

Utilisation of Dredged Sediment as Aggregate Substitute in Cement Composites – A Review

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ABSTRACT - The reuse of dredged sediment as aggregate offers a sustainable alternative to natural sand and gravel replacements, which are becoming increasingly scarce due to over-extraction. This review examines the beneficial use of dredged sediment in construction, highlighting its potential applications, economic advantages, and environmental benefits. The findings revealed that with appropriate treatment—such as particle size refinement, washing, and calcination—DS can replace natural fine aggregates by up to 30% in mortar and concrete mixtures without significantly compromising performance. Optimal substitution rates generally range between 10–20%, improving strength through enhanced particle packing and hydration. However, high fine content and contaminants like chlorides, sulphates, and heavy metals limit higher substitution rates. Treatment techniques like the Novosol process and thermal calcination were effective but cost-prohibitive at scale. The review highlights technical, environmental, and regulatory barriers, while also emphasising the potential of DS to support circular economy practices in the construction sector. By reviewing recent studies and case examples, this paper aims to provide a comprehensive understanding of both the potential and the obstacles associated with the reuse of dredged sediment.

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1. INTRODUCTION

Sediments are an assemblage of unconsolidated particles consisting of clay, silt, and sand, which are generated by the process of rock and soil erosion, biological processes, and anthropogenic activities [1]. Equilibrium disruption of water masses and navigation hindrance are anticipated consequences of settling sediments at the bed of rivers and seas [2-4]. The deposition of sediments also contributes to a substantial reduction of the storage capacity of water structures [5]. Removal of the accumulated sediment from the bed of waterbodies through dredging operations is essential to maintain navigable depth [6-10] and for flood minimisation [11,12]. Sediment is also regularly dredged from harbors, turning basins, jetties, docks, dikes, breakwater, berthing sites, locks and dam [13]. In addition to these, dredging is performed for rehabilitation purposes and development of canals [14]. Huge volume of sediment dredging is required for the construction of new marine structures, waterways and ports [15]. The dredging process is generally performed using specialised equipment such as coring, grab and hydraulic suction (for large scale).

In fact, dredging activities for maintenance and navigation of waterways are associated with a worldwide annual dredged sediment (DS) production of more than one billion m³, which is equivalent to 1300 metric tons of DS with a wet density of 1300 kg/m³ [16]. Dredging operation accounts for production of 300 million m³ of sediment in Europe [15,16], 50 million m³ in France [15,17], 300 million m³ in USA [15,18], 100 million m³ in China [20] and 3 million m³ in Turkey [21]. These sediments arise from marine dredging, which is conducted in harbors and coastal areas and from riverine contributions [22]. In the United States, dredging operations support an extensive network that includes around 25,000 miles (40,234 km) of navigation channels, in addition to over 400 ports and upwards of 200 deep-water harbors [23]. The characteristics of dredged sediment are significantly influenced by the type of waterbody from which they are extracted. Marine sediments often contain higher levels of organic matter and nutrients, while freshwater sediments may have varying proportions of sand, silt, and clay [24]. Sediments from different environments also exhibit distinct grain size distributions due to the varying energy levels of transport medium, transport mechanisms, and depositional conditions characteristic of each environment [25].

Consequently, significant waste management concern arises from the large volume of dredged sediment generation, particularly in the context of environmental and economic issues [20-23]. The various sediment management methods commonly available are reliant upon the degree of contamination as well as the legal restrictions that are in place in the area, as discussed by Dede et al. [30]. For instance, dredged sediments extracted from industrially contaminated sites can lead to environmental degradation at disposal areas and their surroundings, as harmful elements like heavy metals and toxic by-products may leach into the soil and groundwater [31]. Mousavi et al. [32] highlighted that until recently, sea

dumping had been the predominant approach for managing dredged marine sediments globally. However, there has been growing criticism of the practice of sea disposal, leading to decreased waste disposed of in the sea and tightening environmental regulations [26,27]. To preserve the aquatic ecosystem, the London Convention prohibits the disposal of contaminated DS into the ocean in countries that have signed this protocol [8]. After sea, disposal in landfills is the second prevalent option in handling dredged sediment [28,29]. Nonetheless, the process of land disposal is frequently associated with significant expenses and necessitates extensive land areas [36]. In land disposal method, Beddaa et al. [11] stated that national regulations typically classify dredged sediments as waste. Sediment with high concentration of contaminants is considered hazardous and requires treatment before reclaiming or landfilling to reduce the contaminants to acceptable levels [37]. Otherwise, they also can be stored in confined facilities specific to hazardous wastes.

Past papers collectively highlighted that the conventional sediment management methods; sea disposal or storing in confined facilities is no longer economically, environmentally, or socially sustainable due to the significant volumes of dredged sediment produced annually and the stricter regulatory requirements for sediment management [2,3,31,32]. As a result, a growing body of research is focused on the sustainable management of dredged sediments by treating them as an alternative resource, promoting the implementation of a circular economy (CE) in sediment management. The application of dredged sediment as a partial substitute in construction materials has been explored by various studies [11,33-39]. Valorising dredged sediment as a valuable local resource has the potential to offer both economic and environmental benefits, aligning with the concept of CE [1,40]. The extent to which DS utilised in land reclamation for engineering purposes varies across different countries. In Ireland, it accounts for up to 20% of its usage, while in the USA it ranges from 20-30% [9]. In the Netherlands, it reaches up to 23%, in Spain it accounts for around 76%, and in Japan it goes as high as 90%. Dredged sediment has been successfully adopted in road construction [33,41-44], brick manufacturing [35,45,46], also in cement composites; either as supplementary cementitious materials (SCM) [36,38,47,48] or as aggregate substitute [19,39,49-53].

The use of dredged materials, in most cases, differ significantly from one nation to another [60]. Furthermore, reuse of DS as alternative resource also varies according to its application. For instance, Zhao et al. [55] reported that currently, fewer studies have explored the reuse of sediments in cement-based materials (mortar & concrete) in comparison to DS utilisation in road construction. From the solidification and stabilisation of dredged sediment emerged as an effective technique in addressing the mechanical properties required for utilisation in road construction and the established standard for environmental impact through addition of cement, lime and other binders, as such fly ash and slag [56-62]. Concrete, being the most extensively used building material globally, requires significant quantities of cement, aggregate, and water, along with mortar [55,63-65]. Consequently, these cement-based products have great potential for the extensive valorisation of sediment [72].

Currently, the construction industry is experiencing scarcity of conventional resources due to overexploitation of natural resources, most of which are non-renewable [42, 43, 51, 52]. Using DS as a partial or full replacement for natural aggregates will solve the problem faced from the depletion of sand and gravel resources, whose extraction causes ecological damage and contributes to carbon emissions. Moreover, DS is often locally available, which helps reduce the carbon footprint and cost associated with transporting conventional aggregates. Technically, with appropriate treatments such as dewatering, drying, or stabilization, DS can be processed to meet the physical and mechanical requirements of fine aggregates used in non-structural or low-grade concrete [73]. Reuse of DS also presents a promising approach for sustainable waste management. Disposing of this material is often costly and environmentally harmful; therefore, incorporating it into construction materials like concrete can reduce landfill pressure and promote circular economy practices. Overall, using DS in concrete not only promotes sustainability but also offers economic and technical advantages that support its broader adoption in the construction industry.

In response to the growing environmental and material sustainability challenges in the construction sector, this review evaluates the viability of using dredged sediments (DS) as a substitute for natural aggregates in cement composites (concrete and mortar). Despite extensive research on various waste-based replacements in concrete, the potential of dredged sediment remains underexplored due to concerns over its variability, contamination, and lack of standardised treatment protocols. There is a need to consolidate the fragmented literature to guide researchers on when, how, and to what extent DS can be effectively used in cement composites. Thus, this review aims to bridge this gap by systematically analysing the physical and chemical characteristics of DS, evaluating treatment techniques, examining its performance in cementitious systems as aggregate substitute, and highlighting practical and regulatory challenges. Readers will gain insights into best practices, research gaps, and potential applications, enabling them to make informed decisions on using DS in future studies or projects.

2. CHARACTERISATION OF DREDGED SEDIMENT

For evaluation of the most suitable approach for managing the sediment and its reuse potential, a thorough characterisation is always crucial. This is because even in geographically proximate zones, DS exhibit significant variability in their properties, which is contributed by various interdependent factors, including the inherent properties of the raw materials, the extent of erosion, the economic activity in the vicinity, and even the timing of sediment production during dredging [74]. The composition and physiochemical characteristics of DS is greatly dependent on a case-by-basis. The ratio of sand, silt, and clay composition of DS varies based on the source material and erosion period, whereby

Mymrin et al. [75] found that regularly dredging a channel result in bigger particle sizes. Therefore, suitability of reusing DS as aggregate substitute is essential to be determined by analysing and defining its properties [68,69]. Amar et al. [38] and Bortali et al. [70] outlined the standards and procedures for characterisation tests associated with DS in their studies. In this regard, the research often focuses on comprehensively analysing all aspects of dredged sediment characterization, including both on-site evaluations and laboratory tests [79]. This has led researchers to explore a wide range of characterisations, such as physical, microscopic, chemical, mineralogical, environmental, mechanical, and geotechnical analyses [10,68,72-76]. It is important to evaluate the trace elements, organic-matter concentrations, nutrients, and organic compounds to establish the probable end users and assess the necessity for any pre-treatment [85]. Regulatory frameworks often require characterisation studies of dredged sediments to identify their optimal destination, due to the increasing interest in sustainable development concerns [78,79].

Granulometric analysis is fundamental in determining the feasibility of using DS as a replacement for natural sand. The particle size distribution significantly influences the workability, strength, and durability of concrete and cement mortar. Granulometric composition is generally determined through dry sieving for DS with particles greater than 400 μm , while laser diffraction analyser is used for DS with particles smaller than 400 μm [84]. Standards such as ASTM C136 [88] and BS EN 12620 [89] are commonly referred for sieve analysis of DS. The particles shall pass through 4.75mm sieve and retain on 150 μm sieve, as per ASTM C136 and BS EN 12620. For the formulation of standard mortar, it is necessary to have clean sand for which the coarsest grained aggregate is less than 2 mm ($D_{\text{max}} < 2 \text{ mm}$). According to Amar et al. [38], mix formulation of a standard mortar requires fine aggregates that are finer than 2 mm ($D_{\text{max}} < 2 \text{ mm}$), otherwise considered as clean sand. DS is recognised to comprise a high percentage of fines content ($< 50 \mu\text{m}$). DS typically composed of more than 80% silt and clay particles [4,80,81]. However, some source reveals about 57% of fine particles [92], highlighting the heterogeneity aspect of DS. The sediment from the Safi Harbor (Morocco) study [78] was classified as medium to fine sand, with approximately 90% of particles between 0.315 mm and 1.25 mm. Meanwhile, sediments from Klusov and Ruzin reservoirs (Slovakia) [93] contained a high proportion of particles $< 50 \mu\text{m}$, thus requiring further treatment process such as milling to be reused as supplementary cementitious materials or sieving to be used as sand substitute. To match particle size distribution of natural sand as closely as possible, processing of DS such as washing, drying and sieving are necessary.

Investigation by Rosman et al. [56], reported that DS from Kuala Muda, Kedah, Malaysia has moisture content (wc) of 91.96% and specific gravity (G_s) of 2.57, while DS obtained through similar manner from Kuala Perlis, Perlis, Malaysia has wc and G_s of 218.07% and 2.68. The characterisation study above corresponds to range of water content suggested by [45]. Sediment characterisation by Casado-Martínez et al. [73] reveals that sandy sediment has tendency to contain higher organic content (24%) than coarse sediment (1%). Benslafa et al. [23] and Ferrans et al. [83] utilised loss on ignition test to determine organic content of sediment revealed an organic content of 24.7% and 12.7%, respectively. Studies observed that average density of sediment (2,450 kg/m^3) is lower than natural sand [23]. The lower density can be explained by the high organic content and fineness of sediment compared to conventional sand. The high fine content and porous impurities of DS is likely to result in a higher rate of absorption [11]. The interaction between clay minerals and organic matter in sediments also allows for the absorption or desorption of nutrients and trace elements, either naturally occurring or anthropogenic [91].

Ferrans et al. [4] reported that chemical characterisation of DS is useful in determining contamination baselines of the water besides assessing the potential reuse of DS. Chemical analysis can be performed through analysis such as thermogravimetric (TGA) analysis, X-ray diffractometry (XRD) and X-ray fluorescence (XRF) for quantification of fractions, identifying mineral phases and chemical elements, respectively [16]. Concentration of trace elements in DS can be determined from inductively coupled plasma atomic emission spectroscopy (ICP-AES) [4,53,70]. Copper (Cu), lead (Pb) and zinc (Zn) are reported as the primary hard metal contamination of DS with a concentration greater than 5 mg/L [4,10,70,81,82,84]. Chemical analysis of different fractions of DS shows that metal contaminations are distributed more in the finer fractions, since they are typically retained in silt and clay content [70,85]. Hence, researchers are encouraging valorisation of coarser fractions by employing particle size cut-off to minimise trace metal contamination of DS [11,70].

Analysing DS for chloride and sulphate is necessary, particularly for DS obtained from marine water for utilisation in reinforced structures. Hence, due to influence of chloride and sulphate content on durability of concrete and mortar, the chemical analysis must be exhaustive. Contamination by chloride and sulphate ions will degrade the structural integrity of the cementitious matrix over the time. Study by Benslafa et al. [23] and Bortali et al. [70] highlights that DS samples are typically contaminated with high concentrations of chloride ions, exceeding the reference threshold but contains insignificant amount of sulphate ions. Hence, treatment of DS is required to lower the chloride and sulphate content through fresh water washing to acceptable limits.

From literature, silica (SiO_2), alumina (Al_2O_3), calcium oxide (CaO) and iron oxide (Fe_2O_3) are identified as the primary chemical elements of sediment [23,49,70,72,75,86-90]. Various studies reported DS to have alkaline pH (> 8) [80,82,91-93], which can be attributed to the traces of alkalis (Na_2O , K_2O , MgO , CaO) in the chemical composition of DS. Sediments contain a significant amount of carbon (9-10%), mostly in the form of organic matter, with total organic carbon (TOC) accounting for around 60% and as evidenced by XRD mineralogy, carbon content also contributed by carbonates, dolomite, and calcite [59]. Mineralogical characterisation through XRD analysis highlights the presence of crystallised mineral of quartz (SiO_2), calcite (CaO) and dolomite (CaMgCO_3) [19,23,53,70]. Though, these elements are

commonly present in DS, XRD analysis of dredged sediments reveals variations in mineral composition and contamination levels across different global regions. The sediment minerals can be transferred from the watershed or generated by existing mineral transformations or formed through chemical precipitation [30,94]. In the Indian continental margin, XRD analysis showed diverse mineral compositions, including clay minerals like illite, smectite, and kaolinite, across multiple offshore sites. The high composition of quartz in dredged sediment is similar to natural sand [103], which contributes to its high stability and strength in construction applications.

3. TREATMENT OF DREDGED SEDIMENT

Characteristics and environmental safety, prior to its integration into construction material. The treatment procedure often comprises many stages, such as dewatering, particle size modification, and elimination of contaminants, as listed in Table 1. Since it has been established that contaminants are prone to be bound to finer fractions of sediment, researchers have opted for particle size cutting off to valorise the coarser fractions Couvidat et al. [53] used size cut off at 80 μm , while Ozer-Erdogan et al. [19] managed contamination of DS through particle size cut off at 63 μm . The results obtained by the authors shows a clear improvement in mechanical performance when treated DS sample was utilised. Organic and inorganic contaminants can be treated naturally by leaching and dewatering, followed by chemical treatment with phosphate for reuse as mortars in civil engineering [96]. Submitting contaminated DS to simple washing can potentially decrease the amount of free chloride ions by as much as 80% [75,88]. Calcination at high temperature is performed to remove organic contents and to activate the clay mineral [15,84], a useful step in reusing DS as SCM. Through the removal of organic content by calcination, density of DS can be enhanced as exemplified in the study by [74]. Iron oxide (Fe_2O_3) concentration dropped from 9.7% to 5.3% following calcination, which explained the color alterations of sediments, as depicted in the Figure 1. Grinding method is generally adopted when DS is used as SCM [14,84] and is not required for DS samples to be utilised as aggregate substitute.

The highly contaminated DS samples are often treated through Novosol process, which involves chemical treatment whereby heavy metals are inertised and elimination of organic pollutant through heat treatment. The chemical treatment in the Novosol process is phosphatation using 2-3.5% of phosphoric acid, H_3PO_4 and the process involves calcinations above 650°C [61]. The phosphoric acid will transform the calcium ions present in unprocessed sediment into minerals similar to apatite, which will effectively stabilise the heavy metals; this is then followed by subjecting the phosphatised sediment to thermal treatment to eliminate organic pollutants [22]. Given that the Novosol process entailed both chemical treatment and calcination, it ended up becoming a costly treatment method of DS. Treated sediments have been effectively used as a raw material in brick construction, demonstrating the efficiency of the Novosol Process [95-97]. Moreover, application of sediment-based brick at an industrial scale highlight that the treatment method does not cause any environment effect [35,45].

Table 1. Treatment methods of DS

Treatment	References
Sieving, washing, oven drying (250°C for 4hrs)	[53,98]
Particle size cut off (> 75 μm , ASTM C136)	[14,15,47,50]
Calcination (Heating at high temperature, eg 850°C for at least 1 hr)	[15,19,84]
Decantation and dewatering	[21]
Novosol process: phosphatation (2–3.5% of phosphoric acid H_3PO_4) calcinations at $\geq 650^\circ\text{C}$	[19,52,55,88]



Figure 1. Color change of dredged sediment after calcination [74]

4. FEASIBILITY OF DREDGED SEDIMENT AS AGGREGATE SUBSTITUTE

Research shows that up to 30% of sediment volume can be used as concrete aggregate with minimal impact on properties, though organic content and fine particles can affect performance [11]. Concrete made from dredged sediments can meet minimum strength requirements for C20 mix, suitable for various construction applications [108]. Junakova et al. [100] focused on reusing of coarse-grained DS (0–4 mm) in place of natural aggregate and fine grained DMs in place of cement. Results of this study showed that concrete made from coarse grained DMs with 20% substitution is comparable to conventional concrete, demonstrating suitability of DS as raw material. Benslafa et al. [23] reported that 20% of DS substitutions resulted in mortars with better mechanical performance than control mortar with compressive strength and flexural strength of 46.6 MPa and 7.5 MPa and are effective in resisting acid attacks. Hence, making the DS based mortar suitable for aggressive environments such as tunnel lining. This is because the inclusion of amorphous silica in DS materials facilitates cement hydration and minimises the ettringite development. The study suggests that the higher specific surface area of DS leads to increased absorption of mix water, which can improve the density and strength of the mortar. Substitution of sand with DS at appropriate rate, such as 20% provides improvement in strength performance of cement composites, which is contributed by the increased skeletal compactness from the addition of fines, resulting in improved filling effect [37]. Improvement of compressive strength is attributed to the formation of a more compact interfacial transition zone by inclusion of DS [61]. Secondly, the presence of fines provides more nucleation sites, thereby optimising cement hydration.

Table 2 presents the optimum incorporation of DS as fine aggregate reported by various researchers. The maximum rate of sediment incorporation in cementitious matrices is dictated by technical considerations of sediment nature, including granulometric composition, as well as the intended application, performance, and durability [72]. Review of the literature reveals that the full substitution of DS as sand substitute is often not feasible. Agostini et al. [52] recommended utilisation of treated DS in moderate substitution as 100% substitution is constrained by the high porosity of the aggregate due its fine particles leading to increased water absorption and drying shrinkage of the cementitious matrix. Moreover, valorisation of DS as sand substitute is also affected by the metal contamination and organic contents [101,102]. Sediment variability affects concrete properties, with finer fractions containing organic matter negatively impacting hydration and strength [112]. Manap et al. [98] observed that incorporation of DS increases the water to cement ratio of cement mix, resulting in reduced workability and this scenario worsens as substitution rate of DS is further increased. This is because the high fine content of DS is associated with large surface area which leads to increased water demand in addition to delayed cement hydration and elevated setting time [104-107]. Some authors maintained the water to cement 9w/c ratio of the mix incorporating DS identical to the reference mix; w/c ratio of 0.55, 0.4 and 0.44 were employed for concrete formulation by Manap et al. [107], Vinothkumar et al. [117] and Limeira et al [56], respectively, whereby plasticiser additive was added by Limeira et al [56] to maintain workability. However, Couvidat et al. [53] in their study adjusted the water demand of the cement mortar mix to maintain similar slump (61 mm \pm 2 mm) which represents same workability. Similarly, Ozer focused on maintaining the slump of the freshly prepared concrete (150mm) with the addition of superplasticizer.

Experimental study by Soleimani et al. [66] demonstrated that while DS incorporation rate of 40% can maintain concrete strength, it is not sustainable. The authors instead recommend a maximum sand substitution of 20% based on consideration of environmental and economic factors. Substituting sediment for sand in concrete at a higher level necessitates the use of additional superplasticizer to compensate for the deterioration of concrete's workability [49,66]. Although superplasticizer is considered to be the essential element for enabling a greater rate of sand replacement by dredged sediment, its cost and environmental effects restrict the rate of inclusion. Scholars also have highlighted the necessity of proper treatment of DS in obtaining good mechanical performance comparable to the conventional material. Study of [21], [117] shows that adopting treatment method that reduced the chloride and sulphate ions level of sediment significantly improved the compressive strength of the concrete sample. Similarly, the study by Ozer-Erdogan et al. [66] reveals that inclusion of untreated DS downgraded the concrete samples to lower strength class for same incorporation rate. Incorporation of untreated DS is associated with presence of organic and inorganic impurities, the use of additional admixtures, fine sediments and their resulting chemical interactions which explained the reduction in strength performance of the concrete [38,47].

It is observed that DS is often incorporated as sand substitute in combination with other waste materials. Dredged sediments combined with recycled concrete aggregates have shown promise in road subgrade construction, meeting physical and mechanical requirements when properly treated [34]. Study by Ozer-Erdogan et al. [19] reveals that incorporation of composites of DS, which has been treated and assessed according to Turkey National Legislation into cement mix with other recycled waste material, stone dust as fine aggregate produces concrete with no adverse impact to mechanical and durability performance. Vinothkumar et al. [108] and Johnson et al. [110] investigated the reuse potential of DS in their study by utilising it as replacement of manufactured (M) sand. However, Chu et al. [111] made observation that DS rarely has been incorporated in fiber reinforced cementitious material. Overall, incorporating dredged sediments in concrete offers environmental and economic benefits, reducing waste and lowering production costs by up to 41% [54].

DS can also be utilised to manufacture lightweight aggregate (LWA) through the sintering process [29,112-116]. Conventionally, LWA is manufactured from shale, clay, slate, and sludge materials [125]. LWA is generally employed

for applications requiring lightweight materials with low density and hydrological retention ability, such as in horticulture and green infrastructure [118-122].

Table 2. Optimum incorporation of dredged sediment as fine aggregate

Author	Cement composite	Percentage of sand weight substituted by dredged sediment	Optimum percentage of incorporation of dredged sediment (%) as fine aggregate
[131]	Mortar	5%, 10%, 15%, 20%	10.0
[22]	Mortar	33%, 66%, 100%	33.0
[57]	Mortar	25%, 50%	25.0
[132]	Mortar	20%, 25%, 30%, 35%	20.0
[29]	Mortar	10%, 15%, 20%	20.0
[133]	Concrete	12.5%, 20%	12.5
[118]	Concrete	10%, 20%, 30%	20.0
[72]	Concrete	20%, 30%, 40%, 50%	20.0
[117]	Concrete	0%, 20%, 30%, 50%, 100%	30.0

5. CHALLENGES FACED IN REUSING DREDGED SEDIMENT

The market demand of reuse of DS as sand substitution seems to be slower than expected, despite the promising findings of the research [126,127]. The beneficial reuse of DS is still at small scale applications due to competition with the conventional products as it is regarded as not feasible technically, commercially, and environmentally in the existing market, attributable to a number of barriers that must be addressed [6,69,78]. The roadblocks are classified as technical, environmental, socio-economical, psychological and regulatory barriers. Bose et al. [69] identified the lack of stringent regulations against landfilling by DS and inadequate legislative frameworks for managing DS as the primary obstacles to the widespread reuse of DS, in addition to unfavourable market factors. From a technical point of view, variability of DS imposes a significant challenge in its reuse potential, as since findings of previous studies were mostly site specific, hence cannot be generalised. Characterisation of sediment obtained from site is necessitated by the identification its appropriate application as construction material and it varies on case-to-case basis [69,70,79,128,129].

Dredged sediments often contain large concentration of fine particles, organic matter, and contaminants like heavy metals and chlorides, which can compromise the strength and durability of concrete [11,109]. As such, high substitution level of DS in concrete and mortar offsets any sustainability benefits and often optimised at moderate substitution of 20% or less [72]. Studies have reported that fineness of dredged sand, contributed by high silt and clay content negatively affect the workability of concrete mixes, due to increased water demand and reduced slump flow [11,98]. Meanwhile, the high organic content of DS will delay cement hydration and alters setting time, compressive strength, and shrinkage when incorporated at high substitution rate [11]. Among the barriers mentioned in the literature, the management of salts and heavy metals in contaminated dredged sediment is a significant concern, since directly reusing it in concrete could cause reinforcement corrosion and chloride attacks [23].

To improve sediment properties for cementitious applications, various characterization and treatment techniques, such as calcination and chemical treatment, are often necessary [45]. However, these treatment processes are often not environmentally and economically sustainable. The Novosol process can be incur a high cost as it involves both chemical and heat treatment. Moreover, incorporation of DS often requires the addition of superplasticiser to compensate for increased water demand, whereby such inclusion will result in higher cost and reduced sustainability. However, researchers are currently focusing on developing methods and technologies for superplasticisers with improved performance at reduced costs and environmental impact [139].

The degraded perception associated with waste provides a challenge, considering even if the waste can be recycled, it will still be viewed negatively by the people. Hence, particularly in the early stages of discussions, the status of waste of DS might negatively impact potential of reusing sediments among local stakeholders and organisations [37]. The waste status of sediments reduces the social acceptability of reusing sediments as construction materials among stakeholders. Utilisation of DS as construction material also likely to contribute to a high transportation cost [69,78]. While dredging operations are conducted near water bodies, the construction sites where sediments are utilised as a replacement for aggregate might be situated far from dredging locations, requiring long-distance transportation of heavy and bulky dredged sediments. Consequently, this leads to elevated fuel consumption and necessitates the use of specialised transportation vehicles, such as trucks or barges, hence raising the overall cost. The high transportation cost is considered as a major drawback as stakeholders and organisations generally opt for the project with the lowest cost option [86].

6. CONCLUSIONS

Reusing dredged sediment as an aggregate in cement composites presents a promising opportunity for sustainable construction practices, with both environmental and economic benefits. This review has highlighted the significant potential of utilizing dredged sediments as natural sand substitute in cement mortar and concrete. However, the effective incorporation of dredged sediments into cement composites is bottlenecked with few challenges. Variability in sediment composition, potential contamination with harmful substances, and the need for standardized processing techniques are significant barriers that must be addressed. To move forward, further research should focus on optimisation of treatment techniques to eliminate contaminants and stabilise sediments, the establishment of guidelines to standardise the quality of dredged materials, and the exploration of novel applications of sediment-based aggregates in various types of cement-based materials. In conclusion, while the use of dredged sediment as an aggregate in cement composites holds significant promise, realising its full potential will need a focused endeavour to address the technical, environmental, and regulatory challenges. Overcoming these challenges might transform dredged sediments into a valuable resource for the development of sustainable construction materials, therefore supporting the circular economy and environmental conservation initiatives.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest

AUTHORS CONTRIBUTION

Asma Ahmed (Study conception and design; Writing – original draft, review and editing)

Siti Aliyyah Masjuki (Supervision)

Saerahany Legori Ibrahim (Writing – Reviewing)

Nor Farah Huda Abd Halim (Writing – Reviewing)

AVAILABILITY OF DATA AND MATERIALS

The data used to support the findings of this study are included within the article.

ETHICS STATEMENT

Not applicable.

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