Offshore Cofferdam Construction Technology with Bagged Soil Solidification

La technologie de endiguement dans l'eau avec sac de moulage durci

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ABSTRACT : This paper focuses on the engineering characters of bagged soil with low dosage of cement, researching on the influence factors of strength, proposing that the bagged soil has a higher shearing capacity and higher water content and has a good integrity with the geotextile bag. Meanwhile, the construction technology for bagged soil solidification was also studied to establish a mixing system and a filling system and established a practical construction technology. Application has made a good embankment with bagged soil solidification.

RÉSUMÉ : dans cette article il étude facteur de l'influence de résistance du ciment durci mélange faible l'eau et des propriétés du projet sur la base de projets concrets sur le terrain,, a souligné que le sol solidifié présentant une plus grande résistance au cisaillement élevée et de teneur en eau, l'action commune avec le sac de moulage a une bonne intégrité.Dans le même temps, il a effectué une étude de procédé de construction de sac de moulage solidifié et recherche et développe une système d'agitation, système de remplissage tel matériel de construction , formant un modèle du processus et de procédure de construction pratique, l'utilisation de boue locale pour construir un digue en sac de moulage solidifié du sol avec succès, et de bonne qualité.

KEYWORDS: Solidified soil, Strength, cofferdam

1 INTRODUCTION

With the development of economy, more and more artificial islands and harbors are needed, and lots of seawalls and causeways are built. The seawalls and causeways are built by riprapping or hydraulic reclamation in traditional way. Masses of sand and gravel are required by using this construction method. For the area shorting of sand and gravel, this construction method makes the rising of the engineering cost. While for the area with much sand and gravel, this construction method will harm the local environment. The bagged soil solidification technique is a engineering method that direct digging the underwater soft soil, injecting the soil stabilizer (such as cement), mixing the soil and soil stabilizer by mechanical agitation until forming flowing mixed soil, filling this mixture into the large geotechnical mold bag, then placing the bags into position to forming the seawalls or causeways[1][2]. This construction technique can save lots of engineering material cost, reducing the damage of the waves on the cofferdam especially in the cofferdam forming period. Therefore, it is necessary to study the offshore cofferdam construction technology with bagged soil solidification.

2 THE PROPERTIES OF SOLIDIFIED SOIL WITH LOW ADMIXTURE AMOUNT

Due to the main role of bagged soil solidification is filling the interspace. There are no special requirements on the strength of bagged soil solidification to satisfy the gravity load. The bagged soil solidification is mainly to meet the requirements of bearing capacity and settlement control standard on the construction stage and after construction stage. In order to reduce the engineering cost, the amount of admixture should be low. Former research shows that the mixed engineering material can meet the need of design and construction of bagged soil solidification technique when the cement is 8%. Thus, studies should focus on the engineering feature of solidified soil with low admixture amount.

2.1 *The factors affected the strength of solidified soil*

Many factors can influence the strength of solidified soil, such as the property of natural soil, the amount of cement, curing condition, strength testing method and so on.

(1) The relationship between the natural soil moisture content and solidified soil strength

Figure 1 shows the solidified soil strength for different natural soil moisture with the same amount of cement. From the figure, we can see that for solidified soil with same cement amount and same testing method, the larger natural soil moisture, the higher unconfined compressive strength is.

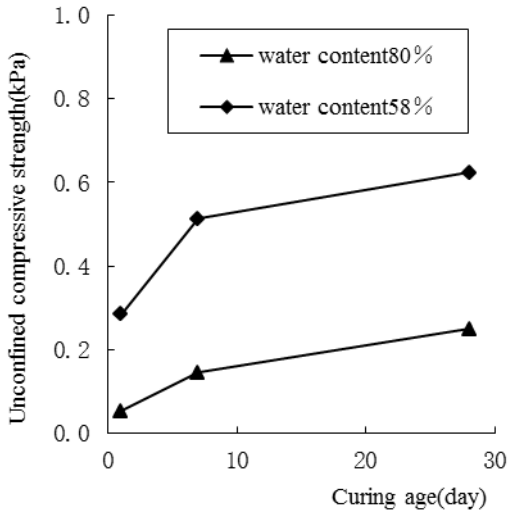

Figure 1. The unconfined compressive strength for solidified soil with different natural moisture

(2) The relationship between cement amount and the solidified soil strength

Laboratory test results illustrate that the more cement, the higher unconfined compressive strength is. The results are displayed in Figure 2.

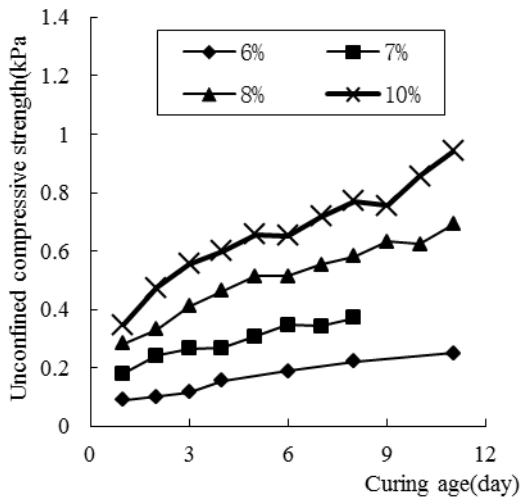

Figure 2 The unconfined compressive strength with different cement amount (Cement: P.O.32.5, moisture content of 58%)

(3) The relationship between unconfined compressive strength and the property of natural soil

The mud, silt clay, mucky silty clay and silt are used for mixing in the tests. The cement grade is P.O.32.5, and the amount of cement is 8%. The results are shown in Figure 3. This figure illustrates that the strength of mixed soil used mucky silty clay and silt are higher than the mixed soil used mud, silt clay. The strength growth rules with the increasing curing days for all 4 kinds of solidified soil are almost the same. This phenomenon reveals that the cement amount for these 4 kinds of natural soil can be calculated based on the mud. This makes the digging natural soil more convenient.

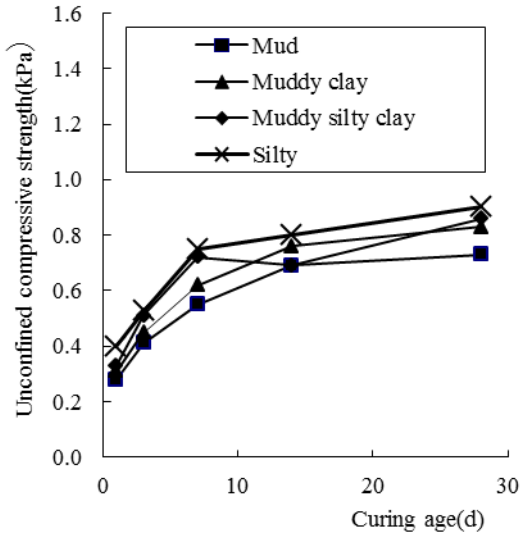

Figure 3 The unconfined compressive strength

Based on larges of lab tests' result, we believe that the solidified soil strength is affected by the natural soil moisture, the property of natural soil and the amount of cement. The solidified soil strength is little influenced by the curing condition, the cement's mixing method, the volume of water used in mixing and the loading rate in strength test.

2.2 *The engineering properties of solidified soil*

The engineering properties of solidified soil (such as physical condition, structure, physical property indexes) are much different from the natural soil. The solidified soil moisture is 20% ~ 50% higher than the natural soil. The density of solidified soil is 10% ~ 15% smaller than the natural soil. The void ratio of solidified soil is twice as large as the natural soil. The liquid limit of solidified soil is 3 ~ 4 times as large as the natural soil. The particle size of solidified soil is almost the same with the natural soil.

Compared with the original mud soil, the structure and state of the solidified soil changed radically. The original mud soil is in the soft plastic to flow plastic statement before mixed. Especially adding some water on the process mixing, the strength of the original mud is considered zero. When add some curing agent, there are not great changes of the water content and unit weight. Due to the interaction of soil particle and cement, the cohesive force and supporting role increase and a relatively complete skeleton is formed, which make the strength of solidified soil increased significantly. According to condition of the site soil tests, the solidified soil generally form a certain strength within 24h, the solidified soil become block structure, in figure 4. The block structure has a certain cohesive strength, can still maintain good integrity under a small wave force action.

Figure 4 The statement of solidified soil after 24 h

The shear strength feature of solidified soil is more similar with the consolidated clay, having high shear strength. According to many samples' testing results, the cohesion after 28 days curing is about 58±30kPa, and the internal friction angle is about 29±10°.

3 CONSTRUCTION TECHNOLOGY AND PROCESS

The construction technology of bagged soil solidification for offshore cofferdam construction is very complex. The key steps are introduced as followed: sewing and processing the mod bag; placing the first layer of mod bag; mixing the solidified soil; filling the mod bags with the mixed solidified soil by pumping; constructing the next layer until the strength of this layer meeting the requirement in Figure 5; doing as the former steps until the offshore cofferdam is already built [3].

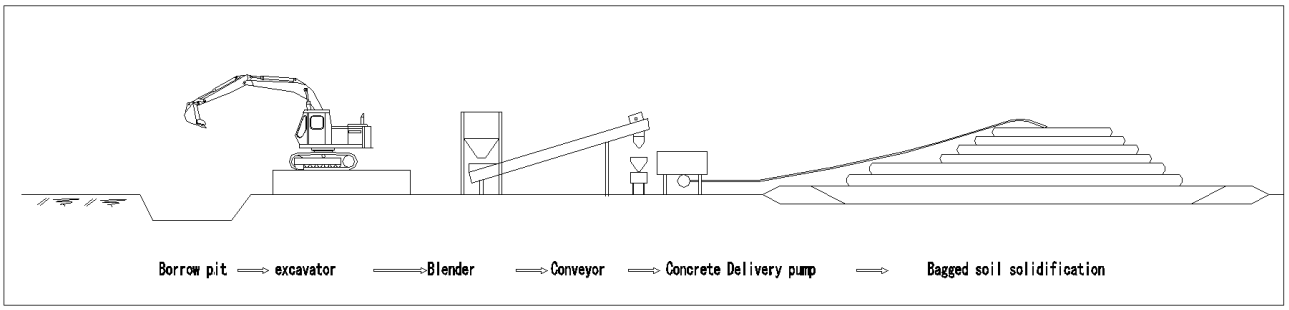

Figure 5 the construction schematic of bagged Soil Solidification

The key technique in the whole process is the solidified soil mixing system. Therefore, we develop the solidified soil mixing machine. This machine is consist of hydraulic steel grille board for mud squeezing system, cement counting and stirring cage, solidified soil stirring tank, and mud pumping and stirring cage these four parts. This machine can ensure the right amount of cement and mixing the cement with the natural soil. The hydraulic steel grille board for mud squeezing system can remove the impurities in the mud. The cement counting and stirring cage can count the cement mount. The solidified soil stirring tank, and mud pumping and stirring cage can mix the solidified soil evenly and then pumping the mixture into the mod bag.

4 CASE STUDY

4.1 Engineering case

The first-stage of west inner seawall of the north seawall in Tianjin port is 2000 m long. The core of seawall is constructed with the bagged soil solidification technique. The surface of seawall is covered with the mod bag filling with concrete. The bagged soil solidification in the seawall core has 7 layers, and the design thickness of each layer is 50cm. The typical cross-section is illustrated in Figure 6.

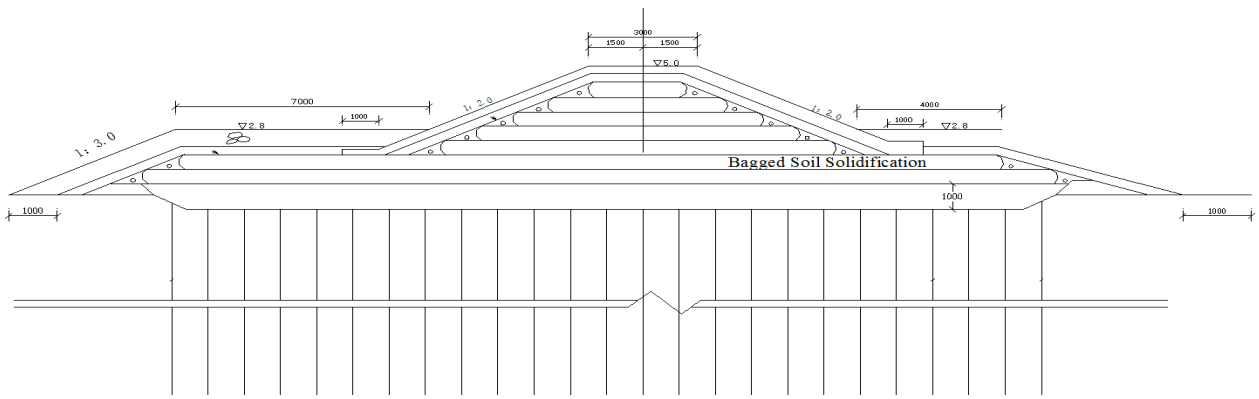

Figure 6 The typical cross-section

4.2 Applications of bagged solidified soil technique

This engineering case used the local mud as the mixing material. 8% of cement is mixed with the natural soil using the solidified soil mixing machine to produce the solidified soil constructing the core of seawall. The seawall is shown in Figure 5. The in-site test and theoretical analysis results show that the residual settlement after the completion of seawall is 30 ~ 50 cm. This settlement is caused by the settlement of basis and the compression of solidfied soil. This phenomenon can be reduced by reserving a part of settlement before construction or extend the project duration for mixing and placing the solidified soil mod bag.

Figure 7 The completion of seawall constructed with the mod bagged soil solidification technique

5 CONCLUSIONS

This paper studies the engineering feature and construction process of bagged soil solidification technique. The local mud is made full use in construction by using this technique. The engineering case shows this technique is feasible and the quality of seawall made with this technique is well.

(1) The solidified soil with low cement amount has high shear strength and high moisture. The solidified soil with 8% cement can meet the design and construction requirements of the bagged soil solidification technique.

(2) The strength of solidified soil with low cement amount is relative with the natural soil moisture, the property of natural soil, the cement amount. It is little affected by the curing condition, the mixing way of cement, the volume of water used in mixing and the loading rate in testing.

(3) The construction process is studied, and the solidified soil mixing machine was developed. A systematical construction process for offshore cofferdam constructing with bagged soil solidification technique is formed.

6 ACKNOWLEDGEMENTS

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