A REVIEW ON FEASIBILITY OF GEOPOLYMER SEA SAND CONCRETE IN INTERLOCKING CONCRETE PAVEMENT BLOCKS

Afrin fathima[1], Dr.Smitha K K[2]

[1]PG student, Civil Engineering Department, Toc H Institute of Science and Technology, Kerala, India
[2]Associate Professor, Civil Engineering Department, Toc H Institute of Science and Technology, Kerala, India

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Abstract - *Interlocking Block Pavement (IBP) has been extensively used in a number of countries as a problem-solving technique for providing pavement in areas where conventional types of construction are less durable due to many operational and environmental constraints. Portland cement concrete is a major material used in interlocking pavement blocks. It is a composite material comprising Portland cement, coarse aggregate, fine aggregate, and water. But its increased use in construction is exhausting natural resources used in its production and also cause environmental effects, making it necessary to find alternative materials. One potential method is to use sea sand as fine aggregate to produce alkali activated fly ash/GGBS concrete. Sea sand has various advantages, it is more rounded or cubical similar to river sand, the grading is generally good and consistent, contains no organic contaminant or silt and can be mined at a low cost, also the utilization of fly ash and GGBS as an alternative to Portland cement in producing alkali-activated slag concrete (ASC) contributes to environmental protection by reducing* CO_2 *emissions. This study presents a critical review of existing studies on the effects of using sea-sand and alkali activated geopolymer concrete.*

Key Words: **Fly Ash, Ground Granulated Blast Furnace Slag, Alkali Activated Concrete.**

1. INTRODUCTION

River sand is an essential raw material in construction industry for making concrete. Especially during monsoons the sources of river sand are unpredictable due to the rise in river water table. Also governments have imposed norms on the mining and utilization of river sand for construction purposes. The over collection of river sand from river beds affects our ecological cycle directly or indirectly and so instead of river sand, sea sand that is present at high level in comparison with the river sand in nature at sea shores. Only if the concrete has natural aggregates, the strength and durability would be enhanced. In the current scenario, most of the building agencies and MNC companies adopt artificial sand in their projects. Sea sand is less expensive and reduces the overall construction cost, which also helps to protect river sand from being destruction.

Construction has been most important human activity since ancient time. Concrete is widely used and reliable material for construction. Some of challenges in industry are global warming and insufficiency of construction material. One of the methods for replacing concrete constituents is the use of geo-polymer which helps in using very less quantity of cement in concrete.

1.1 Sea Sand in Concrete

Sea sand is a potential method is to use as fine aggregate in concrete. It is less expensive and reduces the overall construction cost, which also helps to protect river sand from being destruction. The chloride ions present in sea sand, make its application potentially threatening to the durability of concrete structures made by using it. Therefore, the salt content of the sea sand must be eliminated before it is utilized to avoid the potential hazards. Desalination can be done by the various methods like, water immersion, natural Sunlight exposure, rinsing, mechanical methods etc. , after preliminary treatments chloride analysis are done for maximum chloride content of sand deemed acceptable for concrete works.

1.2 Geopolymer Concrete

In 1978, Davidovits proposed that a binder could be produced by a polymerisation process involving a reaction between alkaline liquids and compounds containing aluminium and silicon. The binders created were termed "geopolymers". Unlike ordinary portland/pozzolanic cements, geopolymers do not form calcium-silicate-hydrates (CSHs) for matrix formation and strength, but silica and alumina reacting with an alkaline solution produce an aluminosilicate gel that binds the aggregates and provides the strength of concrete. Source materials and alkaline liquids are the two main constituents of geopolymers, the strengths of which depend on the nature of the materials and the types of liquids.

2. LITERATURE SURVEY

In recent years, many studies were conducted by various researchers on environmental friendly concrete materials. Geopolymer concrete is a construction materials that can be used in the construction industry. The goal which is expected from the paper is to study the effect of geopolymer sea sand concrete in interlocking concrete pavement blocks.

2.1 Studies on Interlocking Concrete Pavement Blocks

Jamshidi, et.al (2019) conducted comprehensive researches on the State-of-the-art of interlocking concrete block pavement technology in Japan as a post-modern pavement (PMP). They studied the relevant literature in English and Japanese, including journals, conference proceedings, technical reports, books, and theses, over a span of 47 years (1971–2018), and found the structural and functional performances of the ICBP in different facilities. Also examines its waste material use, less noise emission, air purifying characteristics, and heat island reduction, the environmental performance of ICBP was in harmony with sustainable practices. In addition, pavements users, both able and differently abled, rated the ICBP as a more appropriate pavement system owing to its physical appearance, serviceability, aesthetic features, lower heat island effect, rapid maintenance, and positive psychologic effects after earthquake and tsunami events. From all the studies they concluded that, the ICBP can be recommended as a PMP for the design and development of resilient transportation infrastructure assets in Japan.

Sadek, et.al (2017) evaluating the physico-mechanical and durability-related properties of concrete paving blocks containing cement kiln dust (CKD) used as a partial replacement or as an addition to cement. Hexagonal-shaped metallic moulds with approximately 34,000 mm2 area and 80 mm thickness was selected here. From the study they concluded that, It is possible to use high volumes of CKD in the production of environmental-friendly interlocking paving blocks. The quality of paving blocks depends on both of method of using CKD (i.e., addition or replacement of cement) and its percentage in the mix. At the same CKD percentage, using CKD as an addition is better than being used as a partial replacement of cement. Paving blocks containing 20% CKD as an addition to cement have comparable properties to the control blocks without CKD. Up to 40% CKD can be used in the production of paving blocks for heavy traffic applications, while 60% CKD blocks are suitable for areas subjected to medium traffic applications such as in city streets. Also, it is recommended to use the control blocks and 20% CKD blocks (as addition) in heavy traffic applications, even after 11 months of exposure to 1% HCl.

2.2 Studies on Concrete Made With Sea Sand

Cheng, et.al (2018) investigate the durability performances of coral sand concrete (CSC) produced by using porous coral sand aggregate and supplementary cementitious materials compared to river sand concrete (RSC). The durability properties of CSC were evaluated in terms of chloride penetration, water absorption, drying shrinkage, accelerated carbonation, and sulphate drying-wetting cycle. The results indicated that the CSC exhibited higher drying shrinkage, capillary water absorption, carbonation depths, and a slightly lower later compressive strength compared with RSC. However, porous coral aggregate provided a more rapid early age strength, better resistance to chloride ion penetration, and sulphate drying wetting cycle than the RSC due to its internal curing. Additionally, the combinations of internal curing and pozzolanic reaction contributed to the microstructure improvement of CSC, which conformed good durability properties of CSC containing SCMs. Moreover, the ecological evaluation demonstrated that the CSC incorporation of SCMs resulted in a significant reduction of CO_2 emission.

Xiao, et.al (2017) provide a critical review of existing studies on the effects of using sea-sand and/or seawater as raw materials of concrete on the properties of the resulting concrete, including its workability, short and long-term strength as well as durability. Both sea-sand and seawater are likely to accelerate the strength development of concrete during early stages due to the rich chloride content in sea-sand and seawater. Concrete made with sea-sand and/ or seawater has a significantly higher 7-day compressive strength, a comparable 28-day compressive strength and a similar long-term compressive strength to ordinary concrete. Also it is shown that the use of sea-sand and seawater may have a significant effect on chloride induced steel corrosion but has only a negligible effect on the carbonation process of concrete. Strong evidence exists that a combination of mineral admixtures for the concrete and reinforcement with fiber reinforced polymer can effectively solve the durability problem associated with the abundance of chloride ions in sea-sand seawater concrete.

Erdogan, et.al (2016) studied the potential beneficial use of untreated and treated marine dredged material (DM) in ready-mix concrete (RMC) as a fine aggregate. For this study DMs collected from four Turkish ports/harbours. Here silica sand was replaced with untreated- and treated-composites of marine at five ratios, 0%, 25%, 50%, 75%, and 100%, respectively. For all the mixes Mechanical, durability, leaching, mineralogical/micro-structural properties are analysed. Test results shows that, concretes having 50% untreated dredged materials and 100% treated dredged materials met the minimum requirement of control mix. Therefore Marine DM can be beneficially used in RMC production after pre-treatment.

Sun, et.al (2014) analyse the micro structure of sea sand concrete by the Accelerated Surface Area and Porosimetry System (ASAPS) to detect the concrete micro-prorous structure distribution, the Tabletop Scanning Electron Micro-scope (TSEM) to analysis the sea sand concrete internal microstructure, as well as the X-Ray Diffractometer (XRD) and the Thermal gravimetric/Differemtial Thermal Anylyzer (TG/DTA)to observe the composition of concrete. The influence on hydration processes of concrete caused by sea sand was reseached from four aspects which are the influences of fly ash on concrete, chlorine salts on sea sand concrete, chlorine salt on fly ash added sea sand concrete and desalination sea sand and not desalination sea sand concrete micro structure eatures to evaluate the effect of sea sand on regular sea sand concrete and fly ash added sea sand concrete micro structure features and chemical composition. Test results shows that, 20%fly ash added concrete is rich in hydration products and the content of C-

S-H gels coming from the secondary hydration are more than the concrete without fly ash added. In XRD picture both of $Ca(OH)_2$ crystal's diffraction peaks are not high and the endothermic peaks of Ca crystal are similar in TG/DTA picture.

2.3 Studies on Alkali Activated Slag Concrete

Thunuguntla, et.al, (2018) studies the mechanical and durability performance of Alkali Activated Slag Concrete (AASC) prepared using ground granulated blast furnace slag as the sole binder material. The influence of sodium hydroxide concentration (1 M and 8 M), binder content (300 kg/m3 and 450 kg/m3) and alkaline solution/ binder ratio (0.4 and 0.55) on the mechanical and durability properties of alkali activated slag concrete (AASC) were reported. From the study they concluded that, NaOH concentration is found to be the most influential parameter on mechanical and durability characteristics of AASC. The capillary sorptivity of AASC is low, which indicates it offers high resistance to water absorption, also offers high resistance to nitrates and chlorides compared to sulfates. The deterioration of AASC specimens immersed in sulfuric acid started at corners and progresses inwards, few pop outs were also observed on the surface of specimens. AASC mixes with higher NaOH concentration exhibited better resistance to acid attack as compared to mixes with lower NaOH concentration, which may be attributed to high alkalinity and strong porous structure of concrete.

Puertas, et.al, (2018) studied the behaviour of fresh and hardened alkali-activated slag (AAS) and OPC concretes and was compared and the effect of mixing time assessed. Two mixing protocols was deployed to prepare both the OPCC and AASC systems. Protocol 1 corresponds to AAS concrete dosage previously determine in RILEM TC 247-DTA. In protocol 2 a longer mixing time of all concrete components was considered according to previous rheological studies. From the study they concluded that, the slump and rheological behaviour of OPCC and AASC differed, particularly where AASC was activated with water glass. It has been demonstrated that the nature of the alkaline activator is the key determinant in AAS concrete rheology. Longer mixing times had an adverse effect on dynamic and static yield stress and prompted significant and irreversible coagulation among cement particles (decline in workability) in OPC and AAS N concretes. In contrast, longer mixing times were favourable in AAS-WG concrete, in which they would be required to break down the microstructure to enhance rheological behaviour. These results proved that for AAS-WG concrete preparation is recommended to longer mixing time. That would have effect on future standardization of these eco-efficient building materials.

Mohebi, et.al (2015) studied the abrasion resistance of Alkali-Activated Slag (AAS) concrete. Four affecting factors including curing temperature, alkaline solution to slag weight ratio, concentration of sodium hydroxide solution and sodium hydroxide to sodium silicate weight ratio was considered to achieve the maximum compressive strength and abrasion resistance of AAS concrete using the Taguchi design of experiment method. From all the results and discussions they concluded that, the mixture with alkaline solution to slag weight ratio of 0.45, curing temperature of 95°C, sodium hydroxide concentration of 6 M and sodium hydroxide to sodium silicate weight ratio of 3 resulted in the maximum compressive strength and also, the mixture with alkaline solution to slag weight ratio of 0.4, sodium hydroxide concentration of 6M, sodium hydroxide to sodium silicate weight ratio of 3, which had been cured at 25°C, was found as optimal mixture for the maximum abrasion resistance. Water curing regime improved the surface condition and considerably increased the abrasion resistance of AAS concrete. Comparison between alkali-activated slag concrete and ordinary Portland concrete efficiency showed that the CO_2 footprint of alkali-activated slag concrete was approximately 51% less than that of comparable concrete containing 100% ordinary Portland concrete binder and the eco-mechanical performance of alkali-activated slag concrete was superior than that of ordinary concrete.

2.4 Studies on Alkali Activated Slag Sea Sand Concrete

Yang, et.al (2019) studied the mechanical properties of alkali-activated slag concrete (ASC) mixed by seawater and sea sand. Four types of ASC are prepared by considering the effects of seawater, sea sand and combination of the two constituents, respectively. Based on the SEM (scanning electron microscope) and XRD (X-ray diffraction) analysis, the seawater and sea sand are found to have some effect on the morphology and hydration products of the ASC. The strengths of the four ASC are close to each other. The ASC with seawater or sea sand has slightly higher drying shrinkage but better resistance to chloride ion permeability. Bond performance of FRP (fiber-reinforced polymer) and steel bars to ASC is studied using pull-out tests. The short-term bond strength, interfacial shear rigidity and shear fracture energy of steel bars with ASC are apparently higher than those of FRP bars with ASC. But the ratios of the residual frictional stress to the bond strength are larger for the FRP bars. The bond strength and residual frictional stress in the ASC with sea water or sea sand are slightly higher and the largest shear fracture energy is observed in the ASC with the combination of sea water and sea sand.

Nguyen, et.al (2018) studies the mechanical properties of geopolymer concrete prepared with sea sand as the fine aggregate, and the corrosion of steel bar embedded in the concrete subjected to accelerated corrosion tests. From all the results and discussions they concluded that, the compressive strength of geopolymer concrete using sea sand as fine aggregate reached its highest value at an alkaline to fly ash ratio of 0.35–0.45. This range is similar to that of normal geopolymer concrete. For sea sand geopolymer concrete, the effect of aggregate to fly ash ratio is the same as aggregate to cement (A/C) in conventional concrete. When this ratio is low, the geopolymer paste tends to cover the aggregate, and fill the voids inside the concrete specimens. As a result, the geopolymer concrete has enhanced high compressive strength. There was a regular increase in compressive strength, when the Si/Al ratio changed from 1.16 to 1.52. And then, the compressive strength slightly went up as the Si/Al increased from 1.52 to 1.67. Under accelerated corrosion conditions, the potential of steel bar in the geopolymer concrete using sea sand as fine aggregate was higher than in Portland cement concrete, result shows that it takes more time for steel bar in geopolymer concrete using sea sand to be attacked and corroded, compared to the steel bar in normal concrete. In conclusion, geopolymer concrete using sea sand as fine aggregate shows good potential as an alternative material to traditional Portland cement concrete.

3. CONCLUSIONS

To avoid scarcity of river sand, sea sand is used as a fine aggregate in concrete batching. Researchers say that using sea sand as a replacement for river sand would increase the bonding between cement and sand because of lesser amount of silt content present in the sea sand .Sea sand and seawater develops its early strength faster than that of ordinary concrete, but the former achieves a similar long-term strength to the latter. Many researches shows that use of mineral admixtures can improve the properties.

In the context of reducing CO_2 emissions, the one prospect currently practiced is replacing Portland cement with high volumes of supplementary cementitious materials (SCMs). Effective use of locally available SCMs like fly ash and ground granulated blast furnace slag (GGBFS) in producing concrete reduces the burden on the landfills and environmental pollution. AASC has numerous advantages over OPCC like low environmental impact, high strength, and rapid gain in strength and better durability characteristics. The type and nature of binding material, quantity and nature of alkaline activator solution and curing conditions strongly influence the mechanical and durability properties of AASC. Sodium silicate and sodium hydroxide based activators are suitable considering the mechanical properties of GBFS and FA geopolymer. GBFS is a glassy phase material, it is, therefore, easier to activate than fly ash. Fly ash contains a larger portion of crystalline phase and usually requires temperature between 40 and 85 ^{o}C to accelerate the reaction. The mixtures with alkaline solution to slag weight ratio of 0.45, sodium hydroxide concentration of 6M and sodium hydroxide to sodium silicate weight ratio of 3, which had been cured at 95 ^{o}C , was chosen as the optimal mixture given the maximum compressive strength.

AASC using sea sand as fine aggregate shows good potential as an alternative material to traditional Portland cement concrete. The compressive strength of geopolymer concrete using sea sand as fine aggregate reached its highest value at an alkaline to fly ash ratio of 0.35–0.45. This range is similar to that of normal geopolymer concrete. The ASC with seawater or sea sand has slightly higher drying shrinkage but better resistance to chloride ion permeability.

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