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STRENGTH OF CONCRETE MADE FROM DREDGED SEDIMENTS

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Graphical abstract

Abstract

Sea and river dredging has produced a large volume of dredged waste over the years which could trigger geo-hazards including dispersion of contamination from sediments. One of the ways to overcome this issue is by incorporating it into geotechnical engineering purposes including the production of concrete for foundation, retaining wall and highway construction. This research aims to investigate the strength of concrete made from dredged sediments and to compare it with the strength of conventional concrete. This research emphasises on the usage of two types of dredge waste; silt and sand, obtained from Kuala Perlis, Perlis and Sungai Bebar, Pahang, respectively. The dredged sediments from Sungai Bebar will be used as fine aggregates while sediments from Kuala Perlis will be used as admixtures and fine aggregates for production of concrete. The concrete will then be tested for its strength. As a result, the concrete made from these two rivers are able to produce the minimum strength requirement for C20 concrete mix. This enables the concrete mixtures used in this research to be applied in the construction of foundation, retaining wall and highway. This research helps in reducing the amount of wastage from dredge work as well as providing a new material source for concrete.

Keywords: Dredged sedimen; concrete; waste management; geo-hazard

1.0 INTRODUCTION

In recent years, the construction industry is facing the issue of increasing demand for construction materials for geotechnical engineering purposes including in the construction of foundation, retaining wall and highway [1-3]. New quarries are opened and excavated in order to meet the demand [4, 5]. This problem worsens because as the world become more environmentally conscious, various restrictions have been put upon the industry.

As of 2004, due to geo-hazards including dispersion of contamination from sediment, licences for sand dredging activities along the coastal areas in Malaysia have ceased from being issued by the Federal Government while expired licences cannot be renewed as the marine ecology is in danger due to the activities [6]. The limitation causes shortages of sand and ultimately affects the construction sector in the country. In order for the industry to address the issues, new sources for the construction materials have been introduced over the years. One of the sources that holds potential for widespread use is the by-product of dredging activities.

Dredging is an excavation process done on the bottom of a body of water, such as river or shallow sea. The excavation process is mainly done in order to keep the depth of the waterways enough for it to be navigable for ships. Besides that, dredging is also done to obtain construction materials, mainly sand and gravels, for the production of concrete. In this case, selected areas that have low amount of contamination are commonly selected for excavation of aggregates.

The usual practice of managing dredged sediments is that the sediments will be dumped in open waters or Confined Disposal Facilities (CDF) [7]. In Europe, managers for dredging activities are encouraged to seek an environmentally friendly alternative for managing the dredging by-product from harbour and channels maintenance [8]. Therefore, one of the proposed ways is by using the unwanted dredged sediments as material in concrete production.

One of the problems when it comes to dredging is the management of the waste from the dredging activities [9-11]. If the dredged material is not contaminated, the material can be used without any major problems. As a matter of fact, in Japan, 90% of the dredged materials are safe to be used [12].

Dredged sediments are often taken in ports and docks. It is a by-product of maintenance dredging, in which current waterways are dredged to maintain suitable depth for ships to travel. Usually, these sediments are dumped at a specified location, either offshore or on land. However, this practice brings adverse effect to the ecology of the surrounding in the form of pollution. Dumped sediment will cause re-suspension of the sediments. This will cause a disruption on the ecosystem of the marine body [13, 14].

Therefore, one of the ways to curb this problem is by using the dredged sediments in other industry. Currently, dredged sediments have been successful in being used for engineering, agricultural and construction purposes [7, 15-20]. In New York and New Jersey in the United States of America, habitat creation, enhancement and restoration is an integral part of the for the Dredged Material Management Plan of the area [21]. However, despite sediments from dredging activity having a big potential as sediments source, not many of the usage of dredged sediments involve the production of concrete [16].

The initiative for using dredged sediments, especially in concrete production, could be beneficial in the long run. Thus, this research aims to investigate the strength of concrete made from dredged sediments and to compare the strength of conventional concrete with the concrete made with dredged sediment. The research specimen, which is the dredged sediments, including sand and silt, was taken from Sungai Bebar in Pahang and Kuala Perlis in Perlis. The reason behind this is because both areas perform dredging on a constant basis. Both areas are widely used for fishing and transportation purposes. After the retrieval of the specimen, it will be used to make concrete at Soil Mechanics laboratory in the Faculty of Technology Management and Business (FPTP), Universiti Tun Hussein Onn, Johor. After the concrete has been produced, the concrete will be subjected to strength test in FPTP. Two areas can benefit from this research; the environment and the construction industry. In terms of the environment, Malaysia might face with the issue of having to find new area to dispose dredged sediments as it is expecting an increase of dredging activities in the future. Therefore, using the dredged sediments will help solve problem as the waste is used for other purposes instead or just being dumped. Besides this, using the dredged sediments will also help in reducing pollution in the sea. Dumping of dredged sediments in the sea will cause several environmental problems. Therefore, reusing the dredged sediments will reduce this problem from happening and thus reducing the rate of pollution. In terms of the construction industry, reusing the dredged sediments will reduce the need to open more quarries. It is becoming more difficult to open new quarries and this causes natural resources to be depleted in an alarming rate over the years [19].

1.1 Dredging

Dredging is performed in order to excavate construction materials from the sea, mainly sand and gravels. In addition, the importance of dredging is listed in Figure 1. Since organic pollutants such as polycyclic aromatic hydrocarbons (PAH) and polychlorobiphenyls (PCB) as well as inorganic pollutants such as lead, mercury and zinc are often present in contaminated dredged sediments, they are not always desirable for any construction purposes [22].

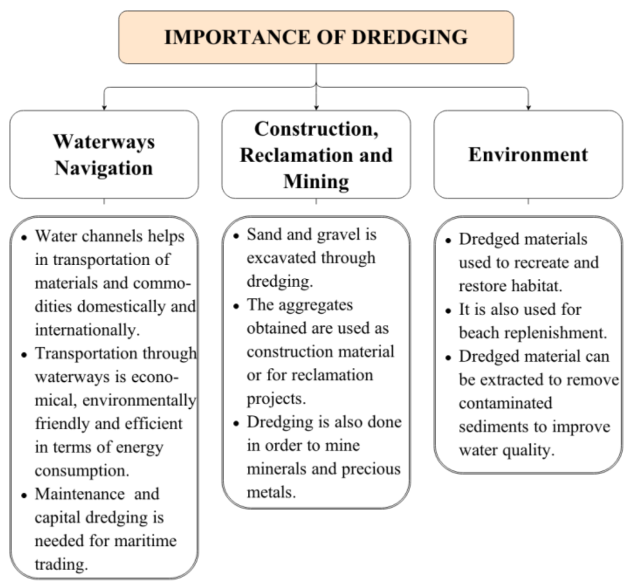

Figure 1 Importance of Dredging [25]

1.2 Maintenance Dredging

Maintenance dredging is often performed in existing docks and ports. As time passes, the water channel for ports and docks become shallow due to the accumulation of deposits. Therefore, maintenance dredging is required in order to keep the waterways navigable for ships. Since it cannot be used, the sediments are often treated as waste.

For unpolluted sediments, the sediments can be used for a number of ways. However, for the polluted sediments, it is often considered as waste and is subject for disposal. The disposal of the sediments can be highly controversial as it involves high cost and not environmentally-friendly method of disposal. One of the alternatives of the waste disposal is the Confined Disposal Facility (CDF).

Dredged material can be used in many ways in the construction industry as listed in Table 1. The usage range from reclamation projects to construction material [15]. However, managers for dredging activities were encouraged to seek an environmentally friendly alternative for managing the dredged by-product from harbour and channels maintenance in Europe [19]. These dredged sediments commonly will be dumped in open waters or Confined Disposal Facilities (CDF).

Table 1 Past Research Regarding the Usage of Dredged Sediments as a Construction Material [22-24]

Type of Research	Result
Design of new blended cement based on marine dredged sediment [22]	Marine dredged sediments can be used for blended cement production but analysis for industrial usage should be performed
Dredged marine sand in concrete: An experimental section of a harbour pavement [23]	The dredged marine sand tested can be used for harbour road pavement with concrete strength of 30MPa
Marine dredged sediments as new materials resource for road construction [19]	The tested dredged sand and sediments have good mechanical properties and can be used for foundation and base layers for roads

1.3 Concrete

Used by the Romans since 300BC, concrete has been one of the main materials used in the construction industry. Concrete is a composite material, consist of a mixture of aggregate, cement and water. When mixed with water, the cement reacts chemically with it to form a hard substance when dried. It acts as a binder for the aggregates to form the material that is called concrete. Despite its short-comings, it is still popular in the construction industry.

Table 2 listed the advantages and disadvantages of concrete. The strength of a concrete is defined by the maximum load or stress that it can bear. Since concrete is brittle, the tensile strength of concrete is very low. Therefore, most of the time, concrete structure is designed to bear only compression force, while steel reinforcement is added to the concrete to bear the tension.

Table 2 Advantages and Disadvantages of Concrete

Advantages	Disadvantages
Low production cost	Relatively high density
Good compression strength	Brittle/Low tensile strength
A variety of finishes can be applied	Susceptible to frost/ chemical deterioration

There are a few factors that will affect the strength of concrete, such as raw material quality, water/cement ratio, coarse/fine aggregate ratio, aggregate/cement ratio, age of concrete, compaction of concrete, temperature, humidity and curing. There are several concrete mixes that consists of different amount of cement, sand and coarse aggregate. Each of the mixes has different strength as shown in Table 3.

Table 3 Concrete Mixtures [26]

Grade	Minimum requirement for concrete mix (Cement:Sand:Aggregate)
C17	1:3:6
C10	1:2 ½:5
C15	1:3:5
C20	1:2:4
C25	1:1 ½:3
C30	1:1:2

2.0 MATERIALS AND SPECIMEN PREPARATION

The preparation of sample includes sample collection and sample remediation, as shown in Figure 2. During the sample collection, the dredged sediments will be collected and stored inside a big plastic container. For the samples taken from Sungai Bebar, the sediments will be sifted in order to remove unwanted objects, such as dead leaves, large stones and branches.

For the samples taken from Kuala Perlis, the water content of the sediments will be reduced through thermal treatment. The samples will be dried in the oven at a temperature of 250°C for 24 hours. This is to ensure the silt samples are completely dried. Besides that, the thermal treatment induces thermal immobilisation in which causes organic content to be broken down at high temperature.

The concrete mixture will follow the concrete production of grade C20. Concrete of grade C20 is a medium strength concrete, mainly used for the concrete frame of a building, such as beam and column. The ratio of cement, sand and aggregate used is 1:2:4, with the remediated sediments used as one of the components of the concrete replacing sand and aggregate. The water ratio of the concrete mix will be fixed at 0.45.

Figure 2 Materials and specimen preparation

For the samples taken from Kuala Perlis (silt), the water content of the sediments was reduced through thermal treatment. The samples were dried in the oven at a temperature of 250°C for 24 hours. This is to ensure the silt samples are completely dried. Besides that, the thermal treatment induces thermal immobilisation in which causes organic content to be broken down at high temperature.

The concrete will be put into a mould and after it is dried, it will be cured for 7 days and 28 days. After the curing period, the concrete will be taken out from its mould and will be subjected to a compression test.

The readings from the compression test will be tabulated and graphed in section 3.0. The data obtained will be compared against the strength of conventional concrete when C20 mix is used. The compressive strength of C20 mix is 20 N/mm² after a curing period of 28 days. For a curing period of 7 days, the concrete will achieve 65 % - 70% of the C20 mix concrete strength [27, 28]. An average of the percentage which is 67.5 %, will be taken for the purpose of this experiment (concrete strength of 13.5 N/mm²).

3.0 RESULTS AND DISCUSSION

In this chapter, the data obtained from the laboratory works are graphed and analysed. The graph will show the strength of the new blended dredge sediment concrete produced. The strength will be compared with the strength of conventional C20 concrete mix, which is represented by the red lines on each graph.

3.1 Analysis of Concrete Made of Sand from Sungai Bebar

In new blended dredge sediment concrete of Sungai Bebar, the concrete produced a compressive strength that is slightly above the normal strength of the C20 concrete mix. After cured for 7 days, the concrete achieved an average of 19.7 N/mm² of strength and when cured for 28 days, the strength is 30.6 N/mm² on average. The concrete shows a difference of 6.2 N/mm² and 10.6 N/mm² in strength respectively (Figures 3 and 4).

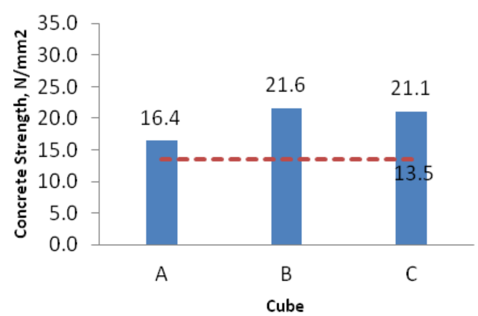

Figure 3 Strength of Concrete made from Dredged Sediments from Sungai Bebar, Pahang - 7 Days Curing

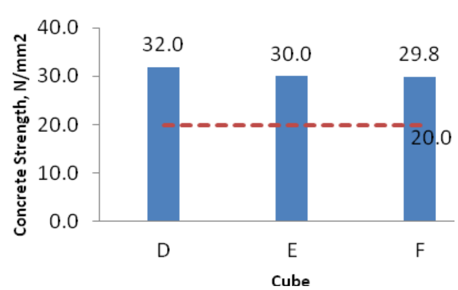

Figure 4 Strength of Concrete made from Dredged Sediments from Sungai Bebar, Pahang - 28 Days Curing

3.2 Analysis of Concrete with Silt from Kuala Perlis as an Additive

In new blended dredge sediment concrete of Kuala Perlis, which are used as additive, the concrete produced much higher concrete strength as opposed to the existing C20 concrete. When cured for 7 days, the concrete produced an average of 35.5 N/mm² of strength and when cured for 28 days, the strength is 48.8 N/mm² on average. The concrete shows a difference of 22.0 N/mm² and 28.8 N/mm² in strength respectively. The concrete are able to produce a much higher strength when 3 % of silt is added (Figures 5 and 6).

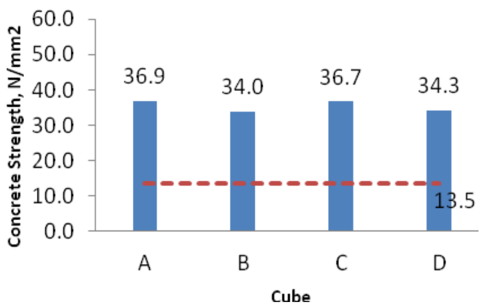

Figure 5 Strength of Concrete with Silt from Kuala Perlis Added - 7 Days Curing

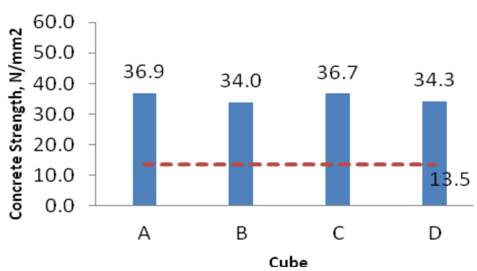

Figure 6 Strength of Concrete with Silt from Kuala Perlis Added - 28 Days Curing

3.3 Analysis of Concrete with Silt from Kuala Perlis Replacing the Fine Aggregate

When sediments from Kuala Perlis are used to replace the fine aggregate normally used in a concrete, the concrete shows a decreasing strength as the percentage of silt in the mix increases. The highest reading is 26.1 N/mm² for 10 % silt content while the lowest is 11.9 N/mm² for 50 % silt content. The mix with silt content of 10 % to 40 % is able to produce the minimum required strength of 13.5 N/mm² for a curing period of 7 days. The result supports the notion that an increase amount of silt will require more water, which will make it weaker (Figure 7).

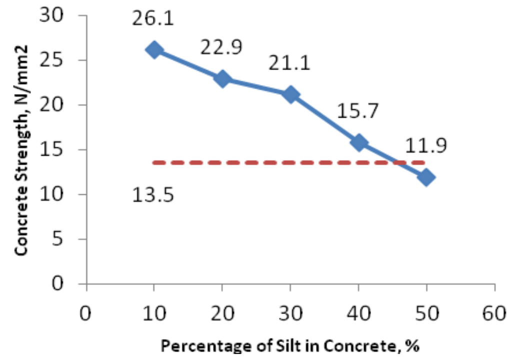

Figure 7 Strength of Concrete with Fine Aggregate Replaced with Silt from Kuala Perlis

4.0 CONCLUSION

The first objective of this research is to investigate the strength of concrete made from dredged sediments. The strength of concrete made with sediments (sand) from Sungai Bebar replacing 100 % of sand and aggregate components is, on average, 19.7 N/mm² for a curing period of 7 days and 30.6 N/mm² for a curing period of 28 days.

Meanwhile, the strength of concrete made with silt from Kuala Perlis as additive is, on average, 35.5 N/mm² for a curing period of 7 days and 48.8 N/mm² for a curing period of 28 days. Finally, the strength of concrete made with silt from Kuala Perlis replacing the fine aggregate has shown a decreasing strength as the percentage of silt in the mix increases. The highest reading is 26.1 N/mm² for 10 % silt content while the lowest is 11.9 N/mm² for 50 % silt content.

The second objective of this research is to compare the strength of conventional concrete (C20 concrete mix) versus the strength concrete made from dredged sediments. The strength of concrete made with sediments from Sungai Bebar is, on average, 6.2 N/mm² stronger than the minimum strength for the mix for 7 days of curing and 10.6 N/mm² stronger for 28 days of curing. This fact supports the notion that dredged sand is suitable to be used for concrete production since river sand are often used as fine aggregates.

Meanwhile, the strength of concrete made with silt from Kuala Perlis as additive is, on average, 22.0 N/mm² stronger than the minimum strength for a curing period of 7 days and 28.8 N/mm² stronger for a curing period of 28 days. This result supports the research made by Ch (2013)[29].

Finally, the strength of concrete made with silt from Kuala Perlis replacing the fine aggregate has shown that only the mix with silt content of 10 % to 40% are able to produce the minimum required strength of 13.5 N/mm² for a curing period of 7 days. The result supports the notion that an increase amount of silt will require more water, which will make it weaker.

The results from this research will help the construction industry in finding new sources for construction material that will be used for foundation, retaining wall and highway construction that are, in practice, greener and much more sustainable.

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