A Review on sustainable reuse of dredged sediments in earthwork infrastructures

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ABSTRACT

Earth structures like embankments involve the use of a huge quantity of soil. Major sources of borrow soil are natural hills and embankments which are to be preserved to prevent structural instability and environmental problems. Bulk quantities of soil are dredged out from various waterfront projects, but poor engineering properties limit their use in construction projects. Stabilization of sediments with suitable reagents to use in embankment construction is considered a sustainable approach. With this motive, many studies are being conducted focusing on finding solutions to propose a sustainable alternative for earthwork infrastructural materials. Latest studies are developing engineering improvement of dredged sediments as a solution for the scarcity of earthen resources for construction. The purpose of this paper is to review the results of testing conducted on dredged sediment and their suitability in construction application when stabilized with cementitious materials, the effect of variation of cementitious materials on stiffness improvement of dredge soil, and application efficiency in the reuse of sediments in earthwork infrastructural projects such as highways, railways, and other construction projects.

Keywords: Dredged Sediments; Earthwork

1 INTRODUCTION

Dredged material (DM) is explained as material dredged from the bottom of waterways. Dredging of sediments is essential for the efficient navigation and proper maintenance of harbor etc.(Nguyen et. al. 2018). The sediment deposition in water bodies set up problems in transportation and shipping. Due to the difficulty of identification of storage sites and disposal methods, the removal of dredged sediments from water bodies becomes a major problem. In Thailand, nearly a billion cubic meters of soils are dredged every year for proper navigation in waterways all over the country. These sediments are directly disposed of in the sea or dumping land sites (Kamali et al. 2008). In dredged sediments, chemical stabilization is done by mixing sediment soil with cement, and hydration of cement will result in hardening of soil-cement mixture. Enhanced studies of dredge soil to determine the optimization of stabilizers or hydration effect of the additives aims in improving the soil strength by solidification method (Azhar et. al. 2014).

To propose a solution for sediment disposal, reuse of dredged sediments in pavement materials, such as subgrade, selected material for sub-base and base courses, is considered and highly encouraged. However, most of these dredged sediments from reservoirs are categorized as fine sediments such as silt and clay with poor engineering properties. Therefore, it is essential to stabilize the dredged soil with cementitious reagents to reuse the sediment as pavement materials. Chemical stabilization with ordinary Portland cement (OPC) is one of the most convenient methods of improvement in problematic soils for various applications, resulting in high UCC strength (qu) (Horpibulsuk et al. 2010,2011 Tongwei et al. 2014; Mohammadinia et al. 2015; Jamsawang et al. 2017).

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The basic properties of raw dredged sediment were assessed by various researchers based on the specifications of ASTM and IS standards. The major constituents in dredged sediments include contaminants, organic matter varies from 5% to 30%, high water content ranges from 50% to 200%, and comparatively small particle size of 300 mm. Hence to improve the index and engineering properties, specific methods of characterization and appropriate treatment techniques (calcination, chemical treatment, etc.) is required (Amar et al.2021).

2 DREDGED SEDIMENT RESOURCES AND APPLICATIONS

In coastal areas, dredging of sediment is undertaken for enhancing the draft, maintaining proper navigation of port for harbor activity, and removal of contaminated sediments. A large amount of sediments dredged out disposed of inland, marine and dead lake regions.es, in France, Port of Dunkerque, one of the largest industrial harbor situated on the North Sea coast the important sedimentary activity of tides causes 3.5 millions cubic meters of materials, Which is dredged every year. Dumped marine clay near constructions will cause a lot of problems even after many years. Untreated dredged marine clay is a poor engineering material due to its weakness in engineering properties and cannot support structures on it, Improving dredged marine clay will be a definite solution for most of the foundation problems and it can minimize the expense too. Various stabilization methods are experimented with by researchers with lime, cement, fly ash, etc.Sediments collected from the harbor represent a good resource for civil engineering works. In comparison to sands, fine-dredged material contains high moisture content, presence of organic matters and pollutants, etc. (Dubois et.al. 2011). The presence of organic matter induces water retention capacity of sediment (Mustin, 1987) but salt content reduces the plasticity properties of swelling clay in dredged sediments (Van Paassen, 2002).

For effective utilization of the dredge material proper treatments to reduce water content and organic matter is required.Angular-shaped sediment dredged from the reservoir is less contaminated and less porous than crushed limestone sand with excess chloride content was used as a partial replacement of sand. The source of sediment was the port of Barcelona reported in Limeira et al., 2011. Studies were conducted to use reservoir sediment as a partial replacement of cement in the production of concrete (Junakova and Junak, 2017). The strength attainment of concrete got reduced due to the partial replacement and developed strength varied from 80% to 86% at 28 to 90 days. The study concluded as careful supervision is required for the use of reservoir sediments as binders in concrete.An experiment was conducted by Vander Wal et al. 2011. to test the strategy of replenishing beach and land reclamation using dredge sediments in Westerchelde estuary. Clear sand from the water body was deposited as seawards of an eroding tidal flat to improve the morphology. By frequent inspection on successive five years, it was found that the condition of the tidal flat was improving.

3 SEDIMENTS TREATMENT METHODS

The treatment methods aim to improve the poor engineering properties of dredged material to fulfill the requirements of a specific application. The enhancement of strength and other characteristics depends on the ability of sediments to react with the constituents of pozzolana. Each processing technique will differ based on their purpose of actions and chemical reactions. Generally, solidification methods adopted for problematic sediments tend to decrease their water content. Granular additive (compound of 35% of dredging sand (Dunkerque harbor) and 65% of quarry sand, quarry of Boulonnais) and twice the amount of dry fine sediment can artificially decrease the water content. Also, it can reduce the influence of organic content on strength attainment. For reinforcing the granular Skelton, use lime and cement proportions as per AASHTO (Dubois et. al. 2011).

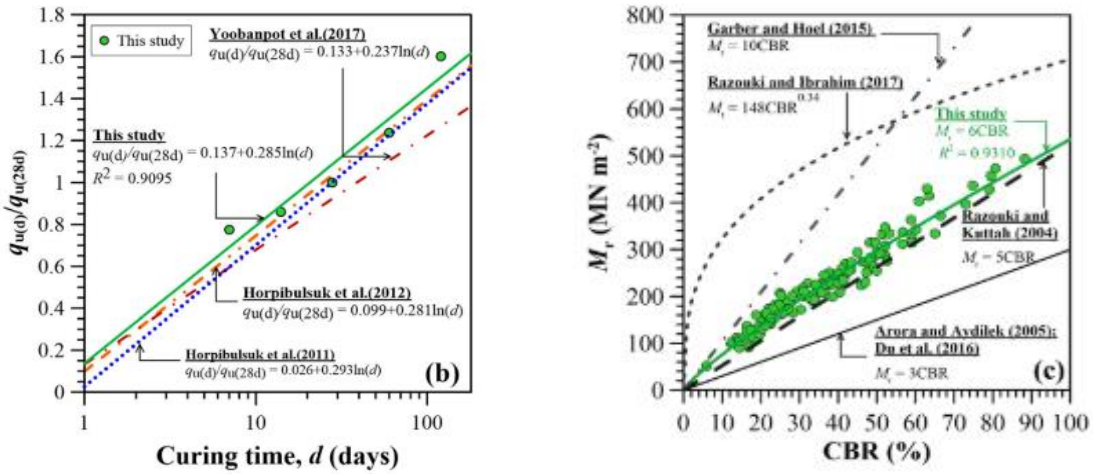

Figure 1. (b) qu at any curing time with respect to any 28-day qu and (c) Correlation of the CBR with qu (Yoobanpot et. al. 2020)

Figure 1. shows results of series of UCC, CBR, and Modulus of resilience tests were performed on oven-dried samples in the study of Yoobanpot et. al. using exclusively OPC and FA. OPC contents of 1.5, 2.5, 5, and 7.5% (by dry weight of sediment) and FA contents of 5, 10, 15, and 20% (by dry weight of sediment) were mixed with the sediments. Optimization of fly ash content on dredged sediment was quantified to be 10%, It increases the rate of improvement of qu, CBR, and Mr results of the samples using a combination of OPC and FA because 10% (Class C) FA produces the most suitable proportions of SiO2 and CaOH2 makes a large amount of CSH products. The results from various studies are based on the stabilization of uncontaminated dredged sediments in which, only the strength of the stabilized dredged sediment is considered for use as pavement materials.

Recent studies by Tomasevic et al. (2013), Wang et al. (2015), and Gupta et al. (2017) explain highly contaminated soil modified by OPC and FA shows high strength and low leachability due to the hydration and pozzolanic reactions of soil with sediments. When the FA content exceeded 10%, qu, CBR and Mr gradually attenuate. FA content above 10% may stop the OPC grains and challenge the interaction between water and OPC, which significantly reduces the degree of the hydration reaction, leading to a reduction in the formation of cementitious products of OPC and FA.

4 STABILIZED DREDGED SEDIMENT IN EARTHWORK PROJECTS

Many studies have been reported by several researchers all over the world regarding recycle and reuse of dredged soil. The studies based on the investigation on index and engineering properties of soil were reviewed in detail. The stabilized dredged sediment showed satisfactory results in the application of modified dredged soil for pavement constructions. Based on the study of Dubois et.al. 2011 (Table 1) to minimize the application of costly treatments in the preparation of sediments, it is necessary to avoid oxidation of organic matters in the soil during the storage period. If the water content of sediments is too high, then sediments proportion can be limited in the mix design for reusing the sediments, but a limit has to be fixed to keep an economical interest. The stabilized dredged soil showed significant improvement in CBR compared to raw dredge soil. By analyzing the CBR values from table 1 (Dubois et. al. 2011), it was clear that unsoaked SDM sample reached to the CBR values three to five times that of RDM, also in unsoaked condition it was 20 to 25 times more.

Table 1. Effective shear strength parameters and CBR of stabilized dredge blends (Dubois et.al. 2011)

	CIU					
	Maximum σ1/σ3 (ASTM D4767)		15% axial strain (ASTM D4767)		CBR (ASTM D1883)	
	ϕ	**C (kPa)**	ϕ	**C (kPa)**	Soaked	Unsoaked
Mix ID						
100% DM					3.1	19.3
DM-5E/0/10	21.7	10.2	28.7	37		
DM-2.5/7.5/25	45.6	4.3	42.7	17		
DM-0/20/0	32.7	17.5	40.2	45		
DM-2.5E/7.5N/10	50.6	19.4	45.2	0	74.7	60.2
DM-2.5/17.5/25	20.2	34.1	49.5	7	64.8	69.7
DM-2.5/17.5/75	39.2	21.3	8.8	449	79.4	107.82

The research in reservoir dredge sediment improvement is for developing pavement engineering, provide a new potential to enhance the sustainable method of construction of pavement layers, and also will ensure the durability of pavement layers. Dredged sediment management are failed to resolve in the context of sustainable development. Therefore, conventional methods such as disposal or immersion will be regulated [Tomasevic et.al. 2013]. Because sediments dredged from reservoirs have particular characteristics. Hence their use in construction applications is very challenging [Tongwei et. al.2014].

A lot of studies are involved in the replacement of additives by cementitious waste like fly ash, bottom ash, and slag in stabilization methods. This review studies the possibility of constructive application of problematic dredge soil with or without treatment in earthwork infrastructures. The dredged soil either was acting as a source of construction soil or just as a filler. Besides, the size and quantity of additives used are important to identify the suitability and effectiveness in stabilizing the poor soils. Previous studies for re-using sediments in road construction have determined to use the stabilization technique by cementitious additives. To obtain sufficient strengths, sediments are required to treat with a large proportion of hydraulic binder, due to the effect of high specific surface of sediments (Boutouil, 1998) and the presence of organic matters will decrease the formation of hydrates, causing an alteration of strengths for the material in an application (Kujala et al., 1996; Clare and Sherwood, 1954).

The proportion of stabilizing agents with dredged sediments sometimes shows interesting results by strengthening the granular skeleton (Colin, 2003). Replacement of conventional materials by stabilized dredge sediments can reduce the construction cost of new roads. Hence it can be considered in the sub-base part of urban roads and stabilized sediment on the surface of rural roads. The roads were durable and reduced the construction cost and increased their durability than that of normal road, indicated by the resilient modulus value according to recommendations of Austroads (2017), In the study of Dabwan et al. 2017, solidified sea bottom sediment used for the construction of tidal flat in Ago Bay, Japan. They developed a solidification system of sea bottom sediments by adding hardener and soil conditioner after analyzing the environmental factors, total organic carbon, loss on ignition, water content, and particle size distribution. The proportion of sediment with sand was finalized at 70:30.

For the application of stabilized sediment in earthwork projects such as road materials in cold climates, it is essential to study both freeze-thaw durability and alternate wetting drying durability tests also, The study promise that the stabilized dredged sediment has sufficient residual strength for maintaining the service life of the road, recommended by Tripathy and Rao (2009). Tebaldi et al. (2016), Wang et al. (2018), and Yilmaz and Fidan(2018). Tang et al. (2011), Kampala and Horpibulsuk (2013), and Kampala et al. (2014) study shows that stabilized dredged soils possess durability against wetting–drying cycles and maintenance cost is less.

5 CONCLUSIONS

The literature review is about the beneficial use of dredged sediment in geotechnical applications. Sediments, when they are used in the field, should give better performance even under adverse conditions like floods. With optimized treatment methods, some beneficial properties can be enabled or improved. It is observed that due to poor engineering properties and lack of a replaceable method of stabilization, the applications for sustainable construction work in dredged sediments are not made to the possible extent. For the geotechnical applications in India, the dredge sediments themselves can be considered as a primary source of soil due to the availability of million cubic sediments from marine, lakes, rivers, and reservoirs. But still, all over the country, the sediment is treated as waste soil.

There is a considerable scope of the study, regarding the sustainable management and recycling of dredged sediments from water bodies. By analyzing the aforementioned studies on dredged soil we can see that it is possible to improve the strength properties of sediments to the specified requirement of construction soil by optimization with cementitious additives, by which the same, waste soil can excel to conventional construction soil. From the past studies, dredged sediments have been used in several other applications also, including cement, brick, etc. More recently, the introduction of dredged sediments as fillers and raw soil for embankment construction also provided desired research outputs.

By analyzing the past studies related to sediment reuse in engineering projects it is found that most of the studies are done on contaminated marine sediment. The Source of sediments is not only confined to the oceanic field but also in all other water bodies including rivers and reservoirs. For better maintenance of rivers, lakes, and reservoirs dredging is essential and producing the bulk amount of sediments with less toxic pollutants. However, for practical application, it is necessary to apply some stabilizing or solidification techniques after systematic investigations for the characterization of each type of sediment. Dredge sediments from freshwater bodies may also give a reliable alternate source of sustainable construction material.

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