Discussion on the application of alcohol combustion method in the determination of soil moisture content

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Abstract. Moisture content is a very important parameter in earthwork filling. In the process of earthwork compaction, the moisture content of the compacted soil shall be measured in time, and the moisture content shall be compared with the design requirements to check whether it is qualified. However, the conventional drying method usually takes about 6 to 8 hours, which will have a great impact on the construction progress. Therefore, this paper mainly discusses the alcohol combustion method in the construction site to temporarily replace the drying method to determine the moisture content of soil. The optimum sampling quantity, combustion times and the range of moisture content of alcohol combustion method are obtained. Finally, it shows the accuracy of alcohol combustion method in the temporary determination of soil moisture content in the construction site.

1. Introduction
With the continuous progress of society, the requirements of water conservancy project construction quality are also constantly improved. In the early stage of construction, the earth filling and compaction project is very important. Moisture content is a very important index. Once the moisture content of earthwork deviates from the optimal moisture content, the compactness of earthwork will not meet the design requirements. In the process of construction, the corresponding moisture content of each layer of earthwork needs to be measured. Although the moisture content measured by the conventional drying method is accurate, this method is time-consuming and affects the construction progress. The method of alcohol combustion can measure the moisture content of excavated soil in a short time, but the accuracy of the data measured by alcohol combustion method is uncertain. Therefore, this paper has carried out an exploratory test on the alcohol combustion method.

2. Test equipment
Drying method:
(1) Electric blast constant temperature drying oven;
(2) Electronic balance: weighing 200g, division value 0.01g;
(3) Weighing box.
Alcohol combustion method:
(1) Electronic balance: weighing 200g, division value 0.01g;
(2) Alcohol of not less than 95% purity;
(3) Weighing box, dropper, match, soil mixing knife.
3. Concept of soil moisture content
Water content of soil refers to the quality of water content in soil, generally speaking, it refers to the absolute water content of soil. It is usually defined as several grams of moisture obtained after drying 100g of soil.

3.1. Importance of water content
Moisture content is a very important parameter in earthwork filling engineering. In the construction process, the construction unit can complete the filling engineering smoothly according to the design requirements only by controlling the sudden moisture content in the construction section. When the water content of the fill is small, the friction force between the soil particles is large, so it is not suitable to be compacted; when the content of the fill is large, the pores between the soil particles are all filled with water and in a saturated state, and it is not suitable to be compacted; only when the water content of the fill is moderate, the friction force between the soil particles is reduced due to the role of water in the soil, so the fill is easy to be compacted. Therefore, it is generally necessary to obtain the optimal moisture content and maximum dry density through specific experiments.

3.2. Calculation of water content

\[ \omega = \left( \frac{m}{m_d} - 1 \right) \times 100 \]

Drying method and alcohol combustion method adopt the above formula, and carry out three parallel determinations, and take the arithmetic mean value. See Table 1 for the parallel difference value.

| Moisture content | Maximum allowable parallel difference (%) |
|------------------|------------------------------------------|
| <10              | ±0.5                                     |
| 10~40            | ±1.0                                     |
| >40              | ±2.0                                     |

4. Determination of soil moisture content by alcohol combustion
In the conventional drying method, the representative sample soil is put into the oven. The drying time shall be no less than 8 hours for clayey soil, no less than 6 hours for sandy soil, and no less than 65°C~70°C for soil containing 5%~10% organic matter. Alcohol combustion cannot guarantee constant temperature. If too much alcohol is used, or too many times of combustion, the test results will be inaccurate. 1. The product of alcohol combustion is water. If the amount of alcohol is not well controlled, the water generated after alcohol combustion will increase the quality of sample soil, resulting in the decrease of water content. 2. If the alcohol burns too many times, the organic matter in the sample soil will be destroyed. Therefore, the amount of soil and the number of alcohol combustion should be strictly controlled. Therefore, when the error range between alcohol combustion method and drying method is controlled between 1% and 2%, it shows that it is feasible to measure the soil moisture temporarily during the construction of alcohol combustion method.
4.1. Determination of water content combustion times and soil sample quality by alcohol combustion method

Clay and sandy soil are used as test soil in this test. The prime minister will dry the two soil samples, and then add water to the two soil samples with water content of (10% ~ 50%). Finally, the clay and sandy soil were weighed into three groups: 10g, 20g, 25g, 30g and 40g respectively, of which three groups were put into the oven for drying; the other three groups were used for alcohol combustion. Use a burette to inject alcohol into the weighing box with the sample until the free liquid level appears in the box. In order to fully mix the alcohol in the sample, tap the bottom of the box on the desktop; ignite the alcohol in the box until the flame goes out. After the sample is cooled for several minutes, repeat the above operations, and weigh the sample soil after the second, third and fourth combustion respectively. See Table 2 below for data obtained by drying method and alcohol combustion method.

Table 2. Test results of the best combustion times of alcohol combustion method for different soil

| Soil type   | Test group number | Amount of soil sample | Moisture content of drying method | Cumulative times and average moisture content of alcohol combustion method |
|-------------|-------------------|-----------------------|-----------------------------------|--------------------------------------------------------------------------|
|             |                   |                       |                                   | Second | Third | Fourth |
| Cohesive soil | 3                 | 10                    | 13.35                             | 12.91  | 13.37 | 13.32  |
|             | 3                 | 20                    | 13.35                             | 12.99  | 13.38 | 13.64  |
|             | 3                 | 25                    | 13.35                             | 12.82  | 13.28 | 13.25  |
|             | 3                 | 30                    | 13.35                             | 12.76  | 13.47 | 13.47  |
|             | 3                 | 40                    | 13.35                             | 11.67  | 12.99 | 12.90  |
|             | 3                 | 10                    | 16.40                             | 15.94  | 16.51 | 16.47  |
| Sandy soil | 3                 | 20                    | 16.40                             | 15.08  | 16.38 | 15.71  |
|             | 3                 | 25                    | 16.40                             | 16.12  | 16.59 | 16.30  |
|             | 3                 | 30                    | 16.40                             | 15.92  | 16.32 | 16.10  |
|             | 3                 | 40                    | 16.40                             | 16.16  | 16.70 | 16.09  |

It can be seen from table 2 that for clay and sandy soil, when the soil sample consumption is between 10-40g and the water content is measured by alcohol combustion method, it can be seen from the second alcohol combustion that the water content basically obtained is less than that measured by drying method. However, the value obtained after the third combustion of alcohol is basically close to the value obtained by the drying method. The data from the fourth combustion of alcohol is generally smaller than that from the third. The water content of dry soil depends on the quality of dry soil. Because the product of alcohol combustion contains water, the water produced in the process of alcohol combustion will lead to the increase of dry soil quality and the decrease of water content. Therefore, when using alcohol combustion method to measure water content, we should control the amount of alcohol and the number of alcohol combustion.

From this test, it can be concluded that when the amount of soil sample is in the range of 10-40g, when the alcohol combustion method is adopted, the amount of alcohol is basically controlled in the box with free liquid level, and the number of combustion is selected three times, so the moisture content is more accurate.

4.2. Applicable range of water content measurement by alcohol combustion method

First, put clay and sandy soil into the oven to dry, and then add water into the two soil samples respectively to form several parts with different moisture content. The moisture content of soil samples with different moisture content is measured by drying method first, and then the moisture content of corresponding soil samples is measured by alcohol combustion method and compared with drying method. The specific results are shown in the table below.
Table 3. Test results of applicable range of water content

| Soil type   | Test group number | Amount of soil sample | Moisture content of drying method | Average moisture content of alcohol combustion method |
|-------------|-------------------|-----------------------|----------------------------------|------------------------------------------------------|
| Cohesive soil | 3                 | 24.21                 | 5.23                             | 5.29                                                 |
|             | 3                 | 24.38                 | 15.21                            | 15.48                                                |
|             | 3                 | 23.96                 | 25.03                            | 24.93                                                |
|             | 3                 | 25.10                 | 30.10                            | 29.86                                                |
|             | 3                 | 25.30                 | 45.01                            | 44.50                                                |
|             | 3                 | 24.15                 | 50.01                            | 49.62                                                |
|             | 3                 | 26.11                 | 5.03                             | 4.94                                                 |
|             | 3                 | 26.01                 | 15.09                            | 14.89                                                |
| Sandy soil  | 3                 | 25.68                 | 25.11                            | 25.33                                                |
|             | 3                 | 25.39                 | 30.08                            | 29.86                                                |
|             | 3                 | 26.33                 | 45.08                            | 44.80                                                |
|             | 3                 | 24.96                 | 50.03                            | 49.89                                                |

It can be seen from the above table that when the moisture content is between 5% and 50% and the mass of soil sample is between 20-30g, the moisture content obtained by the alcohol combustion method (three times of combustion) is basically close to the moisture content measured by the drying method.

4.3. Matters needing attention

(1) The purity of alcohol is required to be 95% by alcohol combustion.

(2) When the organic content of soil sample is high, the moisture content measured by alcohol combustion method will be larger.

(3) If the moisture content of the soil sample is large and exceeds a certain weight, the results measured by alcohol combustion method are different from those by drying method. The main reason is that it is difficult for alcohol to dry the clayey soil.

(4) For the soil with high organic matter content, the alcohol combustion method cannot be used to measure the moisture content.

5. Conclusion

In most earthwork filling and compaction works, the soil is clay and sandy soil. From the above discussion, it can be seen that it is feasible to use alcohol combustion method to temporarily replace drying method to determine the moisture content of soil in the construction site for the earthwork of this kind of soil. The construction unit can control the moisture content of earth filling by using alcohol combustion method, which greatly shortens the construction period and speeds up the construction progress. Alcohol combustion method is easy to operate and the measured data are more accurate, which has a certain practical significance for the future conventional earthwork filling and Compaction Engineering.

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