UTILISATION OF DREDGED SEDIMENTS FOR SUSTAINABLE CONSTRUCTION - POSSIBILITIES AND CHALLENGES: A STATE-OF-THE-ART REVIEW.

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doi: https://doi.org/10.21467/proceedings.179.24

ABSTRACT

Population increase and rapid urbanisation have increased demand for construction materials, exerting pressure on natural resources and the environment. Conventional building materials are known to have a substantial carbon footprint, consume excessive energy, and deplete valuable resources. Sustainable construction practices demand the use of environment-friendly and energy-efficient materials. The utilisation of dredged sediments from ports, harbours, reservoirs, and rivers for construction purposes could provide a solution to the unscientific disposal of these materials, which often leads to environmental degradation. Desilting reservoirs and lakes are essential to improve water collection and maintain quality, resulting in health and economic benefits to local communities. The utilisation of dredged sediments in the manufacture of building materials offers a greener option through the management of waste and energy saving in the production of construction materials. Dredged sediments can be utilised in the production of bricks, blocks, and other building materials with performance comparable to their conventional counterparts. The characterisation and mix design and needs to be researched so as to utilise the dredged sediments in the building industry. The present study explores case studies on the utilisation of dredged sediments in the manufacture of masonry materials by conducting state of the art review of published research. This study attempts to summarise the available data to highlight the benefits and issues associated with the use of dredged sediments in construction applications and demonstrate the multiple advantages of efficient waste disposal as well as the development of energy-efficient building materials with comparable or better properties than standard building materials for future use. The review indicates the need for experimental investigation to characterise and develop mix design specifications for masonry blocks. Being a new material, its application needs to be popularised through its promotion in social housing and public schemes.

1. Introduction

Utilisation of sustainable technologies are highly imperative for green development which is included as SDG goal No: 9 in UN Goals. Sustainable construction technologies should demonstrate energy efficiency, reduce resource depletion, and promote social sustainability. A significant global initiative has been made to improve energy efficiency in residential structures, with particular emphasis on achieving zero-energy, zero-emission, and near-zero energy benchmarks. The two most commonly used masonry building materials, clay bricks and concrete blocks have a detrimental effect on the environment. The need for sustainable masonry is driven by the increased expenses for materials and carbon emissions associated with traditional masonry commodities and the requirement for reasonably priced and ecologically sound housing [1]. Utilising alternative construction materials in place of conventional ones presents a promising means of attaining sustainability. Efforts have been initiated worldwide to replace conventional masonry elements with industrial and agricultural by-products to reduce environmental impacts, and waste generation, and minimise energy consumed [2]. By incorporating innovative materials and advanced building techniques has evidences substantial reduction in environmental impact and also to boost energy efficiency in building construction. Hence, it is vital to embrace these advancements for the purpose of fostering sustainable development and constructing more robust, resilient communities for future generations. Besides, the utilisation of waste materials as replacements for conventional

Proceedings DOI: 10.21467/proceedings.179; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-984081-7-4

raw materials in the fabrication of building components not only signifies a hopeful avenue for sustainable building practices, but also constitutes a more effective approach to enhancing energy efficiency [3].

Integrating alternative building materials, especially waste materials, is crucial for achieving sustainability and improving energy efficiency in construction. Dredged sediments, which are typically regarded as waste materials and are generated in substantial quantities from ports, harbors, and reservoirs during maintenance operations, provide an invaluable resource. These sediments have been successfully utilised in various construction applications globally, such as roads, pavement blocks, concrete, mortar, and fired bricks [4], [5], [6]. The feasibility of using dredged sediments in construction relies on their composition and engineering properties, which can vary significantly due to seasonal and geographical factors. Therefore, it is essential to carefully consider this variability when assessing their suitability for specific construction applications. Construction practices incorporating dredged sediments can help reduce the environmental impact, conserve natural resources, and to enhance the energy efficiency of buildings [7]. In the state of Kerala, it is crucial to desilt dams as and rivers for numerous advantages, including the improvement of storage capacity, the enhancement of flood management, and the increase of water storage capabilities to meet the growing demands [8]. Maintaining navigation channels is an essential component of construction of maritime infrastructures in Kerala, a state with numerous ports and harbours. The process of desilting dams and rivers holds paramount importance as it serves multiple purposes, including improving storage capacity, facilitating efficient flood control measures, and auguring water storage capabilities to cater to escalating demands [9]. It improves water harvesting, purification, flood prevention, and storage capacity. Kerala must improve its water management and reduce the risk of flooding.

The objective of this review is to thoroughly assess the present state of research relating to the application of dredged sediments in sustainable construction, taking into account both the potential benefits and limitations. The objective is to offer a comprehensive overview of the properties and composition of dredged sediments that are significant enough to be utilised as construction materials.

2. Characterisation of dredged sediments

The effective management and potential reutilization of Dredged Sediments (DS) are essential, given their diverse properties. The physical properties of DS, including bulk density and porosity, differ from those of natural clay, with its density being slightly lower. The incorporation of DS in brick production enhances mechanical properties, with optimal proportions (15-20 % by weight) leading to superior bricks in physical, mechanical, and thermal aspects. Furthermore, DS stabilizes heavy metals during the firing process, reducing environmental risks by solidifying these metals within the bricks' glassy matrix [10].

The Figure 1 summarises the physical properties of dredged sediments sourced from four different locations, namely Savannah Harbour, Kuala Perlis, Safi Harbour, and Bejaira Port. There are considerable variations in the sediment composition across these sites. Specifically, Savannah Harbour exhibits the highest clay content, while Kuala Perlis displays the highest silt content. Bejaira Port, on the other hand, has the highest sand content and moisture level. It is noteworthy that the plasticity of the sediments, as indicated by the Liquid Limit and Plastic Limit, is higher in Savannah Harbour and Safi Harbour compared to the other two sites. With regard to pH levels, they are predominantly neutral to slightly alkaline. However, there are disparities in the specific gravity values among the locations, with Bejaira Port recording the highest reading.

Proceedings DOI: 10.21467/proceedings.179
ISBN: 978-81-984081-7-4

Series: AIJR Proceedings
ISSN: 2582-3922

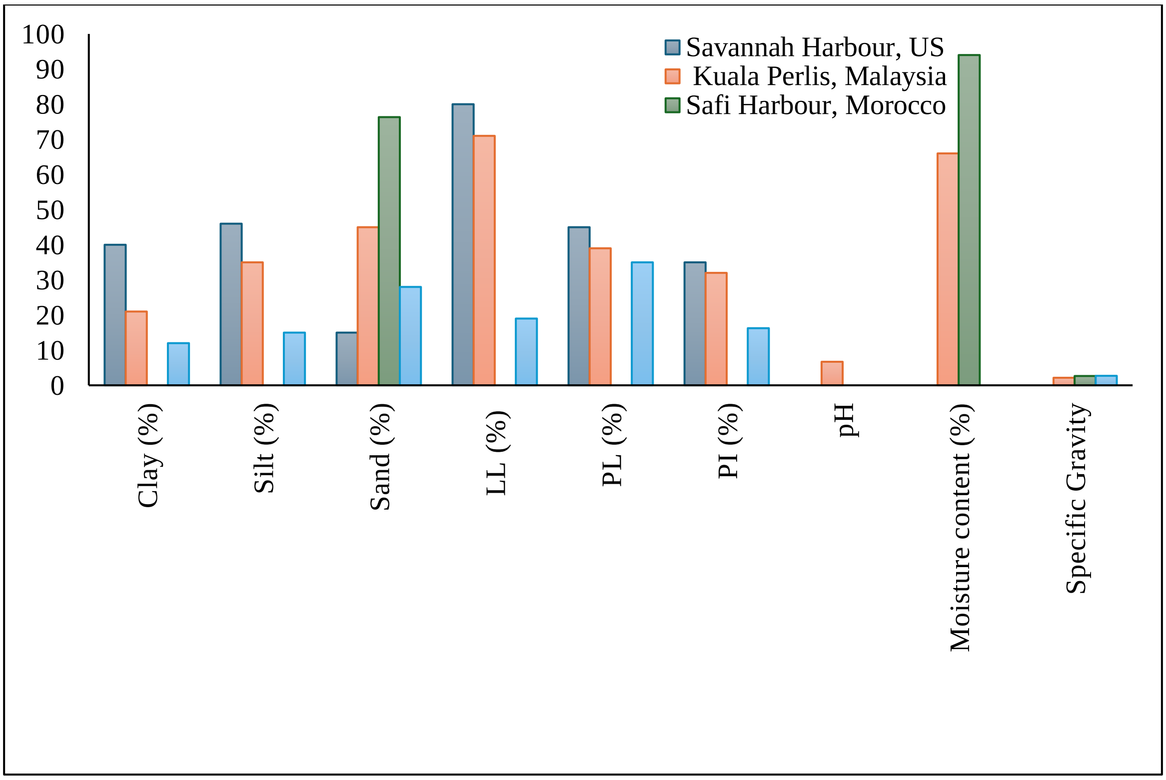

Figure 3: Physical composition of dredged sediments [11], [12], [13]

The Figure 2 provides an overview of the chemical composition of dredged sediments gathered from six different locations sites. Silicon dioxide is the most prevalent oxide in each of the samples, followed by aluminium oxide.

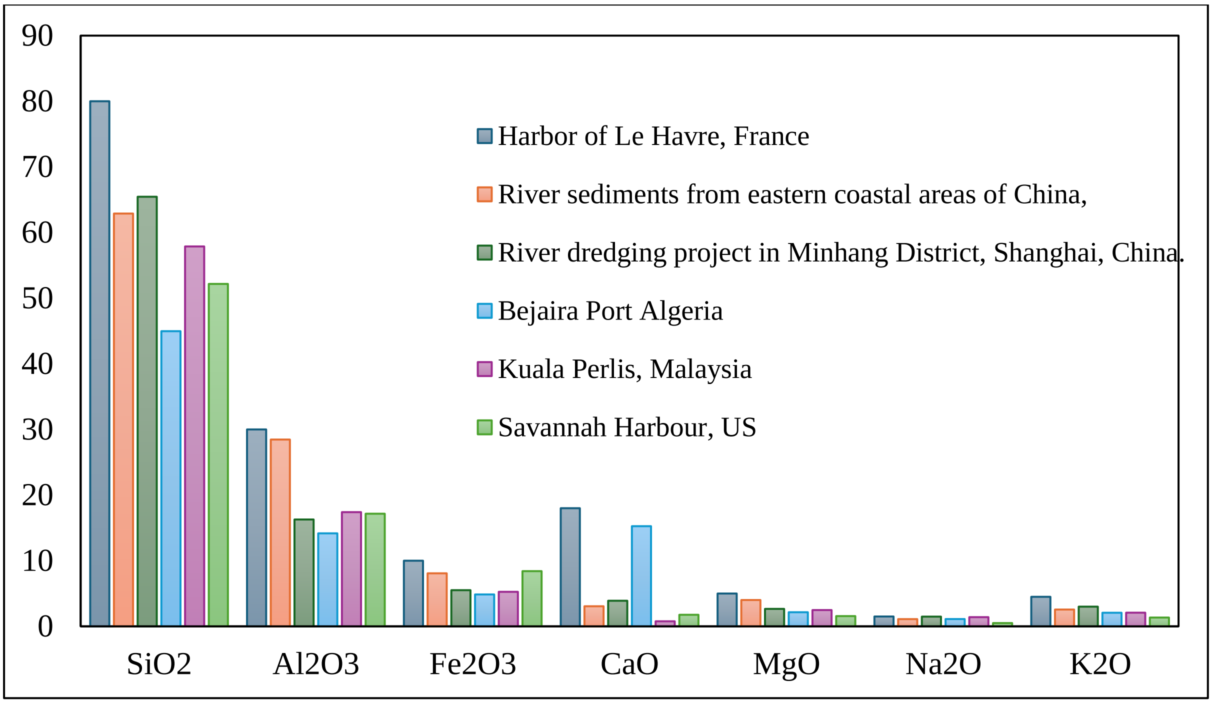

Figure 4: Chemical composition of dredged sediment [11], [12], [13]

3. Application of dredged sediments

In the year 2017, study was conducted to examine the potential use of innovative construction materials made from three distinct types of industrial waste: sediments removed

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ISSN: 2582-3922

from ports in the Atlantic Ocean, construction and demolition debris, and waste generated during lime production.[14]. This research effectively developed construction materials by utilising depositions taken from Brazilian seaports. Furthermore, the examination has shown the complexity of the mineral composition at the microscopic level, as evidenced by the analysis of smaller surface regions using energy-dispersive X-ray spectroscopy.

The usefulness of marine sediments derived from the Port of Koper was investigated in the context of the brick industry in 2018, with a specific focus on clay blocks, roofing materials, and ceramic tiles. The study's findings indicate that marine sediments acquired from the Port of Koper have limited applicability for constructing brick goods when used without any additional chemicals. This is due to severe shrinkage and high-water absorption properties in these sediments [15]. In a scholarly paper, the feasibility of utilising Harbor Dredged Sediment (HDS) as a viable resource for manufacturing clay bricks was studied focussing on the examination of the physical, mineralogical, chemical, and thermal characteristics of HDS. The study's findings indicate that HDS exhibits potential for producing environmentally friendly bricks, showcasing enhanced mechanical and thermal properties. Consequently, using HDS in brick production presents economic advantages and positive environmental implications [16]. The potential utilization of dredged sediments sourced from the Seine estuary and port basins as raw materials for the production of heavy clay, particularly terracotta, was investigated. The study assessed the sediments' physical properties, including plasticity index and salinity, as well as their chemical and mineralogical makeup. According to the findings, the sediments have similar compositions, but their low clay mineral content and high carbonate content limit their use in the ceramic sector. [17].

The relationship between the clay-water/cement ratio and the unconfined compression strength of cement-stabilized clay (CSC) made from dredged sediment was determined by creating two empirical formula models that were used to describe and predict the CSC strength using various parameters, without the use of variable coefficients. The models were observed to predict the CSC strength under diverse parameter variables effectively, and the expected outcomes agreed with the actual measured strength. Nevertheless, the models have constraints and are unsuitable for clay with a low liquidity index or initial strength [18]. Manni et al. (2021) investigated the feasibility of using dredged sediments and solid organic waste as alternatives for natural clay in constructing bricks. The study looks into brick samples' chemical composition and opto-thermal properties, including various quantities of dredged sediments. The data show lower amounts of heavy metals in bricks containing dredged sediments, with minor changes in thermal conductivity, thermal diffusivity, and specific heat [19].

Another research assessed the viability of repurposing fine-grained dredged sediment from the heavy clay sector for the production of tiles and bricks by investigating the interrelation between sediment origin and industrial characteristics by utilising sediment samples from French dam reservoirs and estuaries. The results indicate that categorising sediment sources can aid in predicting the potential reuse of dredged material in the manufacture of tiles and bricks. This research offers invaluable information for managers in the heavy clay industry who are considering the substitution of dredged sediment in order to safeguard fossil resources[20]. The feasibility of producing adobe bricks using dredged sediments from harbors and rivers as an environmentally friendly waste management solution was explored in a pilot study by examining the physical and chemical properties of sediments obtained from Dunkirk Port and Usumacinta River, and comparing the resulting properties of the adobe bricks produced using these sediments. [21].

The use of traditional hydraulic binders and alkaline-activated by-products in treating dredged sediments has been found to be more effective in improving their mechanical properties, especially for sediments with lower organic content. By optimizing the water-to-solid ratio and utilizing alkaline-activated by-products, the valorization of dredged sediments for construction applications can be enhanced [22].

Studies has been conducted concentrating on dewatering, stabilization, and the prospective application of dredged marine sediments as materials for roadbeds, with a particular emphasis on their mechanical strength and environmental implications. The properties of the mixture formulated by integrating these sediments with a hydraulic binder revealed that dewatering effectively diminishes water content, while the incorporation of the binder enhances the stability and mechanical characteristics of the sediments, making them viable for road construction purposes [23].

4. Conclusion

The present study examined the feasibility of utilising dredged sediments as a raw material for construction materials in various areas. Despite their potential, the utilization of dredged sediments faces certain limitations due to their heterogeneous nature and the site-specific focus of previous studies, which impedes generalizability. Excavated marine sediments enhanced with alkali-activated ground granulated blast furnace slag hydraulic binder stabilization with lime and cement, were used in road pavement construction. Additionally, dredged sediments with cement-fly ash-lime and nano-SiO_2 binders dehydrated with hemihydrate phosphor gypsum (HPG) was used to create economical unfired green bricks. CO_2 curing method can be employed to enhance the strength of the material and its potential for carbon sequestration. Incorporating 15-20 % of weight of DS results in bricks exhibiting superior physical, mechanical, and thermal properties compared to control bricks made solely from clay. The advantages of employing dredged sediments for construction purposes may include a decrease in the consumption of raw materials and an impact on the environment, the creation of a new market for dredged sediments to minimize dredging and disposal expenses, the construction of homes, and the generation of employment opportunities for low-income communities in a cost-effective and sustainable manner. Potential issues that may emerge include the possibility that the swelling and shrinking of dredged sediment bricks could be more pronounced, leading to cracks, while the presence of contaminants in the sediments may hinder the bricks' performance and longevity.

Conflict of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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