BORNEO JOURNAL OF SCIENCES AND TECHNOLOGY (BJoST)
VOL.: 7, ISSUE: 2, 38-58
DOI: http://doi.org/10.35370/bjost.2025.7.2-03
e-ISSN: 2672-7439 © 2018, UTS Publisher.

University of Technology Sarawak

ORIGINAL ARTICLE

Evaluating Dredged Sediment from Sungai Pusu, Gombak as Partial Replacement of Sand in Concrete Production

[1]Asma Ahmed, *[1]Siti Aliyyah Masjuki, [1]Luqmanulhakim Abd. Manaf, [2]Nor Farah Huda Abd Halim, and [3]Shuhairy Norhisham

[1]Department of Civil Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, 53100 Kuala Lumpur, Malaysia.
[2]Department of Material and Manufacturing Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, 53100 Kuala Lumpur, Malaysia.
[3]Department of Civil Engineering, College of Engineering, Universiti Tenaga Nasional, 43000 Selangor Darul Ehsan, Malaysia.

ABSTRACT - Due to rising environmental concerns and resource depletion linked to sand mining, alternative materials are essential to meet construction demands. Dredged sediment (DS) offers a potential solution by providing a locally available and sustainable replacement. This study explores the feasibility of using DS from Sungai Pusu, Gombak, as a sustainable partial replacement for natural sand in concrete production, potentially providing a regionally sustainable alternative and aiding waste reduction. Material characterisation shows that DS sourced from Sungai Pusu contains insignificant amounts of hard metals and does not require extensive treatment. Concrete specimens, sized 150 mm × 150 mm × 150 mm, were prepared with 0%, 15%, and 30% DS substitution levels and cured for 7 and 28 days. Results indicate that concrete with 30% DS substitution demonstrates significant improvements in strength, highlighting feasibility of DS from Sungai Pusu as an eco-friendly alternative for sustainable construction practices.

ARTICLE HISTORY
Received: 12 Sept 2024
Revised: 27 Dec 2024
Accepted: 06 Mar 2025
Published: 31 July 2025

KEYWORDS
Dredged sediment,
Concrete,
Mechanical properties.

INTRODUCTION

The construction industry is a significant consumer of natural resources [1]. Globally, concrete is widely utilised in the construction industry owing to its favourable characteristics, such as strength, durability, and low maintenance. In this regard, natural sand, a primary ingredient in concrete manufacturing and serves as fine aggregate, is currently overexploited in meeting market demand [2]. After freshwater, natural sand is recognised as the most employed natural resource [3]. A considerable volume of natural sand and gravel is consumed for construction, whereby an annual estimated 32 to 50 billion tonnes of sand and gravel are extracted globally [4]. According to Dhir et al. [5] and Yehia et al. [6] there will be a 5% annual growth in the use of aggregates worldwide.

Given the evident rise in aggregate consumption, the demand of the construction industry in some countries with respect to quantity and quality cannot be satisfied by the available natural sand resources [7]. Quarrying or alluvial river extraction yields the majority of the aggregates required in concrete production. If not implemented sustainably, exploiting these natural resources leads to environmental damage and depletion [8-10]. Excessive sand mining is associated with various negative environmental

*Corresponding Author: Siti Aliyyah Masjuki, International Islamic University Malaysia (IIUM), email: aliyyah@iium.edu.my

impacts that are increasingly recognized in various regions worldwide [11]. While it supports economic development through job creation and construction material supply, the environmental degradation it causes raises serious concerns. Incision, channel destabilisation, and alluvial water loss are the likely consequences from excessive riverbed sand mining [12-15]. Due to disruption of aquatic animal feeding and respiration, excavation activities increase downstream water turbidity and salinity, reducing aquatic population [16-18]. Low water tables along the riverbed due to sand mining often cause well failure, which negatively influences the local water supplies for agriculture, people, and other uses [19].

Furthermore, there is a growing focus on conserving natural resources, as well as the repurposing and recycling of waste and by-products within the cement industry in contemporary times as a part of sustainable development initiatives. Researchers have been obliged to seek other alternate options that are viable due to the negative environmental effects associated with excessive sand dredging from riverbeds and the lack of land for the disposal of wastes [2; 19; 20]. Numerous research endeavours have been concentrating on proposing environmentally sustainable resources such as dredged sediments (DS) [21].

DS is considered as waste material that resulted from extraction of accumulated sediment at bottom of waterways, essentially for maintenance of waterways and navigation depth. Incorporation of DS in cementitious materials as sand replacement offers dual advantageous points by addressing the issue of sand depletion and providing sustainable waste management. Rakshith and Singh [22] suggest that the shift in perspective from perceiving DS as a challenge to regarding it as an opportunity may be more advantageous. Brils et al. [23] and Crocetti et al. [24] have proposed that the environmental, economic, and social consequences of sediment valorisation could be controlled, and the sediment could even be transformed into a beneficial local resource. Numerous scholars have successfully highlighted that DS has the potential to partially replace natural sand in cement composites. However, the feasibility of such incorporation is highly reliant on the characteristics and contamination of the DS which is influenced by multiple factors such as physiochemical aspects of the deposition environment, natural properties of the source materials, the degree of erosion, organic matter contributed by surrounding watersheds, nearby economic activities, and even the specific timing of sediment collection during dredging operations [25; 26]. Hence, utilization of DS has largely been constrained because of their heterogeneity. Moreover, most of the earlier studies were site specific; hence, these findings cannot be generalized.

The primary research objective of the present study is to evaluate the suitability of DS from Sungai Pusu, Gombak, as an alternative to sand in concrete production. For this purpose, the characteristics of DS have been studied for comparison with natural sand through laboratory testing, as such sieve analysis, XRF and organic impurities test. Mechanical performance of the formulated concretes has been evaluated using both destructive and non-destructive tests. This investigation is motivated by the dual goals of promoting sustainable practices in the construction industry and addressing environmental challenges associated with sand extraction. By finding effective ways to utilise DS locally available, this research could contribute to reducing the environmental impact of concrete production while also providing a practical solution for managing dredged materials.

MATERIALS AND METHODOLOGY

This section begins with an elaboration of the materials utilised in formulation of the sustainable concrete mix, which followed by a presentation of the methods employed to characterise the DS extracted from the Sungai Pusu for their granulometry, pollutant content and organic matter content. The effect of various sediments on concrete hydration, strength and shrinkage is then experimentally quantified.

Material Collection

Concrete is an amalgamation of cement as hydraulic binder, coarse aggregates, fine aggregates and water for hydration. Ordinary Portland Cement (CEM I), which was available at the IIUM concrete laboratory, was employed as the binder for the concrete blend in this experiment. Table 1 shows the chemical composition of cement. The OPC that was employed was in compliance with BS EN 197-1:2011 [27]. Coarse aggregates used in the concrete mix were gravel and crushed rocks with a nominal size of 20 mm, sourced locally. Fine aggregates conventionally consist of natural river sand; however, in this study, DS were utilized as a partial replacement for the sand. DS were collected from Sungai Pusu, Gombak that passes through boundary of International Islamic University Malaysia (IIUM) after performing the necessary site investigations, as depicted in Figure 1. The sediments were extracted from the river through grab method (see Figure 2). The sediment was collected, air-dried, and sieved to remove larger particles, ensuring a grain size distribution that conformed to BS 812-103.1:1985 [28]. Similarly, the coarse aggregates and natural sand were sieved from incorporating in the concrete mix.

Table 1. Chemical composition of cement

Component	(%)
Aluminium oxide (Al_2O_3)	1.97
Silicon dioxide (SiO_2)	12.0
Phosphorus pentoxide (P_2O_5)	0.58
Sulphur trioxide (SO_3)	4.46
Potassium oxide (K_2O)	0.85
Calcium oxide (CaO)	72.4
Iron (III) oxide (Fe_2O_3)	7.01
Strontium oxide (SrO)	0.13
Zirconium dioxide (ZrO_2)	0.01

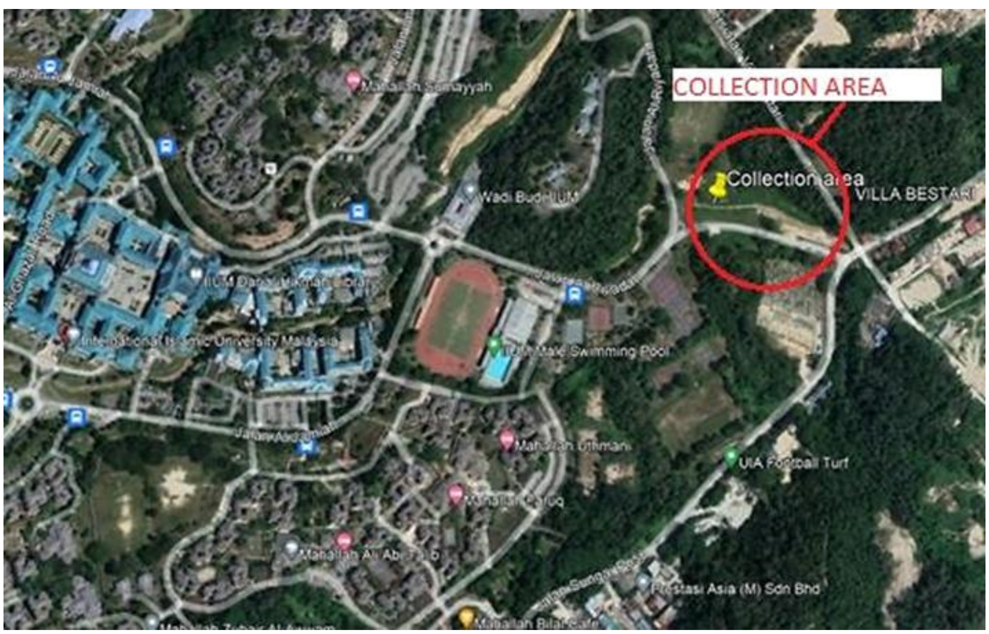

Figure 1. Location of the collection point for DS

Figure 2. Collection of DS through grab method

Characterisation of Dredged Sediments

Given the potential variability of DS, which can be present even among samples gathered from close vicinity, it is crucial to perform a characterisation study to determine if these sediments are suitable for use as fine aggregate in concrete [29; 30]. In their research, Amar et al. [21] and Bortali et al. [31] discussed the established standards and methodologies for testing the properties of DS. Their work emphasised the importance of assessing components like trace elements, nutrients, organic matter, and chemical compounds. This evaluation is critical for determining the need for any treatment, as discussed by [32].

The method of dry sieving, in accordance with British Standard, BS 812-103.1:1985 [28], was employed to determine the particle size distributions of the DS and natural sands, both of which were incorporated in the concrete mix as fine aggregates. The degree of fineness was assessed by sieving both materials through a stack of sieves with decreasing sizes of apertures of 5mm, 2.24mm, 1.18mm, 600 µm, 300 µm, and 150 µm. The percentage passing of each material through the sieves was analysed, and the appropriate grading curve was plotted and presented in Figure 3. Both natural sand and DS show a similar overall trend, but the grading curve of DS is slightly shifted to the left. Figure 3 shows that DS have a higher proportion of finer particles, as indicated by the higher percent passing at the lower diameter range. The dredged sediment is categorised as medium sand, while natural sand is declared as coarse sand according to ASTM C33 [33], as shown by the fineness modulus in Table 2. ASTM C33 outlined that fineness modulus of the fine aggregates shall be between 2.3 and 3.1 [33]. The result of the fineness modulus of materials is consistent with findings that DS often have a higher proportion of silt and clay-sized particles [9; 34]. The finer content in DS can influence its use as an aggregate in concrete. Studies suggest that sediments with finer particles may affect the mechanical strength of concrete mixtures, though stabilization techniques can improve performance [35].

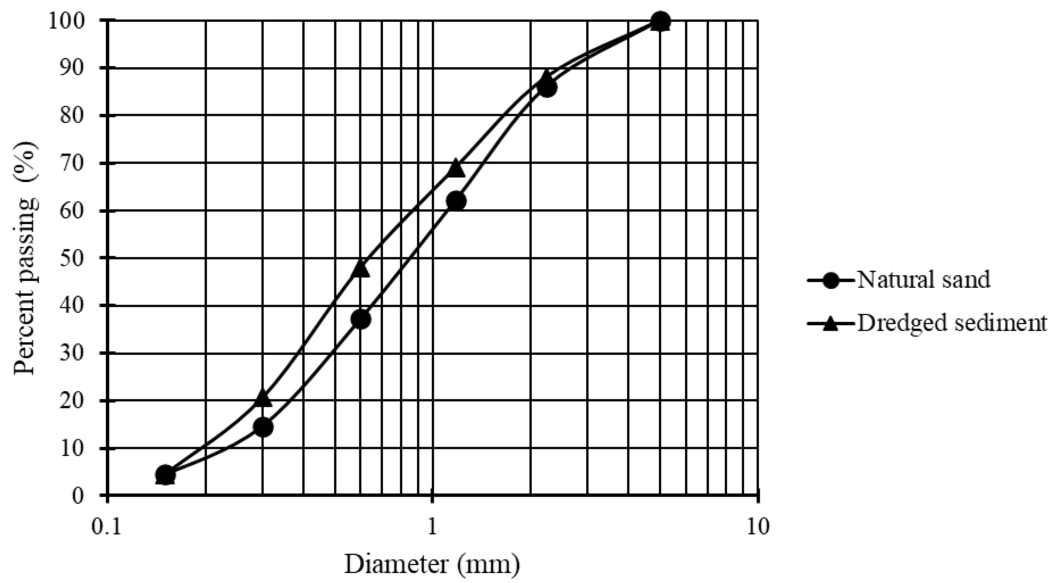

Figure 3. Grading curve

Table 2. Fineness modulus of the fine aggregate

Materials	Fineness modulus	Type of sand
Natural sand	2.95	Coarse sand
DS	2.72	Medium sand

The progression of strength in cementitious matrix is highly affected by chemical characteristics of fine aggregates [36-40]. The X-ray Fluorescence (XRF) method was conducted to compare the chemical composition between the natural sand and DS, providing insights into environmental conditions and contamination levels. The chemical composition of both materials was recorded in Table 3. Mussey et al. [41] in their study, emphasised MgO, Al_2O_3, SiO_2, K_2O, CaO, Fe_2O_3 and Na_2O as the main oxides present in the chemical profile of fine aggregates. The DS shows a higher content of SiO_2 (66.34%) compared to natural sand (33.71%), making it rich in silica, a common feature of sedimentary environments. Characterisation of DS by Limeira et al. [9] and Ozer-Erdogan et al. [42] also reported quartz (crystalline silica) as a major component of DS. DS often has a high quartz content due to the natural composition of sedimentary environments, where quartz, a durable and stable mineral, accumulates over time. Al_2O_3 and Fe_2O_3 levels are similar between natural sand and DS. MgO (35.85%) in natural sand is significantly higher than in DS (6.44%). CaO content is notably higher in DS (4.49%) than in natural sand (0.7%). Dredged materials inherently contain significant amounts of silica, alumina, calcium, and iron oxides.

Table 3. Chemical composition of raw materials (method of XRF)

Elements	Chemical composition (wt %)	
	Natural sand	DS
SiO_2	33.71	66.34
Al_2O_3	7.31	7.38
CaO	0.7	4.49
MgO	35.85	6.44
TiO_2	1.1	0.01
Fe_2O_3	6.9	6.75
K_2O	7.61	4.57
ZnO	0.04	0.05

The XRF analysis of the alternative sand material is also useful in detecting a high concentration of heavy metal content. Table 4 illustrates that heavy metal contents within both materials were almost similar and in low concentration to impose any significant effect. Hence, the sample of DS taken from Sungai Pusu could be declared as an unpolluted sample, particularly when considering the threshold limits imposed by the Department of Environment Malaysia for hazardous wastes [43]. Therefore, the chemical treatment was not necessarily required for this sample of DS. Similarly, Beddaa et al. [44] found the treatment of sediments redundant when it shows low concentrations of contaminants. However, chemical treatments such as phosphoric acid treatment (Novosol Process) as are necessary when dredged sediments is contaminated with high heavy metals [45-48].

Table 4. Heavy metal content of raw materials (method of XRF)

Heavy metal	Chemical composition (mg/kg)	
	Natural sand	Dredged sediment
Chromium	2300	2800
Copper	0	100
Zinc	100	100

Next, an organic impurities test was performed in this research according to ASTM C40 [49] to determine the presence of the organic material in the DS. A similar test was done in research by Yang et al. [50] to guarantee that the sustainable substitute material to natural sand is free from organic contaminants before incorporating in the concrete mix. After 24 hours since the sodium hydroxide solution was shaken with the DS in the bottle, the colour changes were observed and compared with the reference colour. Figure 4 illustrates the changes in colour due to the presence of organic material in the dredged sediments.

Figure 4. Initial colour of solution (left) and changes in colour after 24 hours (right)

Figure 5. Garner colour standard (ASTM C40)

The colour of the solution was observed to be the same as number 3 according to Gardner colour standard in Figure 5. The darker color of the solution proved the presence of organic matter. DS containing high organic material could delay the development of compressive strength [44]. Thus, thermal treatment had been proposed in this research in order to eliminate the organic material in the dredged sediments before it was used as the replacement for natural sand in the concrete mixture.

Treatment of Dredged Sediment

The physical treatment of DS involved sieving, washing, and drying. Initially, the sediment was sieved through a 5 mm mesh to remove unwanted materials like dried leaves and branches, which could negatively impact experimental outcomes. The treatment served two primary objectives: trapping heavy metals and eliminating organic matter. After analysing the chemical composition, it was determined that no further chemical treatment was necessary, as heavy metal concentrations were low. However, the organic matter present could influence concrete strength, prompting further investigation into the use of treated DS as a sand replacement in concrete to improve strength. To eliminate organic matter, a calcination process was performed, as highlighted in Figure 6. The sediment was heated in a furnace at 650°C for one hour, following the procedure outlined by Agostini et al. [45]. The sediment was allowed to cool for one day before being used in concrete mixtures. Heating treatment is also necessary to remove the excess water content of DS [51].

Figure 6. Calcination process in the furnace (left) and calcined dredged sediment (right)

EXPERIMENTAL PROGRAM

Mix Design Procedure

For the study, M30 Grade concrete mix was suggested, and appropriate mix design was specified as per Design of Normal Concrete Mixes, which is published by the British Department of the Environment (DOE). The study was performed on the M30 Grade concrete for 0%, 15%, and 30% replacement of natural sand with treated dredged sediment. Table 5 presents the mix proportions for each batch of the concrete mixture. Reference concrete is abbreviated as RC, while CS15 and CS30 represent mixtures with 15% and 30% dredged sediment, respectively as partial replacement of natural sand. Based on the mix design obtained, mixing process commenced with the uniform blending of cement, coarse aggregate, fine aggregate, and dredged sediment in a concrete mixer, followed by the gradual addition of water to ensure a good quality fresh concrete. Unlike previous studies [9; 42; 52], no plasticiser additive was used in this study. Thus, the concrete samples formulated using dredged sediment were not expected to maintain the same workability as the reference concrete samples. Fresh concrete was transferred into greased steel moulds and compacted using a rod, consistent with BS EN 12390-1:2000 standards [53], specifying cube dimensions of 150 mm × 150 mm × 150 mm. The process of casting the concrete specimens has been described in Figure 7. Next, for each concrete mixture, three cubes were prepared for testing after 7 and 28 days of curing. All samples were cured in water at a controlled temperature of 20 ± 2°C, starting 24 hours after casting.

Table 5. Mixed proportion of concrete specimens

Concrete specimens	RC	CS15	CS30
Cement (kg/m3)	367	367	367
Water (kg/ kg/m3)	180	180	180
W/C ratio	0.49	0.49	0.49
Coarse aggregate (kg/m3)	1063	1063	1063
Fine aggregate (natural sand) (kg/m3)	770	654.5	539
Fine aggregate (DS) (kg/m3)	0	115.5	231
Substitution rate (%) (DS/natural sand)	0	15	30

Figure 7. Concrete casting

Evaluation Tests

The concrete specimens were tested for their performance in both fresh and hardened states. Meanwhile, the mechanical performance of the hardened concretes was evaluated through both destructive and non-destructive tests. Table 6 summarises the evaluation tests utilised, including the size and quantity of specimens, as well as the standards to which the tests complied.

Table 6. Summary of evaluation tests for concrete specimens produced

Evaluation test	Concrete specimens: RC, CS15 and CS30			
	Standards	Sample size	Curing period (days)	Tested samples (no)
Slump test	BS EN 12350-2:2009	Fresh state		3
Vebe test	BS EN 12350-3:2009	Fresh state		3
Compressive strength	BS EN12390-3:2002	0.15m cube	7, 28	3/period
Ultrasonic Pulse Velocity (UPV)	BS EN 12504-4:2004	0.15m cube	7, 28	3/period
Rebound hammer	BS EN 12504 – 2: 2012	0.15m cube	7, 28	3/period

Fresh Properties

The slump test is a widely recognised, low-cost method for assessing the workability and quality of concrete [54]. The slump test was performed for each concrete mix design with conformance to BS EN 12350-2:2009 [55], as presented in Figure 8. The workability and consistency properties of freshly prepared concrete were also assessed with help of Vebe test [56], as shown in Figure 9.

Figure 8. Slump test

Figure 9. Vebe test

Destructive Tests

The mechanical properties of the concrete specimens were determined by performing the compressive strength test in accordance with BS EN 12390-3:2010 [57]. The test was performed using three specimens of RC, CS15 and CS30 for 7 and 28 days using 3000kN capacity compression testing machine, see Figure 10.

Figure 10. Compressive strength test

Non-destructive Tests

The results of the conventional destructive tests such as compressive strength test can be correlated with non-destructive testing (NDTs), such as Ultrasonic Pulse Velocity (UPV) test and rebound hammer test. UPV is a widely employed NDT that is effective in determining the elasticity of the concrete specimens, which correlate with the mechanical strength performance [58]. UPV test was conducted in adherence to BS EN 12504-4:2004 [59]. Prior to performing the test, the UPV device was calibrated to ensure accuracy and reliability of the measurements. The laboratory setup and execution of the UPV test were detailed in Figure 11, demonstrating the positioning of transducers and the specimen alignment.

Figure 11. UPV test procedure

Rebound hammer test was also performed on the concrete specimens in parallel with UPV, following the guidelines of BS EN 12504 – 2: 2012 [60]. 16 readings were taken from a smooth surface of concrete specimen by applying pressure to the plunger of the hammer, ensuring it was positioned perpendicular to the surface and 30 mm from each test point. This process was carried out on four different surfaces of the cube specimens to obtain a comprehensive average result, as illustrated in Figures 12 and 13. Such non-destructive testing methods have been widely employed in prior research to assess surface hardness and estimate concrete strength [61].

Figure 12. Marked position for rebound hammer test

Figure 13. Rebound hammer test procedure

RESULTS AND DISCUSSION

Fresh Concrete Properties

The slump and Vebe test results are given in Table 7. The reference concrete has the highest slump value (30 mm), which is indicative of better workability compared to the mixes incorporated with DS. With 15% sediment substitution, the slump drops to 25 mm and further decreases to 20 mm at 30% sediment replacement. This trend suggests that adding dredged sediment reduces the workability of the concrete mix, possibly due to the particle shape or absorptive properties of the sediment which affect the water availability for flow. Meanwhile, Vebe time, which reflects the energy required to compact the concrete, increases with higher sediment content. The reference concrete has the lowest Vebe time (5.34 s), indicating easier compaction, while the 15% and 30% sediment mixes have progressively higher Vebe times (7.2 s and 8.3 s, respectively). This increase indicates that the mixes with sediments are less workable and require more compaction effort, correlating with the observed reduction in slump values. A similar result is reported by Limeira et al. [9], where improved workability was observed with low percentages of DS. The finer particle size of dredged sediment contributed to an increased specific surface area compared to that of natural sand. Johnson et al. [62] and Zhao et al. [63] noted that the elevated specific surface area of DS led to significant water absorption, resulting in a significant loss of workability. These findings collectively suggest a compromise between sustainable sediment use and the workability of concrete. Higher sediment contents may require adjustments, such as water or admixture adjustments, to maintain suitable workability for construction purposes.

Table 7. Fresh properties of concrete specimens

Test results	Concrete specimens		
	RC	CS15	CS30
Slump value (mm)	30	25	20
Vebe time (s)	5.34	7.2	8.3

Hardened Concrete Properties

The results of the compressive strength tests are presented in Figure 14 with standard deviations; each value is the average of three data. As expected, the concrete specimens gained strength with increased curing period [42]. The evolution of the compressive strength of the concrete specimens clearly highlights that the observed behavior of the modified concrete in conformity with conventional concrete. On both 7 and 28 days, the highest compressive strength were achieved by concrete incorporated with 30% DS as substitution of natural sand (CS30). This observation is corroborated with findings from previous research studies [9; 64-66]. Nel [67] stated that the strength performance of concrete mixes having similar paste volume, is not significantly influenced by fine aggregates employed. Thus, with similar cement content and water to cement ratio, the increase of 7.2% in strength for CS30 can be attributed to particle strength, surface texture and shape of the DS particles [68].

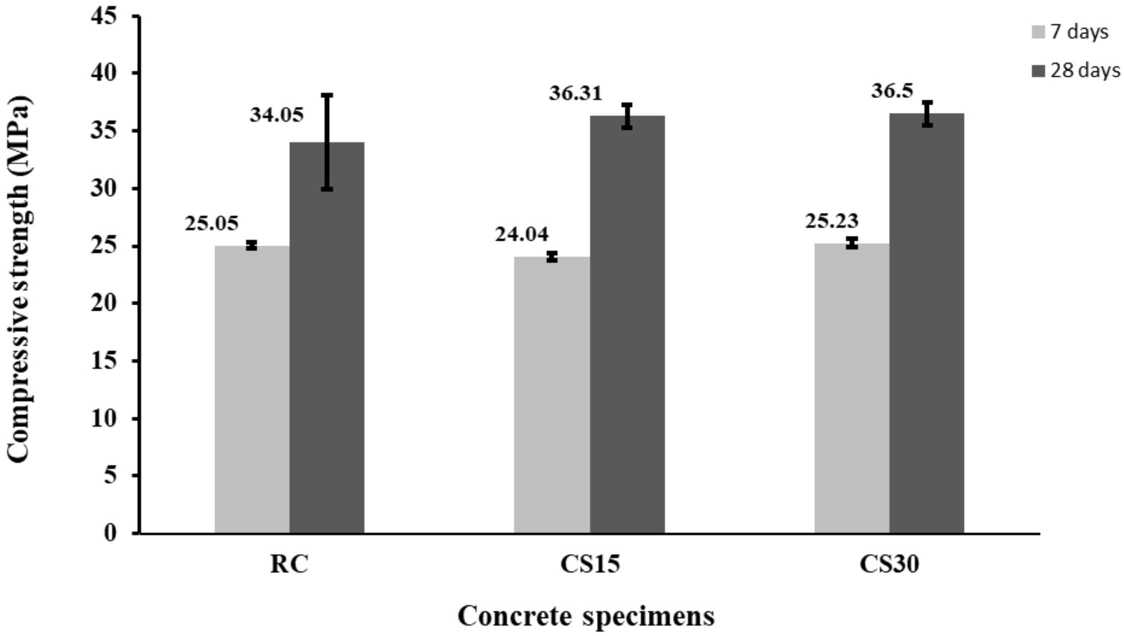

Figure 14. Compressive strength performance of the concrete specimens

The average transit time of four surfaces of three cubes for each concrete specimen after 7 and 28 days of curing is tabulated in Table 8. The transit time which denotes the time it takes for an ultrasonic pulse to travel from emitting transducer to the receiving transducer while passing through the concrete, reflects the structural integrity of the concrete and identify any indications of cracks, honeycomb, or voids in the concrete. The pulse velocity (km/s) is obtained by dividing the thickness of the concrete specimens which equivalent to the path length by the transit time and plotted in Figure 15. CS15 and CS30 show variation in UPV readings at 7 days compared to 28 days. While initially lower than RC, the specimens' UPV readings improved significantly by 28 days. This suggests that curing process plays a significant role in compaction and hydration process for concrete specimens with DS incorporation. Generally, concrete shows improved UPV readings with longer curing period as a result of progressive development of a denser matrix, which supports better wave propagation [69]. The lower UPV readings obtained by DS incorporated concretes suggests formation of a more porous cementitious matrix due to the higher slit and clay contents. Moreover, the irregular shape and varying size distribution of particles in DS can disrupt the compactness of the concrete matrix, leading to increased voids and reduced density, thereby lowering UPV readings. DS may have higher moisture retention properties, affecting the curing process and the final moisture content of the concrete, which in turn influences UPV measurements. Scholars have characterised performance of concrete based on its UPV value, as presented in Table 9 [70; 71]. From this classification, all the concrete specimens with UPV between 3.5 - 4.5 km/s, were noted to display good performance. However, the UPV results did not strictly correspond to compressive strength trends, possibly due to internal variances like micro-cracks or differing pore structures that affected wave propagation without significantly changing compressive strength. This highlights that while UPV is a valuable non-destructive test, it may not always correlate directly with compressive strength due to complex internal characteristics.

Table 8. Average transit time of concrete specimens from UPV test

Concrete specimens	Average transit time of four surfaces (µs)					
	7 days			28 days		
	Cube 1	Cube 2	Cube 3	Cube 1	Cube 2	Cube 3
RC	37	37.7	37.5	36.7	37	38
CS15	38.9	38.3	38.5	37.3	38.3	37.4
CS30	39.5	38.2	37.6	37.3	39	35.8

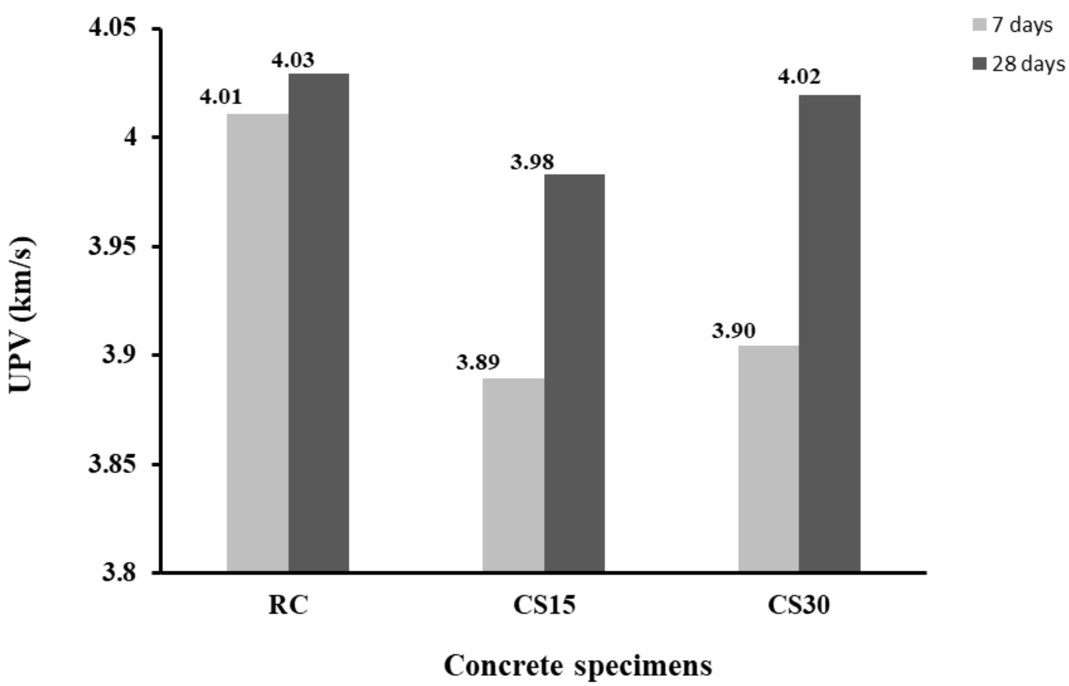

Figure 15. Graph of pulse velocity on 7 and 28 days of curing

Table 9. Categorisations of UPV for concrete quality

Ranges of UPV (km/s)	Concrete quality
4.5	Excellent
3.5 - 4.5	Good
3.0 - 3.5	Doubtful
2.0 - 3.0	Poor
2.0	Very Poor

The rebound hammer test results, as tabulated in Table 10, show that the rebound number readings increase with age, reflecting the progressive hardening of concrete [72]. The data obtained presents a clear trend of increased rebound numbers at 28 days compared to 7 days, indicating improved surface hardness over time. CS30 exhibits the highest progression, with rebound numbers increasing from 22.81 at 7 days to 29.57 at 28 days. However, the estimated compressive strength from the rebound hammer test had not achieved the minimum required strength (30 MPa) on 28 days of moist curing. Low value of estimated compressive strength for rebound hammer test was likely due to the rough textured surface of concrete cube, which might cause excessive crushing by the plunger tip and reduced the rebound number [73]. Similar to compressive strength test, the rebound hammer test successfully highlights that concrete cubes show better mechanical performance at 30% replacement of sand by DS collected from Sungai Pusu.

Table 10. Rebound numbers with estimated compressive strength of concrete specimens

Concrete specimens	7 days		28 days	
	Average rebound numbers	Estimated compressive strength (MPa)	Average rebound numbers	Estimated compressive strength (MPa)
RC	22.15	17.62	28.9	26.16
CS15	22.43	17.85	29	26.38
CS30	22.81	18.32	29.57	27.08

CONCLUSION

In exploring sustainable alternatives to natural sand, this study assessed the feasibility of dredged sediment (DS) from Sungai Pusu, Gombak, for use in concrete. The characterization of DS revealed that it possesses a suitable granulometry and chemical composition, with manageable levels of organic impurities and negligible contamination, making it suitable for sand replacement in concrete mixtures. In fresh properties tests, DS-substituted concrete prepared using same water to cement ratio as conventional concrete demonstrated slightly lower workability. However, the hardened performance of the concrete improved with incorporation of DS as alternative aggregate. Substitution of 30% DS in the concrete mix proved efficient as specimen CS30 exhibited increased compressive strength than RC by 7.2% Additionally, the Ultrasonic Pulse Velocity (UPV) tests confirmed the structural integrity of DS-based concrete, while the rebound hammer tests reflected enhanced surface hardness over time, particularly at higher DS content. These findings collectively suggest that Sungai Pusu DS can effectively replace a portion of natural sand in concrete, offering environmental and practical benefits for sustainable construction.

RECOMMENDATIONS

The promising improvements of transit time and strength development of CS30 over RC highlights the potential of DS as greener alternative to natural sand as fine aggregate in cement composites. Thus, it is recommended to conducted further studies focusing on the long-term durability analysis of DS based concrete to evaluate properties such as shrinkage, cracking resistance, and freeze-thaw durability. It is also highly recommended to assess the sustainability benefits and cost-effectiveness of incorporating DS extracted from the Sungai Pusu.

ACKNOWLEDGMENT

The authors would like to acknowledge and thank the support provided by the International Islamic University Engineering Merit Scholarship 2023.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] J. A. Bogas, J. De Brito, and J. M. Figueiredo, "Mechanical characterization of concrete produced with recycled lightweight expanded clay aggregate concrete," *J Clean Prod*, vol. 89, 2015, doi: 10.1016/j.jclepro.2014.11.015.

[2] R. Rakesh Kumar Reddy, S. C. Yaragal, and V. K. Sanjay, "Processing of laboratory concrete demolition waste using ball mill," *Mater Today Proc*, Mar. 2023, doi: 10.1016/J.MATPR.2023.03.193.

[3] D. Kazmi, M. Serati, D. J. Williams, S. Qasim, and Y. P. Cheng, "The potential use of crushed waste glass as a sustainable alternative to natural and manufactured sand in geotechnical applications," *J Clean Prod*, vol. 284, 2021, doi: 10.1016/j.jclepro.2020.124762.

[4] L. Koehnken and M. Rintoul, "Impacts of Sand Mining on Ecosystem Structure, Process & Biodiversity in Rivers," *Rivers, & Potential Geomorphic Transport Sediment Changes in Response To Sand Mining*, 2018.

[5] R. K. Dhir, J. de Brito, R. V. Silva, and C. Q. Lye, *Sustainable Construction Materials: Recycled Aggregates*. Woodhead Publishing Series in Civil and Structural Engineering, 2019.

[6] S. Yehia, K. Helal, A. Abusharkh, A. Zaher, and H. Istaitiyeh, "Strength and Durability Evaluation of Recycled Aggregate Concrete," *Int J Concr Struct Mater*, vol. 9, no. 2, 2015, doi: 10.1007/s40069-015-0100-0.

[7] P. C. C. Gomes, C. Ulsen, F. A. Pereira, M. Quattrone, and S. C. Angulo, "Comminution and sizing processes of concrete block waste as recycled aggregates," *Waste Management*, vol. 45, 2015, doi: 10.1016/j.wasman.2015.07.008.

[8] R. Achour, R. Zentar, N. E. Abriak, P. Rivard, and P. Gregoire, "Durability study of concrete incorporating dredged sediments," *Case Studies in Construction Materials*, vol. 11, Dec. 2019, doi: 10.1016/j.cscm.2019.e00244.

[9] J. Limeira, M. Etxeberria, L. Agulló, and D. Molina, "Mechanical and durability properties of concrete made with dredged marine sand," *Constr Build Mater*, vol. 25, no. 11, 2011, doi: 10.1016/j.conbuildmat.2011.04.053.

[10] P. Solanki, B. Jain, X. Hu, and G. Sancheti, "A review of beneficial use and management of dredged material," *Waste*, vol. 1, no. 3, pp. 815–840, Sep. 2023, doi: 10.3390/waste1030048.

[11] E. S. Rentier and L. H. Cammeraat, "The environmental impacts of river sand mining," 2022. doi: 10.1016/j.scitotenv.2022.155877.

[12] N. S. H. Johari, N. A. Zaiddin, M. S. Sulaiman, S. K. Sinnakaudan, E. Sathiamurthy, and A. F. Hamzah, "Quick scoping review on the impact of sand mining activities on freshwater ecosystem, hydraulic regime and river morphology," in *AIP Conference Proceedings*, 2023. doi: 10.1063/5.0110438.

[13] D. Padmalal and K. Maya, *Sand Mining: Environmental Impacts and Selected Case Studies*, no. 91. 2014.

[14] E. Park, "Sand mining in the Mekong Delta: Extent and compounded impacts," 2024. doi: 10.1016/j.scitotenv.2024.171620.

[15] M. Rinaldi, B. Wyzga, and N. Surian, "Sediment mining in alluvial channels: Physical effects and management perspectives," 2005. doi: 10.1002/rra.884.

[16] S. Arora, H. K. Patel, A. D. Lade, and B. Kumar, "Turbulence structure and bank erosion process in a dredged channel," *River Res Appl*, vol. 39, no. 4, 2023, doi: 10.1002/rra.4100.

[17] M. A. Ashraf, M. J. Maah, I. Yusoff, A. Wajid, and K. Mahmood, "Sand mining effects, causes and concerns: A case study from bestari jaya, Selangor, Peninsular Malaysia," *Scientific Research and Essays*, vol. 6, no. 6, 2011.

[18] S. Damseth *et al.*, "Assessing the impacts of river bed mining on aquatic ecosystems: A critical review of effects on water quality and biodiversity," 2024. doi: 10.1016/j.hydres.2024.01.004.

[19] A. Srivastava and S. K. Singh, "Utilization of alternative sand for preparation of sustainable mortar: A review," Apr. 20, 2020, *Elsevier Ltd*. doi: 10.1016/j.jclepro.2019.119706.

[20] S. I. Mohammed and K. B. Najim, "Mechanical strength, flexural behavior and fracture energy of Recycled Concrete Aggregate self-compacting concrete," *Structures*, vol. 23, pp. 34–43, Feb. 2020, doi:

10.1016/j.istruc.2019.09.010.

[21] M. Amar, M. Benzerzour, J. Kleib, and N. E. Abriak, "From dredged sediment to supplementary cementitious material: characterization, treatment, and reuse," *International Journal of Sediment Research*, vol. 36, no. 1, pp. 92–109, Feb. 2021, doi: 10.1016/j.ijsrc.2020.06.002.

[22] S. Rakshith and D. N. Singh, "Utilization of Dredged Sediments: Contemporary Issues," *J Waterw Port Coast Ocean Eng*, vol. 143, no. 3, 2017, doi: 10.1061/(asce)ww.1943-5460.0000376.

[23] J. Brils, P. de Boer, J. Mulder, and E. de Boer, "Reuse of dredged material as a way to tackle societal challenges," *J Soils Sediments*, vol. 14, no. 9, 2014, doi: 10.1007/s11368-014-0918-0.

[24] P. Crocetti, J. González-Camejo, K. Li, A. Foglia, A. L. Eusebi, and F. Fatone, "An overview of operations and processes for circular management of dredged sediments," *Waste Management*, vol. 146, 2022, doi: 10.1016/j.wasman.2022.04.040.

[25] G. Dorleon, S. Rigaud, and I. Techer, "Management of dredged marine sediments in Southern France: Main keys to large-scale beneficial re-use," *Environ Sci Pollut Res*, 2024.

[26] A. el M. Safhi, P. Rivard, A. Yahia, M. Benzerzour, and K. H. Khayat, "Valorization of dredged sediments in self-consolidating concrete: Fresh, hardened, and microstructural properties," *J Clean Prod*, vol. 263, 2020, doi: 10.1016/j.jclepro.2020.121472.

[27] BS EN 197-1, "British standard for Cement - Composition, specifications and conformity criteria for common cements," 2011, *BSI, London*.

[28] BS 812 -103.1, "British standard for testing aggregates - Methods for determination of particle size distribution," 1985, *BSI, London*.

[29] B. P. Bose and M. Dhar, "Dredged Sediments are One of the Valuable Resources: A Review," *International Journal of Earth Sciences Knowledge and Applications*, vol. 4, no. 2, 2022.

[30] J. Couvidat, V. Chatain, H. Bouzahzah, and M. Benzaazoua, "Characterization of how contaminants arise in a dredged marine sediment and analysis of the effect of natural weathering," *Science of the Total Environment*, vol. 624, 2018, doi: 10.1016/j.scitotenv.2017.12.130.

[31] M. Bortali, M. Rabouli, M. Yessari, and A. Hajjaji, "Characterizing Harbor Dredged Sediment for Sustainable Reuse as Construction Material," *Sustainability (Switzerland)*, vol. 15, no. 3, Feb. 2023, doi: 10.3390/su15031834.

[32] P. Mattei *et al.*, "Evaluation of dredged sediment co-composted with green waste as plant growing media assessed by eco-toxicological tests, plant growth and microbial community structure," *J Hazard Mater*, vol. 333, 2017, doi: 10.1016/j.jhazmat.2017.03.026.

[33] American Society for Testing and Materials, "Standard specifications for concrete aggregates (ASTM C33)."

[34] L. Ferrans, Y. Jani, L. Gao, and W. Hogland, "Characterization of dredged sediments: A first guide to define potentially valuable compounds - The case of Malmfjärden Bay, Sweden," *Advances in Geosciences*, vol. 49, pp. 137–147, Sep. 2019, doi: 10.5194/adgeo-49-137-2019.

[35] W. lu Zhang, L. yang Zhao, B. A. McCabe, Y. hui Chen, and L. Morrison, "Dredged marine sediments stabilized/solidified with cement and GGBS: Factors affecting mechanical behaviour and leachability," *Science of the Total Environment*, vol. 733, 2020, doi: 10.1016/j.scitotenv.2020.138551.

[36] Chen, B., & Liu, J. (2004). Effect of aggregate on the fracture behavior of high strength concrete. *Construction and Building Materials, 18*(8). https://doi.org/10.1016/j.conbuildmat.2004.04.013

[37] Joel, M., & Mbapuun, I. D. (2017). Comparative analysis of the properties of concrete produced with Portland Limestone Cement (PLC) grade 32.5n and 42.5r for use in rigid pavement work. *Global Journal of Engineering Research, 15*(1). https://doi.org/10.4314/gjer.v15i1.3

[38] Khadka, S., & Mishra, A. K. (2022). Effect of fine aggregate sources on compressive strength of cement concrete. *J Adv Res Const Urban Arch, 7*(1 & 2), 9–16.36] Chen, B., & Liu, J. (2004). Effect of aggregate on the fracture behavior of high strength concrete. Construction and Building Materials, 18(8). https://doi.org/10.1016/j.conbuildmat.2004.04.013

[39] Lee, J., & Lee, T. (2019). Influences of chemical composition and fineness on the development of concrete strength by curing conditions. *Materials, 12*(24). https://doi.org/10.3390/MA12244061

[40] Zhao, Y., Liu, Y., & Xu, B. (2021). Effect of coarse aggregate size distribution on fracture toughness of concrete based on boundary effect model. *Theoretical and Applied Fracture Mechanics, 113*.

https://doi.org/10.1016/j.tafmec.2021.102970

[41] Mussey, B. K., Damoah, L. N. W., & Akoto, R. N. A. (2024). Optimization of concrete mix design for enhanced performance and durability: integrating chemical and physical properties of aggregates. *Material Engineering, 11*(1).

[42] P. Ozer-Erdogan, H. M. Basar, I. Erden, and L. Tolun, "Beneficial use of marine dredged materials as a fine aggregate in ready-mixed concrete: Turkey example," *Constr Build Mater*, vol. 124, 2016, doi: 10.1016/j.conbuildmat.2016.07.144.

[43] Department of Environment Malaysia. (2005). *Guidelines for the application of special management of scheduled waste*.

[44] H. Beddaa, I. Ouazi, B. Fraj, F. Lavergne, and J. M. Torrenti, "Reuse potential of dredged river sediments in concrete: Effect of sediment variability," *J Clean Prod*, 2020, doi: https://doi.org/10.1016/j.jclepro.2020.121665.

[45] F. Agostini, F. Skoczylas, and Z. Lafhaj, "About a possible valorisation in cementitious materials of polluted sediments after treatment," *Cem Concr Compos*, vol. 29, no. 4, 2007, doi: 10.1016/j.cemconcomp.2006.11.012.

[46] J. Couvidat, M. Benzaazoua, V. Chatain, A. Bouamrane, and H. Bouzahzah, "Feasibility of the reuse of total and processed contaminated marine sediments as fine aggregates in cemented mortars," *Constr Build Mater*, vol. 112, 2016, doi: 10.1016/j.conbuildmat.2016.02.186.

[47] M. Samara, Z. Lafhaj, and C. Chapiseau, "Valorization of stabilized river sediments in fired clay bricks: Factory scale experiment," *J Hazard Mater*, vol. 163, no. 2–3, 2009, doi: 10.1016/j.jhazmat.2008.07.153.

[48] Z. Lafhaj, M. Samara, F. Agostini, L. Boucard, F. Skoczylas, and G. Depelsenaire, "Polluted river sediments from the North region of France: Treatment with Novosol® process and valorization in clay bricks," *Constr Build Mater*, vol. 22, no. 5, 2008, doi: 10.1016/j.conbuildmat.2007.01.023.

[49] American Society for Testing and Materials, "Standard test method for organic impurities in fine aggregates for concrete (ASTM C40)."

[50] E. I. Yang, S. T. Yi, and Y. M. Leem, "Effect of oyster shell substituted for fine aggregate on concrete characteristics: Part I. Fundamental properties," *Cem Concr Res*, vol. 35, no. 11, 2005, doi: 10.1016/j.cemconres.2005.03.016.

[51] N. Manap *et al.*, "Performance of dredged sediment as a replacement for fine aggregates in concrete mixture: Case study at Sungai Pekan, Pahang," in *MATEC Web of Conferences* , 2019. doi: 10.1051/matecconf/2019.

[52] L. Ben Allal, M. Ammari, A. Azmani, S. Lamrani, and I. Frar, "Valorisation des sédiments de dragage portuaire du nord du Maroc dans des matériaux de construction en terre cuite," in *Conférence Méditerranéenne Côtière et Maritime* , 2011. doi: 10.5150/cmcm.2011.028.

[53] BS EN 12390-1, "British standard for testing hardened concrete — Part 1: Shape, dimensions and other requirements for specimens and moulds," 2000, *BSI, London*.

[54] M. Malekipour and F. Moodi, "A novel approach to improve quality of delivered concrete using slump estimations of the ready-mixed concrete (RMC) truck mixer," *Journal of Building Engineering*, vol. 44, 2021, doi: 10.1016/j.jobe.2021.103361.

[55] BS EN 12350-2, "British standard for testing fresh concrete - Part 2: Slump test," 2009, *BSI, London*.

[56] BS EN 12350-3, "British standard for testing fresh concrete - Part 3: Vebe test," 2009, *BSI, London*.

[57] BS EN 12390-3, "British standard for testing hardened concrete — Part 3: Compressive strength of test specimens," 2019, *BSI, London*.

[58] S. A. Masjuki *et al.*, "The relation between destructive and non-destructive test of concrete incorporated with dredged sediment as fine aggregate replacement," in *Lecture Notes in Civil Engineering*, 2024. doi: 10.1007/978-981-99-6026-2_21.

[59] BS EN 12504-4, "British standard for testing concrete in structures— Part 4: Determination of ultrasonic pulse velocity," 2021, *BSI, London*.

[60] BS EN 12504 – 2, "British standard for testing concrete in structures — Part 2: Determination of rebound number," 2021, *BSI, London*.

[61] M. Jedidi, "Evaluation of the Quality of Concrete Structures by the Rebound Hammer Method," *Current Trends in Civil & Structural Engineering*, vol. 5, no. 5, 2020, doi: 10.33552/ctcse.2020.05.000621.

[62] A. Johnson, A. Mery Roy, A. Mariam Thomas, C. Uday, and A. Professor, "Exploring the innovative use of dredged material in construction," *International Journal of Engineering Research & Technology*, vol. 9, no. 4, 2020, [Online]. Available: www.ijert.org

[63] Z. Zhao, M. Benzerzour, N. E. Abriak, D. Damidot, L. Courard, and D. Wang, "Use of uncontaminated marine sediments in mortar and concrete by partial substitution of cement," *Cem Concr Compos*, vol. 93, 2018, doi: 10.1016/j.cemconcomp.2018.07.010.

[64] F. Benslafa, D. Kerdal, B. Mekerta, and A. Semcha, "The use of dredged sediments as sand in the mortars for tunnel lining and for environmental protection," *Arab J Sci Eng*, vol. 39, no. 4, pp. 2483–2493, Apr. 2014, doi: 10.1007/s13369-013-0805-9.

[65] S. B. Singh, P. Munjal, and N. Thammishetti, "Role of water/cement ratio on strength development of cement mortar," *Journal of Building Engineering*, vol. 4, pp. 94–100, Dec. 2015, doi: 10.1016/j.jobe.2015.09.003.

[66] W. Tang and H. Cui, "Mechanical and durability properties of concrete using dredged marine sand," in *Materials Science Forum*, 2017. doi: 10.4028/www.scientific.net/MSF.890.406.

[67] P. Nel, "The effect of the aggregates characteristics on the performance of portland cement concrete," *The University of Texas at Austin*, 2003.

[68] H. Donza, O. Cabrera, and E. F. Irassar, "High-strength concrete with different fine aggregate," *Cem Concr Res*, vol. 32, no. 11, 2002, doi: 10.1016/S0008-8846(02)00860-8.

[69] N. H. A. S. Lim, N. F. N. Alladin, H. Mohammadhosseini, N. F. Ariffin, and A. N. Mazlan, "Properties of Mortar Incorporating Spent Garnet as Fine Aggregates Replacement," *International Journal of Integrated Engineering*, vol. 12, no. 9, 2020, doi: 10.30880/ijie.2020.12.09.012.

[70] E. Whitehurst, "Soniscope tests concrete structures," *ACI Journal Proceedings*, vol. 47, no. 2, 1951, doi: 10.14359/12004.

[71] A. M. Abdul Latif and Z. M. R. Abdul Rasoul, "Correlation between the compressive strength of concrete and ultrasonic pulse velocity; investigation and interpretation," *Journal of Kerbala University*, vol. 7, no. 3, 2009.

[72] A. Jain, A. Kathuria, A. Kumar, Y. Verma, and K. Murari, "Combined use of non-destructive tests for assessment of strength of concrete in structure," in *Procedia Engineering*, 2013. doi: 10.1016/j.proeng.2013.03.022.

[73] S. Hannachi and M. N. Guetteche, "Review of the rebound hammer method estimating concrete compressive strength on site," in *Proceedings of International Conference on Architecture And Civil Engineering (ICAACE'14) Proceedings of International Conference on Architecture and Civil Engineering (ICAACE'14)*, 2014. doi: 10.17758/ur.u1214338.