Progressive Agriculture 32 (1): 71-77, 2020 ISSN: 1017 - 8139

Progressive Agriculture
Journal homepage:http://www.banglajol.info/index.php/PA

Properties of locally available river dredged soil stabilized with cement

MB Hossain*, Z Barman, M Dey

Department of Farm Structure and Environmental Engineering, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.

Abstract

In Bangladesh, the topsoil of agricultural land is being used to manufacture burnt clay bricks for a long time. This is one of the major reasons for reducing the cultivable land every year. But, we have a huge amount of River Dredged Soil (RDS) available that could be used for manufacturing building materials as an alternate to the conventional bricks. In this regard, the present study has been performed to investigate various properties of RDS from the Brahmaputra River and different mixes of RDS containing different percentages of cement content. The physical properties such as specific gravity, unit weight, mean diameter, maximum dry density and optimum moisture content of RDS were determined following standard procedures. Cylindrical specimens of RDS were prepared by mixing with different amounts of cement content. All the specimens were cured for 7, 14, and 28 days before testing. Water absorption of the RDS-cement specimens after 28 days was found between 14 to 18% which is in the range of first-class burnt clay brick. It was found that the water absorption decreases with the increase in the percentages of cement content. The unconfined compressive strength was observed to increase with the increment of cement content as well as curing age. The maximum unconfined strength was recorded for the specimens containing 14% cement and the rate of strength increment was about 45% in two weeks. It means the addition of cement with RDS will definitely increase the strength. But, the maximum use of cement must be decided based on the required strength and economic consideration. The deformation at failure was found decrease with the increase in cement content. This indicates that the stiffness of the stabilized RDS would increase upon the increment of cement content. Based on the above test results, it is concluded that the dredged soil from Brahmaputra River can be stabilized with cement for making compressed earth block which would be an alternative to the burnt clay brick that uses valued agricultural soil as raw material.

Key words: River dredged soil, cement stabilization, soil-cement, compressed stabilized earth block, unconfined compressive strength

 ***Corresponding Author:** bellal@bau.edu.bd

Introduction

When man learned to build homes, the earth was undoubtedly being one of the most widely used traditional construction materials in the world. Raw earth was one of the first, oldest and most traditional building materials to be used by man and it has a heritage dating back over at least 10,000 years (Islam, 2010). Earthen buildings have the benefit that they can be built from on-site materials rather than materials with high carbon footprints (Holliday *et al.*, 2016). However, there are few undesirable properties such as loss of strength when saturated with water, erosion due to wind or driving rain and poor dimensional stability (Islam and Haque, 2009; Islam and Iwashita, 2010). Durability and strength are also major problems. Stabilization is the process of blending and mixing materials with a soil to improve the soil's strength and durability. Stabilized soil has been used for the construction of sub-bases of roads, pavements and rammed earth walls. Cement can be used to stabilize any type of soil, without those having organic content greater than 2% or having pH lower than 5.5 (ACI, 1990). Cement stabilized soil can be compacted into a high density block, which can be termed as soil-cement block. Such blocks are used for load bearing masonry structures. The use of cement as an improving agent in various applications in ground engineering is quite common. Soil improvement by the use of cement can also be achieved by means of other techniques, e.g. deep soil mixing, jet grouting and construction of lime or cement-stabilized soil columns. Primarily, it has been used as an improvement material for the stabilization of sub-bases in road foundations (Marsellos *et al.*, 1986). Additionally, in some developing countries, it has been extensively used for the production of compacted soil-cement blocks, which are used for the construction of masonry buildings (Venkatarama Reddy *et. al.*, 2007).

One of the widely used construction materials in Bangladesh is the burnt clay brick. With the increased urge of brick manufacturing, the annual brick production has reached the number of 23 billion (DoE, 2017). Every year large amount of agricultural topsoil is being used in the production of bricks, which is a threat to our food security. To overcome this situation our Government has already taken some steps to reduce the use of agricultural topsoil to 0% within next 5 years for the production of burnt clay bricks. Dredging is essential to maintain and increase the water carrying capacity of the rivers and channels which will reduce flooding propensity in Bangladesh. Besides, the use of the River Dredged Soil (RDS) for manufacturing CSEB will save agricultural topsoil and forest resources for the production of burnt clay bricks and will reduce carbon emission. With a view to the above discussion, the present study was aimed to evaluate the properties of river dredged soil collected from Brahmaputra River and to prepare four different cement stabilized RDS specimens and assess their physical and mechanical characteristics.

Materials and Methods

The experimental program was carried out in two parts. First, the physical properties of the RDS were determined; then, the strength and physical properties of RDS with different cement content were investigated following a discussion on the test results. All the experimental programs were carried out at the Material Testing Lab and Soil Mechanics Lab in the department of Farm Structure and Environmental Engineering of Bangladesh Agricultural University.

Material collection and preparation: Dredging is a displacement of soil carried out under water. During the dredging of the river bed sludge of the Brahmaputra River, the soil was collected from Char Nilakshima, Mymensingh Sadar (Figure 1a). The dredged soil was transported directly to the Material testing laboratory of the Bangladesh Agricultural University. As the soil was partially wet, it was air dried spreading over a large tray until constant moisture content achieved (Figure 1b). The soil was then sieved through a 4.76 mm sieve.

Figure 1a. River Dredged Soil (RDS) piled at riverside.

Figure 1b. River Dredged Soil (RDS) after air drying in laboratory.

Tests of physical properties of RDS: The physical properties such as moisture content, unit weight, specific gravity, sieve analysis was determined in the Laboratory. The sieve analysis of the RDS was performed according to ASTM D422 standard test method. The specific gravity of the RDS was determined by the Pycnometer method.

For soil to be used for bearing load, the compaction characteristic is important to know the maximum dry density and its corresponding moisture content. The compaction (standard proctor) test was performed according to ASTM D698 to know the highest density and optimum moisture content of the RDS.

Preparation of cylindrical specimens: Four different mixes of RDS with cement were prepared for making cylindrical specimens. The cement content of four different percentages (4%, 8%, 12% and 14%) was added to the RDS by weight. The RDS-cement admixtures were mixed with water according to the optimum moisture content of the soil obtained from the compaction test. The optimum moisture content of the RDS was found at about 19%. The soil-cement admixtures were mixed thoroughly using a motorized mixer machine (Figure 2).

The cylindrical specimens were prepared in cast iron molds of size 6” in height and 3” in diameter. Molds were first set up properly with the base of mold by nut-bolt using wrench for making cylindrical specimens. A total of 40 test cylinders were prepared. The average moisture content of the cylindrical specimens was calculated between 17% - 20% by oven drying method. All the specimens de-molded carefully. The cylinders after de-molding were kept on a polythene sheet and curing was done by sprinkling water using a sprayer (Figure 3). The curing period of specimens was up to 28 days.

Figure 2. Mixture machine used for mixing cement with RDS**.**

Figure 3. Curing operation using sprayer.

Test of unconfined compressive strength: Unconfined compression tests have been used in most of the experimental programs reported in the literature in order to evaluate the effectiveness of the stabilization with cement or to access the relevance of specific factors in influencing the strength of soil–cement admixtures. The unconfined compression tests were carried out up to failure, with the maximum load. Compressive strength is calculated by dividing the maximum load by the original loading surface area of a specimen in an unconfined compression test. The test method was followed according to ASTM D2166 standard. A displacement transducer with a data logger was attached to the compression testing machine to record the deformation of the cylindrical specimens at ultimate load.

For testing unconfined compression strength, 3 nos. of each RDS-cement specimens were taken after 7, 14 and 28 days of curing by sprinkling water. Each test specimen was placed onto the flat surface of a circular pressure plate of the compression testing machine (Figure 4). The load was applied very slowly until the cylindrical specimen fails and the ultimate load for specimens was recorded.

Figure 4. Test setup for unconfined compression test with data logger.

Results and Discussion

The particle size distribution of the RDS was known through sieve analysis. Figure 5 shows the distribution of RDS sample. In the sample, the sand content was 72%, silt and clay fraction was 23% and 5% was gravel. A summary of the test results of various physical properties of RDS are presented in Table. 1.

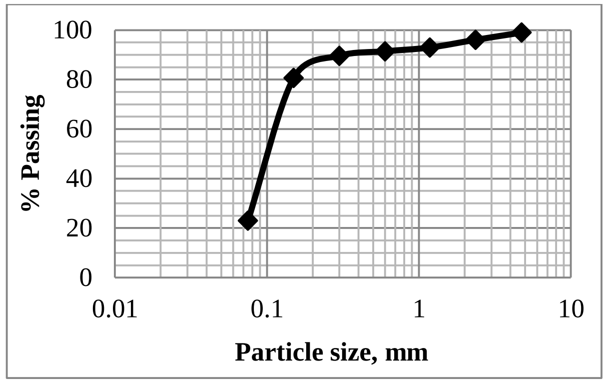

Figure 5. Particle size distribution curve of RDS.

Table 1. Physical properties of RDS.

Physical property	value
Specific gravity	2.63
Unit weight (gm/cm^3)	1.370
Mean diameter, D_{50} (mm)	0.10
Maximum dry density (gm/cm^3)	1.71
Optimum moisture content	19%

The water absorption was determined according to ASTM C140 standard. Water absorption of RDS-cement cylindrical specimens has been tested after 28days of curing.

The result indicates that the water absorption of RDS specimen containing 4% cement is about 18% (Figure 6). A decreasing trend of water absorption was observed with the increase of cement content. The water absorption was found a minimum of 14% for the RDS having 14% cement content. Previous research also revealed the similar characteristics.

In a study, Walker (1997) observed that the water absorption and porosity of some cement stabilized compressed earth blocks and mortars increase with its clay content and decrease with the increasing cement content.

The Unconfined Compressive Strength (UCS) of the RDS with different cement content was tested at 7, 14, and 28 days of curing.

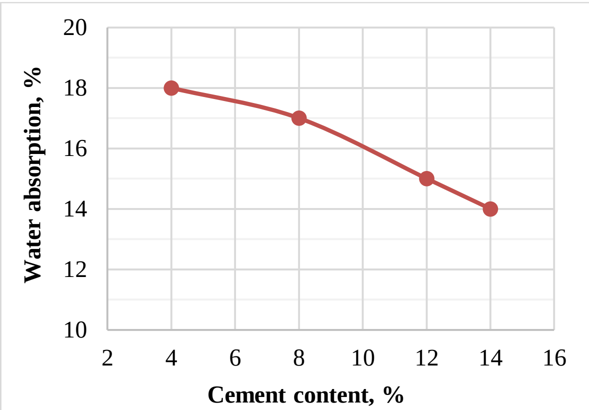

Figure 6. Water absorption of RDS varying the percentage of cement content.

A digital compression testing machine was used for this purpose. The unconfined compressive strength of compressed RDS-cement cylindrical specimens with respect to the curing period is shown in Figure 7. It is seen that after 14 days, the strength values did not increase significantly. But, after 28 days of curing, the compressive strength of all specimens increased notably except those containing 4% cement.

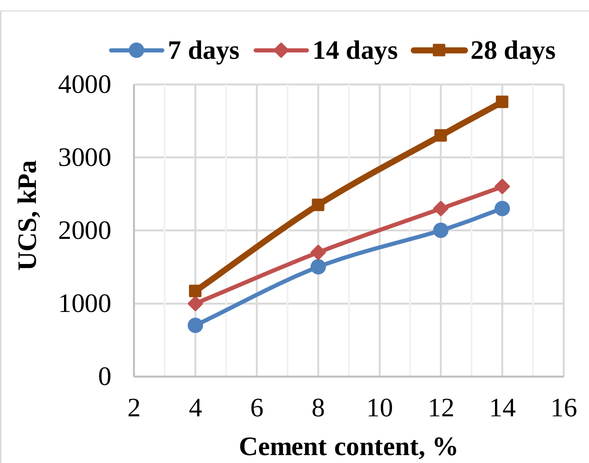

Figure 7. UCS vs cement content curves for different curing periods.

The highest average value of UCS was recorded as 3760kPa in case of the specimens having cement content of 14%. In the last 14 days, the highest strength increment was found nearly 45%. So, it is obvious that the compressive strength is positively related with the percentage of cement content irrespective of curing period. Davies and Fendukly (1994) reported similar cases where the compressive strength of soil-cement blocks increases with the percentages of stabilizer and with the curing age.

The deformation data of the specimens was recorded at ultimate load using a displacement transducer. Figure 8 shows the variations of maximum deformation and its corresponding compressive strength for different cement content after 28 days of curing. It is observed that the deformation decreases with increasing cement content and compressive strength increases with increasing cement content. This indicates that the stiffness of the stabilized RDS-cement specimens increases with the increase in percentage of cement content. So, there is an inverse relationship observed between deformation and compressive strength with cement content.

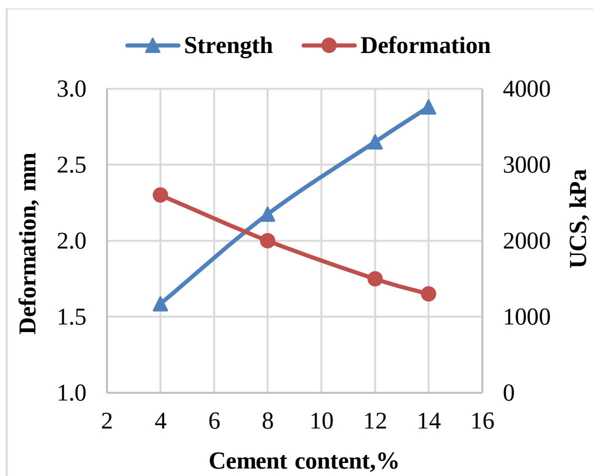

Figure 8. Variations of maximum deformation and compressive strength for different cement content.

Figure 9 shows the typical failure mode observed during unconfined compression test of RDS-cement specimens. The failure was initiated by splitting and ended with crushing at ultimate load.

Figure 9. Typical failure pattern of the stabilized RDS-cement specimen under compression

It was also observed that the rate of the compressive stress fall-off was faster in specimens with higher cement content. This phenomenon is mainly due to the fact that the increased cement content increases the brittleness of the material.

Conclusions

In this study, various properties of locally available river dredged soil were investigated. The soil was then stabilized with four different percentages (4%, 8%, 12% and 14%) of cement content. Finally, the cement stabilized RDS specimens were tested to determine its physical and strength properties. The key focus was to assess the suitability of cement stabilized RDS as an alternative raw material in the construction industry. Based on the test results, the conclusions obtained from this research work can be summarized as follows:

1. In the RDS, the sand content is found 72%, silt and clay fraction are 23% with 5% gravel. The sp. gr. was 2.63 and the mean particle size was 0.10 mm. The maximum dry density and optimum moisture content of the RDS were found 1.71 gm/cm^3 and 19% respectively.
2. The water absorption of RDS-cement specimens ranges from 14%-18% which was found decreasing with increasing cement content.
3. The highest average value of unconfined compressive strength was recorded as 3760kPa in case of the specimens having cement content of 14%. The highest strength increment was found nearly 45% from 14 days to 28 days of curing. The compressive strength was positively related to the percentage of cement content irrespective of curing periods.
4. An inverse relationship is observed between deformation and compressive strength of the stabilized RDS with the cement content. It has also found that higher cement content in specimens reduced deformation at failure and changed soil behavior to a noticeable stiffness behavior.

The above findings indicated that the dredged soil of Brahmaputra River has the characteristics of being stabilized with cement which has improved its engineering properties significantly. Thus, the present study recommends the RDS for making rammed earth block which would be an alternative to the conventional burnt clay brick that uses valuable agricultural topsoil.

References

ACI (2009). Report on soil Cement, ACI Committee 230.1R-09, American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI, USA.

ASTM C140 (2001). Standard test method for laboratory water absorption test. Annual Book of ASTM Standards, West Conshohocken, PA, USA.

ASTM D2166 (2000). Standard test method for unconfined compressive strength of cohesive soil. Annual Book of ASTM Standards, West Conshohocken, PA, USA.

ASTM D422 (2002). Standard test method for particle size analysis of soils. Annual Book of ASTM Standards, West Conshohocken, PA, USA.

ASTM D698 (2000). Standard test method for laboratory compaction characteristics of soil using standard effort. Annual Book of ASTM Standards, West Conshohocken, PA, USA

Davies J, Fendukly LM (1994). Behaviour of soil-cement in unconfined dynamic compression. Journal of Materials Science, 29: 3255-3260.

DoE (2017). National strategy for sustainable brick production in Bangladesh. Department of environment, Ministry of environment and forests, Government of the people's republic of Bangladesh.

Holliday L, Ramseyer C, Reyes M, Butko D (2016). Building with compressed earth block within the building code. ASCE Journal of Architectural Engineering. 22(3): 1-13.

Islam MS (2010). Present status and problems of earthen architecture in Bangladesh: role of education, Proceedings of the Seminar TERRA Education, France, 176–184.

Islam MS, Haque I (2009). Earthen housing for better adaptation to climate change in Bangladesh, Conference on climate change impacts and adaptation strategies for Bangladesh, Dhaka, Bangladesh.

Islam MS, Iwashita K (2010). Earthquake resistance of adobe reinforced by low cost traditional materials. Journal of natural disaster science, Japan Society for Natural Disaster and Science, Japan, 32(1): 1-21.

Marsellos N, Christoulas S, Kolias S (1986). Use of fly-ash in roadworks. Bulletin of Public Works Research Center, 3-4: 113-129.

Venkatarama RBV, Lal R, Nanjunda RKS (2007). Optimum soil grading for the soil-cement blocks. Journal of Materials in Civil Engineering, ASCE, 19(2): 139-148.

Walker P, Stace T (1997). Properties of some cement stabilized compressed earth blocks and mortars. Materials and Structures, 30: 545-551.