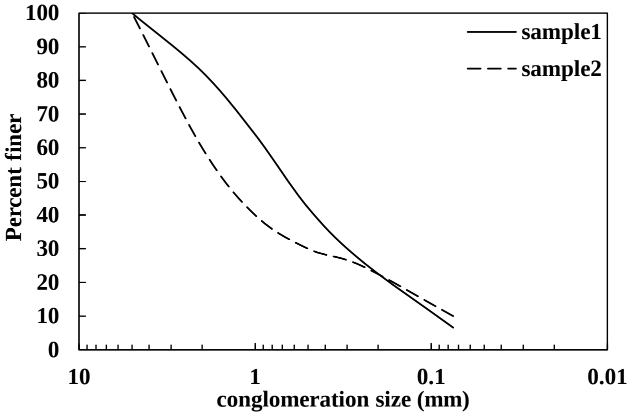
The mass distribution percentage of loess conglomeration in different size of test sample is shown in Table 2. The conglomeration size distribution curves of original loess and one kind of contrast loess are shown in Figure 3. For convenience, the original loess is named sample 1, and the other three comparative samples are named sample 2, sample 3, and sample 4 respectively in this paper. The uniformity coefficient of sample 1 is equal to 9.88 and the gradation coefficient is equal to 0.96 by calculating. Because the gradation coefficient is less than 1.0, the gradation of sample 1 is not good.

From Figure 3, it is seen that the curve of sample 1 is relatively gentle. For the compared sample 2, the uniformity coefficient is equal to 8.4 and the gradation coefficient is equal to 2.1 by calculating. Therefore, the conglomeration gradation of sample 2 is considered to be good. However, the curve shape of sample 2 shows that the two ends are steep and the center is slow. This means that many conglomeration sizes are concentrated in large and small size, and the middle size conglomeration is relatively less. At the same time, the sample 3 is only with large conglomeration gradation size of 1.0-2.0 mm and the sample 4 is only with small conglomeration gradation size of 0.075-0.25 mm. The conglomeration size of samples 3 and sample 4 is only within a single particle size range (Table 2), it is not suitable to draw a continuous gradation curve. So the conglomeration size distribution curves of samples 3 and 4 are not shown in the Figure 3.

Table 2. The mass distribution percentage of loess conglomeration in different size (%). (Self-Elaboration).

Size (mm) sample	5.0~2.0	2.0~1.0	1.0~0.5	0.5~0.25	0.25~0.075	< 0.075
1	17.41	18.65	21.78	15.65	15.65	6.58
2	40	20	10	5	15	10
3	0	100	0	0	0	0
4	0	0	0	0	100	0

Figure 3. Conglomeration size distribution curve of the original loess (sample 1) and contrast sample (sample 2). (Self-Elaboration).



In sample preparation, the loess is dried first and then water is added to the set content. Mix the soil sample evenly and seal it for 24 hours to make the water migrate sufficiently. Finally, part of the soil is directly used in compaction test. And according to the set, the other part of the soil is placed in the ring knife sampler and pressed into samples by static pressure for compression and direct shear test.

Test methods

This paper plans to carry out compaction test, compression test, and direct shear test. The compaction test was carried out to determine the maximum dry density and optimal moisture content of four soil samples. When other parameters are the same, compression tests and direct shear tests are carried out for soil samples with different conglomeration gradation, in order to investigate the effect of the conglomeration gradation on the compression deformation and shear strength. Three sets of parallel tests are conducted for each type of test to minimize the influence of experimental errors. Then the meso-structure was observed and the result was compared with the macroscopic phenomena of the experiment.

Compaction test

Light compaction test method is adopted in this test. The hammer weight is 2.5 kg and the falling distance is 305 mm. The sample was compacted in three layers, with 25 blows for each layer. The compaction energy per unit volume is 592.2 kJ/m^3. The numerical control multi-functional compaction test apparatus is used for the compaction test, which is shown in Figure 4.

Figure 4. The numerical control multi-functional compaction test apparatus. (Self-Elaboration).

Compression test

In order to test the effect of loess conglomeration gradation on compacting performance, compression tests of four kinds of samples were carried out. The instrument for compression test is WG type single lever consolidating instrument. The sample is a flat cylinder with a bottom area of 30.0 cm^2 and a height of 2.0 cm. The sample is first subjected to 1kPa preloading load. The percentile reads zero and then loaded according to the set order. The loading order is 25, 50, 100, 200, 400, 800, 1600 and 2000 kPa, respectively. The stable standard is that the compression deformation is less than 0.01 mm/h under each load. The height of the sample is recorded after the deformation is stable. Because of the time of compression test is long, the sample container was wrapped with fresh film and wet cotton strips were placed to keep the wet of the sample.

Direct shear test

In order to test the effect of loess conglomeration gradation on shear strength, direct shear tests of four kinds of samples were carried out. The preparation and parameters of the samples are the same as those of the compression test. The equipment used in direct shear test is the ZJ fully automatic strain control type direct shear instrument. The test type is consolidated quick shear test. In the test, four vertical pressures were applied to four samples respectively at the same time. The shearing starts when the compression deformation velocity of the sample is less than 0.01mm/h. The shear rate is 0.8 mm/min. The vertical pressures applied to each sample are 100, 200, 300, and 400kPa, respectively.

Meso-structure observation

Microscopic and mesoscopic observations are the important methods for understanding the macroscopic properties of materials (James & Kasinatha Pandian, 2018). In order to analyze the influence of conglomeration gradation on the engineering properties of loess from the meso point of view, the representative samples used in the tests were observed by stereo microscope. The observation instrument is the Karl-Zeiss stereo microscope and the model is Stemi 508, as is shown in Figure 5.

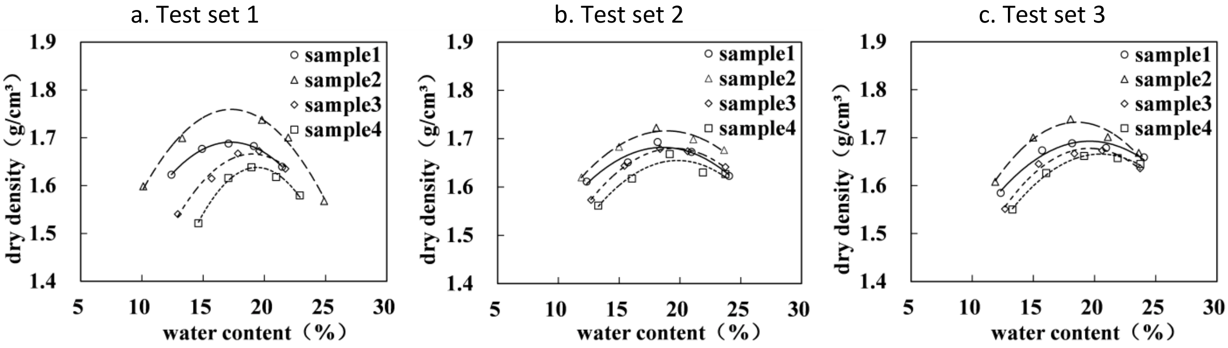
Figure 5. Karl-Zeiss Stereo Microscope. (Self-Elaboration).

Results and discussion

Compaction test

The compaction curves of loess samples with different conglomeration gradations are shown in Figure 6. Three sets of tests are carried out and the average maximum dry density of the four samples is shown in Figure 7.

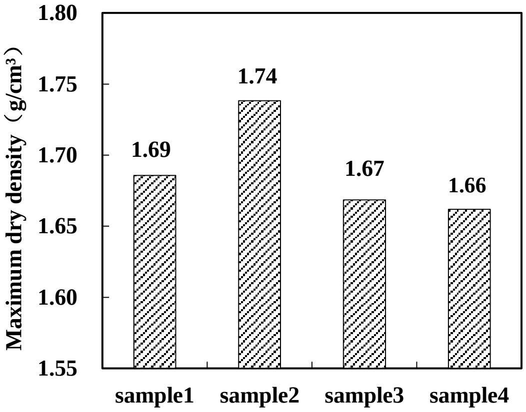
Figure 6. The compaction curves of different conglomeration gradation samples. (Self-Elaboration).


a. Test set 1

b. Test set 2

c. Test set 3

Figure 7. The average maximum dry density of different conglomeration gradation samples. (Self-Elaboration).



From Figure 6 and Figure 7, it can be seen that the maximum dry density of the four kinds of samples is in the order of sample 2 > sample 1 > sample 3 > sample 4. The conglomeration gradation of sample 2 is the best, and the maximum dry density of sample 2 is the highest. The conglomeration gradation of sample 1 is not good; the maximum dry density of sample 1 is lower than sample 2. For sample 3 and sample 4, the conglomeration gradation size is concentrated in a single size range, which is poor gradation. Hence the maximum dry density of sample 3 and sample 4 is lowest. It means that there is a certain degree of correlation between the compaction performance of loess and the distribution of conglomeration gradation. Better conglomeration grading of samples is easier to get greater maximum dry density.

Comparing the conglomeration gradation of sample 2 and sample 1, it can be seen that sample 2 contains more large size conglomerations; the maximum dry density of sample 2 is higher. Comparing the samples 3 and sample 4, the conglomeration size of sample 3 is larger, and the maximum dry density of sample 3 is also slightly higher. These phenomena should be related to the breakage of larger size conglomerations of loess.

The conglomeration of the loess is formed by the aggregation of fine particles of loess, which is mainly influenced by chemical cementation and molecular gravity. Its strength is low, its properties are unstable, and it will be broken after loading. Large size conglomerations are easier to broken than smaller ones. When the large sizes of the loess conglomerations are broken, it will become medium and small size conglomerations, which fill the void in the large size conglomeration and optimize the composition of the conglomeration gradation. It seems that this readjustment can help to make the soil more compact. For the optimum water content, the value of the samples with good conglomeration gradation is lower than that of the samples with poor gradation.

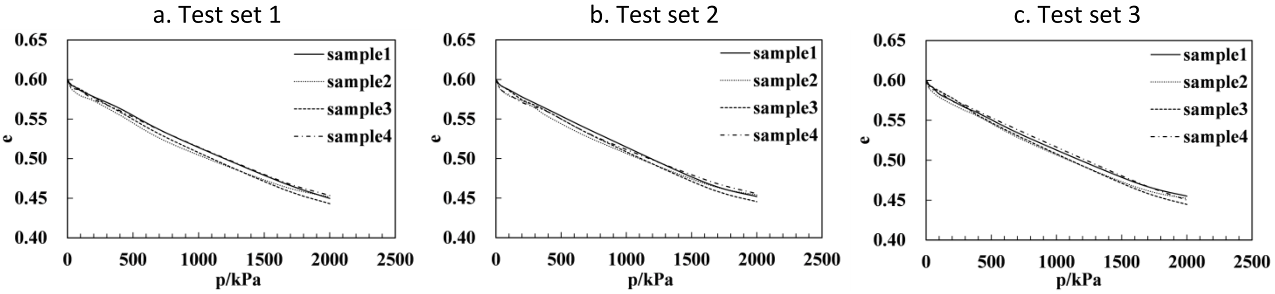
Therefore, in order to obtain better compaction performance, the loess conglomeration should be better graded and contains more large size conglomerations in practical engineering.

Compression test

For convenience of comparison, the four kinds of loess with different conglomeration gradation were all made into the samples with void ratio of 0.6 for compression tests. The dry density is 1.69 g/cm^3 and the moisture content is 18.1%.

The e-p and e-lgp compression curves of four kinds of samples are shown in Figure 8 and Figure 9, respectively. Three sets of tests are carried out for the samples. The compression coefficients and compression indices are shown in Table 3. In this test, the vertical pressure range of compression coefficient is 100 to 200 kPa, and compression index is determined by the slope of the curve in e-lgp coordinate when the vertical pressure is greater than 800kPa.

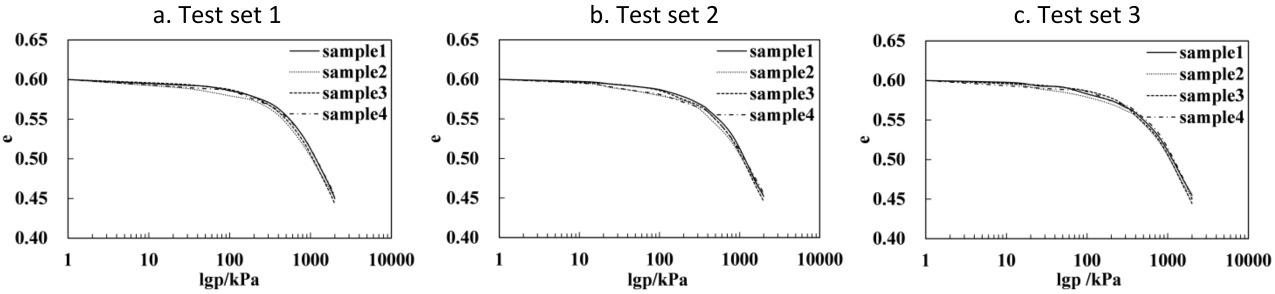
Figure 8. The e-p curve of compression test. (Self-Elaboration).


a. Test set 1

b. Test set 2

c. Test set 3

Figure 9. The e-lgp curve of compression test: (Self-Elaboration).


a. Test set 1

b. Test set 2

c. Test set 3

Table 3. The compression coefficient and compression index. (Self-Elaboration).

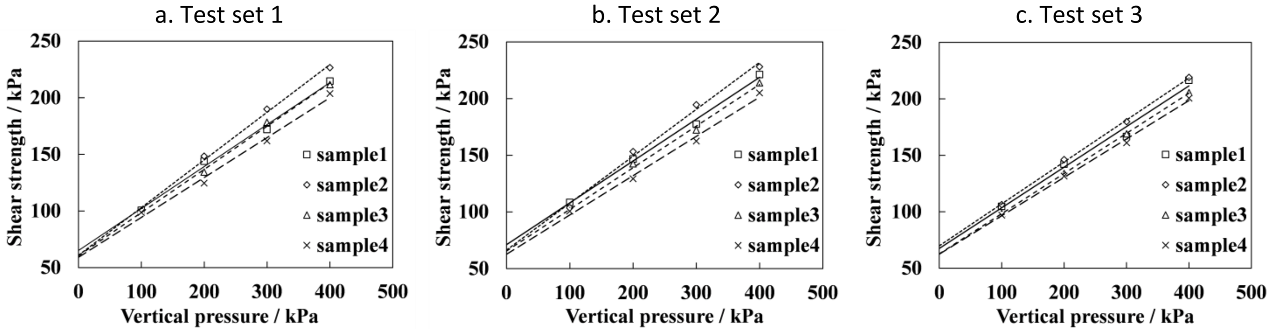
Index		Compression coefficient a_{1-2} (MPa^{-1})				Compression index C_c			
Test set		Set 1	Set 2	Set 3	Average	Set 1	Set 2	Set 3	Average
Sample	1	0.079	0.080	0.085	0.081	0.199	0.197	0.181	0.191
	2	0.064	0.064	0.090	0.073	0.167	0.168	0.175	0.170
	3	0.097	0.116	0.090	0.101	0.201	0.198	0.197	0.198
	4	0.109	0.100	0.121	0.110	0.190	0.174	0.202	0.188

It can be seen that the average compression coefficients of the four kinds of samples are in the range of 0.073 to 0.110 MPa^{-1}, and the maximum difference value is 0.037 MPa^{-1}. The average compressive indexes of samples are in the range of 0.170 to 0.198, and the maximum difference value is 0.028. Both compression coefficient and compression index indicate that these samples belong to low compressibility soil. From the compression curve and related indicators, it can be seen that the compression performance of sample 2 is the best, followed by sample 1, sample 3 and sample 4. But the difference in compression performance of these samples is slight, so the influence of conglomeration gradation on the compressive properties of loess is not significant. Considering that the static pressure was applied to the samples in order to achieve the maximum dry density in the sample preparation, the conglomerations of the sample were broken and rearranged to adapt to the pressure applied. The difference of the samples was not significant when the pressure was reapplied in the compression test.

Direct shear test

The shear strength envelopes of four kinds of samples are shown in Figure 10. Three sets of tests are carried out and the cohesion and internal friction angle are shown in Table 4.

Figure 10. The shear strength envelope of direct shear test. (Self-Elaboration).



a. Test set 1 b. Test set 2 c. Test set 3

Table 4. The cohesion and internal friction angle of samples. (Self-Elaboration).

Index		Cohesion C (kPa)				Internal friction angle ϕ(°)			
Test set		Set 1	Set 2	Set 3	Average	Set 1	Set 2	Set 3	Average
Sample	1	65.15	71.20	67.55	67.97	20.32	20.24	19.79	20.12
	2	60.93	66.40	69.85	65.73	22.84	22.48	20.39	21.90
	3	60.50	65.50	62.70	62.90	20.87	20.18	19.60	20.22
	4	59.15	62.70	62.50	61.45	19.39	19.11	18.78	19.09

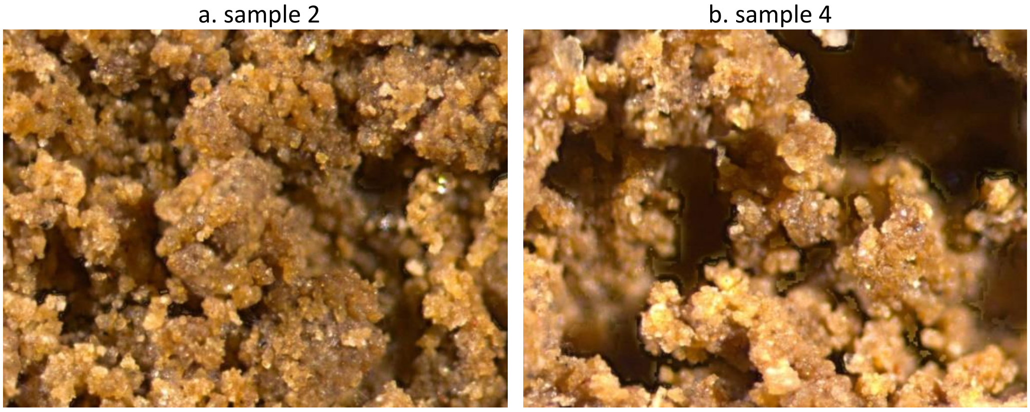
It can be clearly seen from Table 4 that the average cohesions of the four kinds of samples are in the range of 61.45 to 67.97 kPa, and the maximum difference value is 6.52 kPa. The internal friction angles of samples are in the range of 19.09°to 21.90°, and the maximum difference value is 2.81°. From the shear strength envelope curve and shear strength parameter, it can be seen that the shear strength of sample 2 is the best, followed by sample 1. Sample 3 and 4 are almost the same, and both are relatively low. The difference of four kinds of samples is significant. This means that the conglomeration gradation has influence on the shear strength of the loess in a certain degree.

Comparing with compression test, the influence of loess conglomeration gradation on shear strength is more significant. This may be related to the different roles played by loess conglomerations in compression and shearing. When the loess is compressed, the soil mainly relies on the material strength of conglomerations to resist the pressure, and the effect of the inlaying force between the conglomerations is not significant. However, when loess is subjected to shear, the inlaying force between the conglomerations is very important to resist shear failure, and the inlaying force between large conglomerations is greater and the ability of large conglomerations to resist shear is also stronger. In addition, the better grading also helps to reduce the crushing of conglomerations and improve the shear properties of loess. Therefore, the effect of conglomerations gradation on the shear strength of loess is more significant.

Meso-structure observation

Considering that, in the above tests, the engineering properties of sample 2 are the best, while that of sample 4 is the lowest, sample 2 and sample 4 are selected for the meso observation. The mesoscopic observations results are shown in Figure 11.

Figure 11. Meso-observation of representative samples (magnification: 160 times). (Self-Elaboration).



Comparing with the Figure 11a and 11b, it can be seen that the size distribution of loess conglomeration in sample 2 is comprehensive, and the large size conglomerations are surrounded by small size conglomerations. This will help to reduce the porosity of the soil sample and make it denser. In contrast, there are mainly small size conglomerations in sample 4, so the interior of small size conglomerations is bonded and arranged, and the filling degree of soil samples is poor and the density is low. The above two pictures (see Figure 11) are processed and analyzed by software, and the void area and solid particle area are distinguished and counted by gray level. It can be counted that the void area of sample 4 is 9.79% larger than that of sample 2. The meso-observation is consistent with the macroscopic phenomena, so the conglomeration does have a certain degree of influence on the engineering properties of loess.

In addition, it is worth noting that when the loess conglomerations are under pressure, there will be a broken situation on the one hand, but on the other hand, the small size conglomerations can also gather together under the pressure to form a larger conglomeration. This is reflected in Figure 11b. In the sample 4, there were only small size conglomerations at the beginning, but after the pressure, some larger conglomerations appeared, which were formed by the original small size conglomerations. Therefore, the loess conglomeration is very special. It is not only different from the particles of coarse grain soil, but also different from the particles of the fine grained soil. The effect of conglomeration on the engineering properties of loess is very complicated.

Conclusions

This paper mainly studies the influence of conglomeration gradation on loess engineering properties. The compaction test, compression test, direct shear test and meso observation were carried out. The following conclusions were drawn from these experiments.

In the compaction test under the standard compaction energy of 592.2kJ/m^3, the conglomeration gradation of loess can affect its compaction performance. Soils with good gradation and more large size conglomerations are more likely to obtain higher maximum dry density. Large size conglomerations are easier to crumb than smaller ones. When the large sizes of the loess conglomerations are broken, it will become a medium size and smaller size conglomerations, which make the conglomeration gradation readjusted, and it seems that this readjustment is beneficial to the compaction of loess.

The compression performance of various samples is similar to that of compaction test. But the difference in compression performance of these samples is slight, and the influence of conglomeration gradation on the compressive properties of loess is not significant. This is related to the pressure of sample preparation.

In direct shear test, the shear strength parameters of the four kinds of samples are different. This is similar to the result of the compaction test. It means that the conglomeration gradation has influence on the shear strength of the loess in a certain degree. Comparing with compression test, the influence of loess conglomeration gradation on shear strength is more significant. This is related to the role played by the inlaying force between loess conglomerations.

From meso-observation, it can be seen that the conglomeration size distribution of sample 2 is comprehensive, and the large size conglomerations are surrounded by small ones. This can help to reduce the porosity of the soil and make it denser. In contrast, there are only smaller size conglomerations in sample 4, so the void filling of soil is insufficient and the density is low. The meso-observation is consistent with the macroscopic phenomena, so the conglomeration does have a certain degree of influence on the engineering properties of loess.

In practical engineering, the conglomerations size distribution of loess also affects its compression and shear performance, which has an important impact on the settlement of building foundation, the stability of retaining wall and other related practical projects. Therefore, the conglomeration gradation curve of loess should be kept as smooth and continuous as possible, and a sufficient number of large size conglomerations should be contained. This can help to obtain better engineering properties of loess.

The loess conglomeration is very special. It is not only different from the particles of coarse grain soil, but also different from the particles of the fine grained soil. The effect of conglomeration on the engineering properties of loess is very complicated. Many factors such as particle breakage, load level and water content can have an impact. Therefore, there are many problems worth further study in the future.

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