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Analysis of Influencing Factors and Countermeasures for Experimental Determination of Soil Moisture Content Index

Daiqiang Deng*, Buxian Li, Yunfei Yang, Ye Wang

College of Civil Engineering, Xiangtan University, Xiangtan 411105, China
**Correspondence Author*

Abstract: ***Due to early geological movements, the formation of rock layers near the surface of the Earth's crust varied. In the later stages, intact rock layers were repeatedly subjected to external forces, resulting in varying degrees of damage. Additionally, during physical and chemical weathering, the properties of soil and rock materials in different regions of the Earth's surface showed certain differences. Therefore, in civil engineering construction, it is necessary to test the performance indicators of soil and rock in different regions in order to provide reliable basis for civil engineering design and construction. As an important physical property index of geotechnical materials, the testing process of soil moisture content is prone to some human or instrument equipment problems, which can affect the reliability of moisture content index determination. In the teaching of soil mechanics physical and mechanical performance index experimental courses in various higher education institutions, it is necessary to guide students to take some technical measures in testing experiments, enhance the sense of responsibility and standardized operation of testing personnel, and by formulating experimental plans and guidance documents, while following the various operational requirements of geotechnical testing regulations, accurately judge the type of rock and soil, correctly collect experimental samples, standardize the use of instruments and equipment, carry out experiments step by step, accurately weigh, scientifically read, set reasonable drying times, and use multiple sets of data averages. For the testing of moisture content indicators of special soil types in some areas, specialized methods can be used for experimental operations to avoid human operation errors and minimize experimental errors, thereby achieving ideal and efficient soil mechanics experimental goals.***

Keywords: Experimental teaching, Soil moisture content, Engineering geological hazards, Drying method, Particle size distribution, Soil mechanics course, Civil engineering construction.

1. Introduction

Over the past few decades, with the continuous development of higher education globally, educational techniques across various disciplines have seen significant improvements. In this rapidly evolving era of informatization and intelligentization, new concepts, devices, models, and technologies are gradually being integrated into various talent cultivation activities, providing robust support for supplying society with qualified technical professionals [1-2]. In the present era, with the rapid development of the socio-economic landscape, new demands are also being placed on civil engineering construction. The speed of economic development is inevitably determined by strong infrastructural support. Consequently, numerous projects, such as high-grade highways, long mountain tunnels, large-scale underground mining operations, extensive underground commercial systems, undersea transportation routes, and large-span bridges in mountainous and river regions, have commenced during this period of rapid infrastructure development. This has led to a substantial demand for civil engineering professionals [3-5]. The conception, investigation, evaluation, planning, and construction of civil engineering facilities have all led to unprecedented developments in construction techniques within civil engineering projects. The application of new processes, construction equipment, and materials has significantly enhanced the quality and efficiency of civil engineering projects. These advancements are attributed to the comprehensive understanding of construction processes and the properties of geotechnical materials.

As an engineering geological material with relatively complex physical and chemical properties, the physical and mechanical properties of rock and soil mass are crucial information required for civil engineering construction. Due to the anisotropy and site-dependent variability of rock and soil mass, a comprehensive understanding of soil performance parameters is necessary throughout the entire civil construction process [6-7]. The various types of rock and soil materials that are widely present in nature have origins that differ significantly across remote geological eras, leading to distinct physical and mechanical properties depending on their geographic location [8]. During the long geological process, the parent rock gradually weathers, and large intact rock masses are broken down into smaller fragments and debris. Under the influence of physical and chemical weathering, the mineral composition and physical properties of the resulting soil undergo certain changes, leading to specific physical and mechanical characteristics [9-10]. Soil in different geographical environments typically varies in specific gravity, bulk density, particle size distribution, natural repose angle, chemical elements, and mineral composition. To understand the physical performance indicators of soil in a specific region, relevant soil mechanics experiments need to be conducted, and tests should be carried out using instruments in accordance with regulations. To accurately measure the performance indicators of soil, it is necessary for testers to have a solid foundation in soil mechanics experimental testing during their academic training to provide essential assistance for on-site construction.

In the planning and discussion stages of numerous civil engineering projects, testing the soil moisture content within the project area is essential to provide reliable data for engineering design [11-12]. When conducting tests on the physical and mechanical properties of soil according to relevant geotechnical testing standards, experimenters must strictly follow standardized procedures for each step, based on uniform sampling. This is crucial for obtaining representative performance indicators of geotechnical materials [13]. In certain related soil mechanics experimental courses, researchers have conducted tests on soil samples obtained from different regions to assess their related properties. The conclusions provide valuable references for enhancing testing accuracy and engineering analysis [14-15]. Given the experimental goal of accurately testing the moisture content properties of soil, this study, guided by a laboratory manual from a soil mechanics course, elaborates on the testing objectives and procedures, with a focus on analyzing potential factors that may affect the test results. In addition to paying attention to sample representativeness and uniformity during sampling, the slight loss of samples and temperature control during testing can also affect the results. Therefore, it is necessary to make thorough preparations based on the observed surface properties of the soil before conducting the experiment. After obtaining indirect data, calculation formulas are used to convert it into indicative data, thereby providing reliable parameters for future engineering surveys.

2. Analysis of Factors Affecting Moisture Content Experiments

Infrastructure projects like buildings, roads, and bridges, cover vast areas. During the geotechnical survey process in such civil engineering constructions, soil moisture content tests and calculations are typically conducted to fully understand the moisture characteristics of the soils on site. In undergraduate soil mechanics courses at universities, laboratory courses are typically integrated with theoretical lessons. Moisture content, as one of the most critical physical properties of soil, can be used for qualitative and quantitative assessment of soil compressibility. The moisture content level often serves as an indicator of particle spacing and pore quantity. After fully understanding the soil's moisture content index, the moisture content in the soil can be adjusted to reach or approach the ideal moisture content index, thereby increasing the soil's weight per unit volume. This increases the soil's compaction, enabling it to bear additional loads more effectively. In other words, soils at their optimal moisture content typically have higher density, which significantly enhances their strength indices. In educational institutions that offer soil mechanics courses, soil moisture content is invariably included in laboratory teaching, making it essential to have a comprehensive plan for testing this index.

Prior to commencing various infrastructure construction projects, it is essential to have a comprehensive understanding of the physical and mechanical properties of the geotechnical materials. For soil samples collected from civil construction sites, such as foundation treatment sites for residential buildings, pile foundation construction sites for industrial plants, deep excavation slopes for underground construction, surrounding rock and soil bodies in tunnel projects, and immersed tubes and caisson construction sites in underwater traffic routes, due to varying construction conditions across different civil engineering sites, and even significant differences between various types of engineering sites, the methods of obtaining soil samples also vary. For example, when sampling at deep excavation sites, one can use construction geological drilling or directly shovel with a spade. Similarly, at tunnel construction sites and civil engineering construction sites, geological drilling or direct excavation of a suitable amount of soil can be used for sampling. However, for soil sampling at underwater construction sites, special measures must be employed to obtain the samples. This indicates that soil sampling in various types of civil engineering projects must be tailored to the site conditions and construction technical requirements. Generally, the soil samples must be representative.

3. Approaches to Handling Issues in Moisture Content Experiments

Due to the varying perspectives of different testers during the testing process, operators must adhere to geotechnical testing standards and utilize standardized procedures to accurately measure the moisture content of soil. This ensures the precision of experimental results, consequently offering essential technical benchmarks for civil engineering construction. In experiments testing the physical and mechanical properties of soil for civil engineering materials, appropriate methods can be selected based on the soil's characteristics. Currently, in geotechnical courses at universities and in geotechnical experiments conducted by construction units, the soil moisture content index is commonly determined using the drying method (also known as the oven-drying method). As a common experimental testing method, the drying method for measuring soil moisture content is convenient, reliable, and easy to operate. The procedure is clear and easily comprehensible, and the index calculation can be seamlessly carried out using conventional specialized formulas. Consequently, this method has been preferred for many years in secondary and higher vocational education and has been extensively used in the field of civil engineering.

3.1 Moisture Content Experiment Plan and Implementation

Before conducting various scientific and engineering experiments, it is essential to thoroughly review and prepare the entire experimental procedure. After completing the preliminary preparations, the experimental work should be conducted according to the planned schedule. During the implementation of experimental procedures, it is crucial to maintain good operational habits and use correct observation, testing, and measurement methods. It is essential to obtain representative experimental results while minimizing human-induced factors as much as possible. For instance, when collecting soil samples from a construction site, it is important to carefully select the sampling location and area, and to use appropriate tools for multi-point sampling. During the storage and transport of samples, it is essential to prevent moisture evaporation or exposure to rain. In the processes of testing, weighing, and observation, it is also necessary to adhere to the relevant testing standards. Careful attention must be paid to every step and procedure of the experiment to minimize errors or deviations caused by human factors.

3.2 Factors Influencing Testing and Their

Countermeasures

When compared to using the specific gravity method and alcohol burning method for determining soil moisture content, the drying method has its own set of conditions and requirements for soil testing. This method is generally applicable for determining the moisture content in various types of soil environments, such as silty soil, gravelly soil, sandy soil, and cohesive soil, making it suitable for in-situ moisture content measurement. The specific gravity, compacted bulk density, loose bulk density, natural angle of repose, and particle size distribution of these soils vary significantly, resulting in substantial differences in their properties. Therefore, to enhance the accuracy of test results, it is necessary to consider several key influencing factors during testing and adopt appropriate measures based on soil type for determining moisture content. The factors influencing moisture content testing for various soil types are often multifaceted. By identifying and analyzing potential influencing factors, we can summarize methods to avoid improper operation and minimize observational errors in common soil moisture content tests at civil engineering construction sites, as illustrated in Table 1.

Table 1: Factors affecting the determination of water content index and their countermeasures

Number	Soil Type	Influencing Factors	Corresponding Countermeasures
1	Silty Soil	Uniformity in sampling across each soil layer; frequency of sample splitting; minimal loss during transfer.	Collect samples from various points in different locations. Split the sample into 3 to 5 times, and ensure the containers are clean during sample transfer.
2	Gravelly Soil	Consideration of particle size diversity within the sampling range; the in-situ moisture condition of the material.	Maintain full particle size sampling and consider the high permeability of gravelly soil. Prepare in advance to prevent water loss from the soil.
3	Sandy Soil	Significant moisture differences between upper and lower soil layers; the in-situ moisture content of the material.	Account for the overall characteristics of the soil sample, considering the water state in both the upper and lower layers during sampling. For soils with high permeability, make preparations in advance to prevent water loss.
4	Cohesive Soil	Loss during sample inversion when the moisture content is high; setting of drying time; size of the soil blocks.	Especially for saturated and oversaturated soil samples, divide the soil into smaller blocks during drying and to ensure an adequate drying time.
5	Organic Soil	Localized enrichment of organic matter causes distribution variability; neglect of minor organic content during sampling.	Overcome sampling difficulties caused by high localized organic content and ensure reliable uniformity during sample splitting.
6	Frozen Soil	Defining soil layer boundaries during engineering surveys; neglecting coarse particles within the soil.	During drilling or soil sample extraction, consider coarse gravel particles within the soil layer, ideally, sample the area comprehensively.

3.3 Summary of Experimental Data Statistics and Analysis

In soil mechanics experiments that involve testing the soil's moisture content, the first step is to determine the type of soil and then conduct preliminary trials for selecting the experimental method and procedure. For most civil engineering projects, the most common soil types are clayey soils, silty soils, sandy soils, and gravelly soils. Consequently, the drying method is typically used to measure the moisture content of these soils. The tools and equipment generally used include the electric drying oven, the precision electronic balance, the soil cutting knife, the stainless steel basin, the rubber table mat, the desiccator, the lidded aluminum sample box, the plastering trowel, and the small iron shovel. When the experimental tools and equipment mentioned above are fully prepared and verified to be in proper working order, the moisture content experiment is scheduled for the designated time. According to the requirements of geotechnical testing regulations or the soil mechanics experiment manual, the experimental procedures are carried out step by step, and the results of each stage are carefully recorded. Ultimately, by combining the fundamental physical concept of soil moisture content, which is defined as the ratio of the mass of water to the mass of soil particles, the intermediate results are substituted into the formula to calculate the soil's moisture content index.

Table 2: Some relevant issues to be concerned with in soil moisture content experiments

Number	Relevant Engineering Issue	Potential Effect	Notes
1	Sand and Soft Soil Foundation Treatment	In foundation treatment projects, the foundation soil material needs to have high shear strength.	To significantly increase the bearing capacity of a foundation, moisture content measurement is used to determine soil porosity.
2	Deep Foundation Pit Slope of High-rise Buildings	By using reinforcement treatment, the soil material piled on the foundation pit slope gains better cohesion.	To fully assess the compaction of the pit soil slope, moisture content measurements are conducted to determine the soil's internal cohesion.
3	Roadbed Stabilization and Reinforcement Project	The compaction of roadbed materials under various load specifications is extremely beneficial for enhancing strength.	The mechanical force of compaction equipment is used to enhance soil density, thereby increasing shear strength.
4	Mountain Slope Excavation and Fill Project	Through the complementary processes of excavation and fill, the backfill soil needs to be compacted to increase its density and bearing capacity.	The fill area soil needs to be compacted to enhance soil density, thereby increasing shear strength.
5	Cohesive Soil Slope Protection and Management	Adjusting the moisture content in soil pores to maintain optimal performance and self-stabilization.	Soil stability can be enhanced using methods such as lateral compaction, soil nails, single anchor rods, or combined support systems like anchor spraying nets.
6	Highly Weathered Rock Slope Reinforcement	Large soil particle voids need to be filled with finer particles to prevent a loose, cohesionless state.	For loose or broken rock slopes, spraying concrete can prevent further weathering of geotechnical materials.

Various geotechnical materials, which serve as the foundation for civil construction projects, have critical parameters such as minimum porosity, maximum porosity, minimum void ratio, maximum void ratio, liquid limit index, and degree of saturation. These indicators are essential for foundation treatment, highway subgrade reinforcement, railway subgrade stability, slope excavation, and lowland filling in civil engineering projects. The magnitude of these parameters typically serves as a direct assessment of the geotechnical material's compaction and bearing capacity. Therefore, they are essential parameters in engineering surveys and construction acceptance. The testing methods for these indicators need to be determined based on site conditions. In soil moisture content determination tests, factors such as sample uniformity, adherence to standardized procedures, reading accuracy, and sample representativeness can sometimes lead to variations in results. Thus, it is essential to standardize the experimental procedures based on specific issues to minimize measurement errors. Each step of the experimental work should be conducted scientifically and objectively to create favorable conditions for obtaining accurate and reasonable indicator results. Through comprehensive analysis and summary, the engineering issues associated with soil moisture content tests are presented in Table 2.

4. Conclusion

The physical and mechanical performance indicators of civil engineering materials significantly influence the effectiveness of engineering projects. The soil properties in the regions where civil construction projects are situated across different areas of the Earth exhibit variability. Consequently, it is necessary to conduct engineering surveys based on local geological conditions, followed by testing the relevant geotechnical material indicators. As one of the crucial properties of soil, moisture content is a directly measured indicator used to calculate engineering parameters and serves as a basis for engineering design. Therefore, accurate and standardized testing is essential. When testing the moisture content of geotechnical materials commonly found in civil engineering, such as silty soil, clayey soil, sandy soil, and gravelly soil, it is crucial to adhere to standardized procedures based on geotechnical testing methods to ensure accurate results. Specifically, testing personnel must actively consider certain precautions.

During the weighing of soil samples, it is necessary to prevent the loss of soil material. When using aluminum sample boxes, be sure to remember the identification numbers and maintain precise records at each step of the process. When cutting the soil with a soil knife, the action should be quick and steady. The mass of the soil sample to be weighed is typically around 25 g. Once weighing is complete and the soil sample needs drying to remove free water from the soil pores within a specified time, it is necessary to set the temperature to around 106°C. The drying time should also be set to at least 8 hours. During the test, calculate the soil moisture content parameter based on the average value of 3-5 tested soil samples. This provides representative performance parameters. Overall, the experimental process should aim to minimize human observation and measurement errors, and multiple sample measurements should also be used. This method helps achieve ideal results in soil moisture content experiments.

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References

[1] Su Qiang, Luo Jiayin, Qiu Xiaoya, et al. The Coupling Logic and Practical Approach of New Productivity and Scientific Talent Cultivation[J/OL]. Modern Information:1-12.

[2] Rong Yiling, Lin Gai, Jiang Jikai, et al. Teaching Practice of Integrating Craftsman Spirit into Talent Training of Architectural Design Specialty Group — Taking Jiangsu Urban and Rural Construction Vocational College as an Example[J]. Modern Vocational Education, 2024(22):65-68.

[3] Jiao Yang. Our Country's Marine Engineering Technology Innovation Achievements are Abundant[N]. Science and Technology Daily, 2024-07-16(002).

[4] Wang Chen, Zhang Lipeng, Yin Yan. Study on the Impact of Ultra-long Highway Tunnel Construction on Soil and Water Conservation and Its Countermeasures[J]. Construction Technology (Chinese and English), 2024, 53(03):105-109.

[5] Zhou Zaixing. Key Construction Technology for the Whole Lifting and Erection of Large-span Steel Beams of the Hong Kong-Zhuhai-Macao Bridge[J/OL]. Industrial Architecture:1-10.

[6] Zhao Jiajin. Study on the Mechanical Properties of Granite Residual Soil in the Southeastern Region[D]. Shanghai Normal University, 2024.

[7] Chi Lianyang. Key Technologies for Improving Deformation Durability of Comprehensive Utility Tunnels under High Groundwater Level Silt Foundation Conditions[D]. Shandong Jiaotong University, 2024.

[8] Gao Zhijie. Study on Geochemical Characteristics and Genesis of Rocks in Beishan Huangmaotu Ditch South Rock Mass[J]. Sichuan Geology Journal, 2023, 43(02):347-351+362.

[9] Huang Xin, Jin Menggui, Liang Xing, et al. Hydrochemistry and Rock Weathering Processes in the Qingyi River Basin[J]. Earth Science, 2024, 49(07):2614-2626.

[10] Liu Ruonan, Chi Yunping, Xie Yuanyun, et al. Elemental Geochemical Characteristics and Environmental Significance of Granite Weathering Profiles in the Mid-temperate Climate Zone[J]. Geological Science, 2023, 58(04):1373-1393.

[11] Chen Weijuan. Discussion on the Relationship between Various Indicators of Red Clay Geotechnical Testing[J].

Urban Construction Theory Research (Electronic Edition), 2024,(15):79-81.
[12] Zhou Libo. Characteristics and Engineering Applications of Luoyang Sandy Gravel Soil[J]. Jiangxi Building Materials, 2024,(04):170-174.
[13] Zhang Liyang, Hao Yingqi, Ma Wei, et al. Analysis of Soil Mechanics Experimental Teaching in Local Universities under the New Engineering Background[J]. Chizhou University Journal, 2023, 37(03):147-149.
[14] Mo Wei, Feng Yuxin, Mo Qiufeng, et al. Study on the Correlation between Mineralogical Properties and Performance Indicators of Bentonite[J]. Guangxi University Journal (Natural Science Edition), 2024, 49(03):676-685.
[15] Chen Xingjuan. Discussion on the relationship between various indexes of geotechnical test of red clay[J]. Urban Construction Theory Research (Electronic Edition), 2024(15):79-81.