Initial analysis of the influence about manufacturing methods on forming quality of similar material specimen

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Abstract. By comparing the physical and mechanical properties of the similar materials made from the same material making method and the same making method, the influence of different factors on the quality of the specimen is analyzed from the three aspects of the apparent density, the compressive strength and the modulus of elasticity of the similar materials. The test shows that the uniformity of apparent density does not relate to the uniformity and density of the specimen itself, but the control of the quality and size of the single specimen can help to reduce the difference between the specimens. The quality of the die is better than the cylindrical mold; the one-time loading is easier to obtain the less fluctuation of the compressive strength and the modulus of elasticity. And the machine compacted specimen has better molding quality.

1. Introduction
In the field of geotechnical mechanics research, geomechanical model test is most widely used at present. As an important part of geomechanical model, the quality of similar material specimen preparation has a great impact on the accuracy and reliability of research results [1-4]. Specimens of the same material with the same ratio tend to have large differences in measured mechanical properties due to different production methods or experimental methods. Luo Feng [5] studied the error sources of uniaxial compression strength of similar materials through similar material simulation. Zhang Xutao [6] studied the influence of forming pressure on the properties of ferrocrystalline sand mixed similar materials. Lin Haifei [7] analyzed the impact of impact number and impact force on the physical and mechanical properties of the specimen during the time molding of similar materials.

Now make a specimen is not relatively uniform standard, due to its error sources, compactness and uniformity of the specimens is difficult to guarantee, in recent years, relatively few studies in specimen preparation methods, in order to solve the technical problems, in this paper, cement sand gypsum mixed similar material, for example, from mold, mixture loading method, pressing method, etc., through a large number of indoor comparative study on the uniaxial compression test of similar material specimen preparation methods, analyzes the advantages and disadvantages of all kinds of production methods, put forward the improvement suggestion, for reference of the geological mechanical model experiment was carried out [8-11].
2. Method of making test pieces

In this paper, gypsum and composite Portland cement were selected as cementing agents respectively. River sand with a particle size less than 20 was used as the skeleton, and the particle size distribution was shown in Figure 1. River sand combinations with different particle sizes could reduce the porosity of materials and increase the bulk density. According to the single-factor analysis method, in order to ensure that the specimen prepared is not affected by other factors, the same ratio of similar materials is selected, the ratio of sand and rubber is 2:1, and the amount of water is 30% of the cementing agent quality.

![Figure 1. Size distribution of river sand](image)

When making the test piece, first use an electronic scale to weigh similar materials of the required quality with an error of 0.1g, then pour the required proportion of water, fully stir with a special stirrer, and put it into the mold, a Ø 50x100mm standard cylindrical test piece is made in the medium. Two molds are used here, one is a custom-made cylindrical acrylic mold, and the other is a stainless steel split mold. Based on a large number of indoor experience in making test pieces of similar materials, the following 4 methods of making test pieces are summarized and grouped:

Method 1: Fill the mixed similar materials into the acrylic mold in 3-4 times, after each filling it is compacted with an acrylic rod, and the surface is loosened with a stirring rod, and then refilled and compacted to form a Class A specimen.

Method 2: Fill the mixed similar materials into the acrylic mold at one time, and put it on the vibrating table to fully vibrate to make the type B test piece.

Method 3: Fill the mixed similar material into the acrylic mold at one time, put it on the mechanical testing machine, compact the upper end of the similar material, set the pressure to 2.5KN, and make the C type test piece.

Method 4: Fill the mixed similar materials into the acrylic mold and the split mold at one time, put them on the mechanical testing machine, compact the two ends of the similar materials, set the pressure to 2.5KN, and make the D type and Type E specimens. When filling similar materials, use an electronic scale to weigh the quality to ensure that the quality of similar materials in the mold is the same (error 2g), and ensure that the height of the test piece is as consistent as possible during the pressing process.

After the test piece is filled, it is placed for 24 hours and then demolded, and then placed in a dry environment for curing for 7 days. In order to further analyze the influence of cementing materials on the strength of specimens of similar materials, the specimens are divided into two major groups, I and II. The cementing material in Group I is gypsum, and the cementing material in Group II is composite Portland cement. The Group I does not use the split mold, so there are 4 types pieces named A-D, and the Group II has 5 types pieces named A-E; each category makes 5 test pieces.
3. Uniaxial compression test of specimens of similar materials
The specimens of similar materials made by different methods are subjected to the conventional uniaxial compression failure test. The test is carried out on the TAW-200 electronic multifunctional material mechanics testing machine. The mass, diameter, and height of the piece are recorded; the test adopts load control, first applying a preload of 100N, and then applying a load at a loading rate of 20N/s until the specimen is broken. During the test, the computer automatically records the curve of load, displacement and other data over time. The experimental process and damage form are shown in Figure 2.

![Figure 2. Experimental process and form of destruction](image)

The full stress-strain curve is drawn according to the test data of group I as shown in Figure 3. Observing the curve shows that when the specimen is damaged by uniaxial compression, it is mainly divided into four stages: compaction, elastic deformation, plastic deformation and failure. Through the analysis of the curves, it is found that the curves of different types of specimens are quite different, and the curves of each specimen in the same category are also different, which is enough to show that different manufacturing methods have a significant impact on the mechanical properties and molding quality of the specimens.

4. Test results and analysis

4.1. The effect of apparent density
Measure the height, diameter and mass of the specimen, obtain the apparent density of the specimen by calculation, and draw the apparent density change curve of the two groups of specimens as shown in Figure 4. By calculating the variance, the dispersion degree of the 9 types of specimens in the two groups is obtained. Table 1 lists the variance of the apparent density of each type of specimen.

![Figure 3. Stress strain diagram of group I](image)

| Type of specimen | I          | II         |
|-----------------|------------|------------|
|                 | A | B     | C  | D  | A | B  | C | D  | E  |
| variance $\times 10^{-2}$ | 0.015 | 0.117 | 0.015 | 0.06 | 0.02 | 0.989 | 0.13 | 0.089 | 0.122 |

According to the analysis of the graph, the variance of the A and C specimens in group I is small, and the variance of B is the largest; the density changes of A and D in group II are relatively small, similar to group I, the fluctuation of B specimens is the largest. That is, the apparent density of the specimens made by method 2 is quite different. The main reason is that the coarse and fine particles are
stratified by gravity in different degrees during the vibrating process, the manual compaction is not uniformly stressed, and the vibration produces splashing. So that the size and quality of the test piece have a large deviation. In general, the apparent density deviation of the specimens produced by various methods is about ±0.1 g/cm³, and the apparent uniformity is good, and there is no large dispersion.

![Figure 4. Apparent density change about group I and group II](image)

4.2. The effect of uniaxial compressive strength

The uniaxial compressive strength is calculated by formula 1:

\[
\sigma_C = \frac{F}{A}
\]  

\( F \) is the maximum load that the test piece can withstand, and \( A \) is the cross-sectional area of the test piece. The compressive strength of each group of specimens is calculated by calculation, and the broken line diagrams of the compressive strength of the two groups of specimens are drawn respectively, as shown in Figure 5.

![Figure 5. Variation diagram of compressive strength](image)

On this basis, two interference data with large errors are excluded for each type of specimen, and the average compressive strength of all specimens in group I and group II is also used as the expected value of each group to calculate the compressive strength of the specimen. The variance is listed in Table 2.
Table 2. Variance of compressive strength

| Type of specimen | I       | II     |
|------------------|---------|--------|
|                  | A  | B  | C  | D  | A  | B  | C  | D  | E  |
| variance         | 0.021 | 0.031 | 0.028 | 0.011 | 2.341 | 2.717 | 0.440 | 0.320 | 0.047 |

Compressive strength is an important mechanical performance index of similar material specimens. In group I, the uniaxial compressive strengths of C and D specimens are basically the same, while there are obvious strength differences between A and B. On the one hand, the solidification time of the material is inconsistent due to multiple fillings, and on the other hand, it is caused by manual compaction. The pressure cannot be accurately controlled, which eventually leads to inconsistent density of the specimen. Comparing the experimental results of the group II of specimens, the compression strength of the E specimens with split molds has the smallest fluctuation, followed by the D and C specimens, while the A and B specimens have the largest fluctuations, as shown in Table 2. The size of the variance can be seen more intuitively. Type E specimens use split molds, which do not need to be squeezed again when taking the specimens. The integrity of the specimens is better. When the specimens are extruded from the acrylic mold, the degree of solidification of similar materials is different and the friction between the specimen and the inner wall of the mold is different. Different sizes cause varying degrees of damage to the specimen.

To sum up, the test results of the groups I and II are basically the same. The test pieces that use split molds, one-time filling and machine compaction, have smaller fluctuations in compressive strength and are more reliable. The difference of similar materials also has a certain effect on the uniformity of the compressive strength of the specimen. Observing Figure 5, it can be seen that with the same manufacturing method, the degree of dispersion of the compressive strength of group I is much greater than that of group II. The effect of water interaction is different. In the case of the same water consumption, the gypsum of group I has strong water absorption and short initial setting time, and the mixing of group II is more uniform and easier to compact.

4.3. The effect of modulus of elasticity

According to the data recorded in the uniaxial compression test, draw a stress-strain curve diagram. Through the analysis of the test data, the elastic modulus of the test piece is calculated according to formula 2, and the change of the elastic modulus is plotted as shown in Figure 6.

\[ E = \frac{\sigma_b - \sigma_a}{\varepsilon_{lb} - \varepsilon_{la}} \]  

In the formula, \( E \) is the elastic modulus, \( \sigma_b, \sigma_a \) is the stress value corresponding to the end and starting point of the elastic stage of the stress-strain curve of the specimen, and \( \varepsilon_{lb}, \varepsilon_{la} \) is the strain value of the elastic stage of the stress-strain curve.

It can be seen from the figure that group I fluctuates between 118.1MPa and 749.3MPa as a whole, the elastic modulus value of type A specimen fluctuates greatly, and the changes of type B and D are small, within 78.6MPa and 80.2MPa, respectively. Type A specimens with the largest fluctuation are 4.3 times of the fluctuation range of Type B specimens; Group II also has a large fluctuation range of Type A elastic modulus, the other four types have relatively small relative differences, and Type C and D specimens have the smallest fluctuations; The overall consistency of the test pieces of group II is better than that of group I.
Figure 6. The elastic modulus variation

The results show that the use of different methods for compaction will have a greater impact on the elastic modulus of the test piece, and the one-time filling method of the B, C, and D test pieces can effectively reduce the fluctuation of the elastic modulus, and the modulus of elasticity is a physical quantity that characterizes the elastic stage of the test piece. It is different from the compressive strength. If the test piece is manually divided into multiple compactions, it is easy to form a layered structure, so the performance of the elastic stage is quite different.

5. Conclusion
The test method adopted in this test is scientific and practical. Two different similar materials are used. The physical and mechanical properties of the specimen are made by comparing the same manufacturing method, different materials, and different methods of the same material, which increases the reliability and accuracy of test results. The following conclusions are drawn:

1. Keeping the volume and quality of the test piece consistent can only obtain better apparent density consistency, which has little effect on promoting the true density uniformity of the test piece itself.
2. One-time filling materials can effectively reduce the fluctuation of elastic modulus.
3. Machine compaction has greater advantages than manual compaction, and can obtain test pieces with better density and uniformity, and the quality of split mold release and molding is better than that of cylindrical molds.
4. The difference of the cement in similar materials has a certain influence on the molding quality, density and uniformity of the test piece. Similar materials that have a slow solidification time and are easy to be pressed should be selected, and a retarder should be added if necessary to improve the molding quality.

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