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"EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF CEMENT BY SEWAGE SLUDGE ASH AND GGBS IN CONCRETE"

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Abstract - *Sewage sludge management is a growing worldwide trouble for water treatment plants (WTPs) and governments. Considering the insufficiency of raw materials in many parts of the earth and rival properties of sewage sludge ample research have been conducted on the utilization of sewage sludge in the manufacturing of construction materials such as bricks, roof tiles, lightweight aggregates, cement, concrete, and geopolymers. This paper reviews the development in the utilization of sewage sludge in construction materials, by consolidating results from recent studies. Research findings have to divulge that affiliation of 10.5% sewage sludge ash in concrete is adequate with a small reduction of mechanical performance. Using the sewage sludge ash the concrete presented better mechanical strength. Concerning sewage sludge ash application in concrete, 10.5% replacement of cement by sewage sludge ash and GGBS was considered the ideal value for the application in a variety of concrete without adverse effects on concrete mechanical performance. Furthermore, this paper reviews the properties of sewage sludge ash and its application as supplementary cementitious material in concrete. A workability test was carried out on fresh properties of concrete while compressive strength, split tensile strength, and flexural strength was carried out on hardened concrete.*

Key Words: Sewage Sludge Ash (SSA), Ground Granulated Blast Furnace Slag (GGBS), Compressive Strength, Split Tensile Strength, Flexural Strength, and Workability.

1. INTRODUCTION

Since the time of the Greek and Roman civilizations, concrete has been the primary material for creating dependable and durable structures. The most often utilized construction material worldwide is concrete. More novel techniques and materials are being developed for the manufacturing of concrete as a result of the rising demand for it. Cement, water, and aggregates—with or without chemical admixtures—make up concrete. Cement is the component of concrete that is most crucial. When used as a sole binder, cement generates a lot of hydration heat. Since there are significant CO2 emissions during the manufacture of this raw material. The cement industry's carbon dioxide emissions have a significant negative impact on the environment. Many studies have been conducted recently to lower CO2. Utilizing industrial by-products or supplemental cementing ingredients including sewage sludge ash (SSA), ground granulated blast furnace slag (GGBS), fly ash (FA), silica fume (SF), and metakaolin are viable ways to reduce CO2 emissions from the cement industry (MK). To solve these issues, cement is being replaced in the current experimental work with SSA GGBS.

2. LITERATURE REVIEW ON SEWAGE SLUDGE ASH

Mourtada Rabie G [1] They estimated a new way of discarding the large amount of sludge produced from wastewater treatment plants in Egypt. One track of this solution is to utilize sewage sludge in Construction field concrete mixtures and manufacturing interlock brick samples, evaluated the reuse of sewage sludge from urban wastewater treatment plants in a mixture with cement, and develop new construction materials. They did the testing program comprising obtaining fresh properties by applying the slump test and the compressive Strength of all samples at 7, 28 days. They examined the properties of concrete like workability, compressive strength, and densities To study all these properties of concrete by utilizing dry and wet sludge as an additive, sewage sludge Ash was used at a content of 0, 5, 10, 15, and 20% of cement weight. To obtain the samples for Compression testing the 15X15X15 cm mold cubes were used.

Piasta W, Lukawska M [2] This investigation study focused on examining the effect of sewage sludge Ash (SSA) and Fly ash (FA) and the effect of these ashes on the properties of fresh pastes and hardened mortars has been presented. They determined the specific surface area, chemical composition, and grading of sewage sludge Ash. They detected the occurrence of crystalline materials utilizing XRD analysis and the morphology of ashes was investigated using SEM. The initial and final setting times were defined using the visit softening point. The replacement of cement with 10 or 20% sewage sludge Ash resulted in a set time extension. They investigated that the setting times extension was caused by the occurrence of phosphorus in sewage sludge Ash. They also found that the standard comprehensive strength of 10% and 20% sewage sludge Ash were lower. they studied that the partial replacement of cement with sewage sludge Ash makes the kinetics of strength development slow down. consequently, the long-term increase in comprehensive strength of mortar was higher compared to ordinary Portland cement mortar.

Chen Z, Poon CS [3] This study was proposed to identify the mechanisms behind some beneficial effects of sewage sludge ash on the strength development of mortars through a comparison study with fine sewage sludge ash (FSSA) and pulverized fly ash (PFA). The findings of this study recommended that the presence of sewage sludge Ash accelerates the rate of heat evolution from cement hydration while pulverized fly ash does not produce this effect. A higher content of sewage sludge ash or fine sewage sludge ash produces a greater effect. Replacing cement with sewage sludge ash or fine sewage sludge ash up to 10% did not induce significant changes to the pore structure of the pastes. The pulverized fly ash reduces the drying shrinkage of the mortars, but SSA causes greater drying shrinkage due to the increasing content of mesopores with sizes less than 0.025 mm.

Fontes CMA, Toledo Filho RD, Barbosa MC [4] The main aim of this presented study is the utilization of sewage sludge after the calcination process, as a mineral admixture in the production of concrete. High-performance concretes were engendered with substitution content of 5% and 10% by weight of Portland cement with sewage sludge ash (SSA). The physical and mechanical tests were conducted to analyze the influence of sewage sludge ash. Analysis showed that the mixtures containing sewage sludge ash have lower values of compressive strength than the reference. The results of absorptivity, porosity, and hastened penetration of chloride ions, present that mixtures holding ash showed reductions compared to the reference. This indicates that SSA provided refinement of the pore structure, which was confirmed by the mercury intrusion porosimetry test.

Nakic D [5] This study focused on the potential environmental benefits of using SSA as a supplementary cementitious material have been investigated and quantified by the life cycle assessment (LCA) model on a concrete example. In this investigation, the Controlled combustion of sewage sludge collected in Croatia from the wastewater treatment plant (WWTP) in Zagreb produced SSA that was used as an alternative for cement in concrete production. This study has proved that the use of sewage sludge Ash as a partial cement replacement is a technically workable solution, i.e. when 10% of the cement was replaced with SSA, with only a minor increase in the share of superplasticizer, concrete of the same peculiarity (flexural and compressive strength, workability, water permeability, total shrinkage and leaching concentrations of heavy metals) as the reference was obtained.

Dunuweera SP, Rajapakse RMG [6] This study presented the different types of cement products, their compositions, properties, and typical uses. The cement manufacturing processes are correlated with emissions of large quantities of greenhouse gases and environmental adulterants. They have given quantitative and qualitative analyses of the environmental impact of cement. As the cement industry is one of the biggest CO2 emitters, it is pertinent to conference different techniques or methods and means of CO2 capture, which will be done next. This study investigated an account of the production of nano cement and the advantages related to nano cement. Nanofillers such as nano-titania, nano-silica, and nano alumina can be generated on a large industrial scale via the hierarchical viewpoint of reducing the size of naturally available bulk raw materials to those in the nano range of 1 nm–100 nm. They mentioned the preparation of nano-titania and nano-silica from Sri Lankan mineral sands and quartz deposits, respectively, for use as additives in cement products to enhance performance and diminish the amount and cost of cement production and resultant environmental collision. In this study, the newest trend of making nano-cement and its development concerning the current growing and modernizing world is marked out in advance.

Liu M, Zhao Y, Xiao Y, Yu Z [7] Studied the Performance of cement pastes containing sewage sludge ash (SSA) at elevated temperatures. An experimental program was carried out to investigate the residual compressive strengths and the related physical, chemical, and microstructural evolution at elevated temperatures was measured by XRD, FTIR, DTA, MIP, and SEM analysis by preparing the SSA blended cement pastes which are subjected to thermal treatment at 600–1000 C. In this investigation, the results showed that the SSA blended cement pastes exhibited higher relative residual compressive strength than plain cement paste, indicating the incorporation of SSA enhanced the high-temperature resistance of cement pastes.

Krejcirikova B, Ottosen LM, Kirkelund GM, Rode C [8] This study was carried out to investigate the possible use of ash procured as a burned by-product in sewage sludge treatment, as a possible supplementary cementitious material. The results from previous studies are presented and compared with the physical and hygroscopic properties of cement-ash-based mortar. The effect of different ratios of cement replacement and two pre-treatment techniques for ash, i.e. ash grinding and water washing, on the physical properties of mortar were investigated by using density, porosity, and compressive strength as essential indicators of the mortar quality. The hygroscopic surface assimilation properties of the discrete constituents alone and the resulting mortar samples were described by soaking up isotherms for water vapor and by a capillary water absorption test. The Results showed that the SSAs consistently comprise larger particles compared to the cement particles. The incorporation of ash is derived in more porous mortar structures compared to cement-based mortar, which high-flows the material's mechanical properties such as compressive strength. 28-day compressive strength decreased with increasing ash content and porosity. 28-day compressive strength reduced with enlarging ash content and porosity.

Ishwarya G, Singh B, Deshwal S, Bhattacharyya SK [9] This study examined the Effect of sodium carbonate/sodium silicate activator on the rheology, geo-polymerization, and strength of fly ash/slag geopolymer pastes. In this investigation, a Composite mix of Fly ash and slag was initially dried in an oven at 100 ± 5 oC for 24 h to remove their surface moisture. To

study the effect of sodium carbonate/sodium silicate activator, the activating solution of Na2CO3 and sodium silicate solution were amalgamated in the ratio of 1.5:1 and thoroughly mixed with the help of a mechanical stirrer and the composition of various geopolymer pastes was cast in a 25 x 25 x 25 mm cube mold. The samples were cured at room temperature (27± 2 oC) for 24 h, de-molded, and then stored for 28 days foregoing to test.

Lynn CJ, Dhir RK, Ghataora GS, West RP [10] This study examines the use of sewage sludge ash in concrete and concrete-related implementation. In this investigation, the physical and chemical characteristics of materials and their use as raw feed for cement clinker and as cement components in producing cement paste, mortar, and concrete mixtures, as well as fine, filler, and concocted lightweight aggregates. The experimental results showed that using sewage sludge ash in the production of concrete, normal weight and aerated blocks, and controlled low-strength materials, through the development of the viable application of the material can only be considered at existing at the initial stages.

Chakraborty S, Byung WJ, Jun HJ, Zafar B [11] This study focused on investigation deals with the utilization of recycled sewage sludge ash (SSA) combined with quicklime (QL) and blast furnace slag (BFS) as a cementitious material in controlling the physical and mechanical performances of mortar. The performance of the sewage sludge ash-based mortar (SAM) was evaluated by measuring the bulk density, apparent porosity, compressive strength, flexural strength, shrinkage strain, etc. The obtained results show an effective alternative technique for disposing of sewage waste utilizing SSA as a potential alternative cementitious material for construction purposes. In this investigation, the effect of alkali-activated SSA combined with the QL and BFS in controlling the physical and mechanical properties of the mortar was studied. Based on the results, it is ascertained that the bulk density and the apparent porosity of the SSA-based mortar increase and decrease, respectively, with the increase in alkali activator and QL content.

Kappel A, Lisbeth MO, Gunvor M. Kirkelund [12] The main aim of this presented study is to determine the color, compressive strength, and workability of mortar when cement is partly replaced by sewage sludge ash (SSA). In the study, an iron-rich sewage sludge ash was dry-milled into six different fractions. The results showed that the color, compressive strength, and workability parallel to one another gently changed when the particle sizes of the sewage sludge ash decreased. The grinding of the sewage sludge ash altered the performance of mortars to the amount that the compressive strength and workability were comparable to the performance of ordinary mortar. At the same time, the color increased to the extent that the mortar changed color from grey to a reddish color as the particle size of the SSA decreased due to better distribution of smaller particles in the matrix. Overall, the results of the study showed that simple pre-treatments of SSA: drying, and milling affect the performance of the mortar, which provides an occasion to adjust the sewage sludge ash in conferring with requirements set for the application.

Xinyu C, Shuang Lu, Yunhe G, Yan Y, Mohamed E, Xianming S [13] The main aim of this laboratory study investigated a variety of modification methods aimed at improving the value of sewage sludge Ash. For pre-treatment, they have selectively performed three different methods of physical modification including low-temperature drying, grinding, and high-temperature calcination. They also explored the Microwave treatment as a substitute for the calcination procedure. by amalgamation with quicklime (QL) for likely chemical activation consequently, chemical modification of the sewage sludge Ash was performed. The effectiveness of these treatments was appraised in terms of the leachability of heavy metals out of the treated SSA and the reduction in total organic carbon (TOC). High-temperature calcination of sewage sludge Ash enhanced the immobilization of heavy metals (e.g., Mn, Zn, and Ba). they compared calcination at 500 degrees celsius for 2h, 15 min microwave heating of pre-treated sewage sludge Ash reveal better performance in immobilizing the heavy metals and nearly as good performance in reducing the TOC in the sewage sludge Ash Finally, based on the compressive strength data of the cement pastes, microwave treatment is an effective alternative to thermal calcination, in terms of mitigating the side effects of admixed SSA on the cement hydration.

Maozhe C, Denise B, Mathieu G, JacquesM, Remy G [14] This study focused on determining the appropriate substitution ratios to satisfy both technical and environmental criteria. For this investigation, elemental composition and particle size distribution of the ashes were measured then the ashes were used along with Portland cement and sand at different ratios of replacement to produce mortar and concrete which were cured for up to 90 days into parallelopiped or cylindrical monoliths. They investigated that the mechanical properties of the monoliths were measured to avail oneself of standard procedures for flexural and compressive strengths, and compared to blanks containing no ashes. The results showed that the characteristics of the ashes ranged between those of cement and sand because of their larger particle size and higher content in SiO2 as compared to cement. when the ashes were used in the partial replacement of cement at relevant ratios, the concrete monoliths evinced similar compressive strengths as the blank samples. The most appropriate ratios were found to be a 10% substitution of cement and a 2% substitution of sand.

Gomes SDC, John LZ, Wengui Li, Long G [15] In this paper, they critically review the progress in the application of WTS in construction materials, by blending results from recent studies. They studied that the incorporation of ≤10% alum-based sludge in ceramic bricks is satisfactory with a small reduction of mechanical performance. Using the iron-based sludge, the bricks confer better mechanical strength than the reference clay bricks. It is observed that the production of cement and concrete with the partial addition of WTS, is potentially feasible, especially as a pozzolanic addition and replacement of sand in concrete up to 5%. It is clearly shown that Used as a substitution, WTS can make saving for raw materials and energy, replace landfill as solid waste management, and devote to sustainable construction materials production.

3. CONCLUSIONS

This paper represents an overview of the mechanical properties of sewage sludge ash and GGBS in concrete at different variations of sewage sludge ash and GGBS. From the performance of sewage sludge ash and GGBS in concrete the major conclusion drawn from this research work is presented as follows.

- Sewage sludge ash has been demonstrating as an efficient pozzolana with properties similar to that of fly ash.
- Not much research is being accomplished in India on sewage sludge ash. Since India is a populous country with an enormous production of sewage waste. If sewage sludge is converted to sewage sludge ash, it can solve the problem of disposal of sewage to a significant extent.
- Since the properties and composite of sewage sludge ash depend upon the source, it is necessary to carry out a detailed depiction study on sewage sludge ash.
- The workability of concrete was found to increase with the increase in sewage sludge ash and GGBS in concrete.
- Comprehensive strength and splitting tensile strength were slightly increased due to the percentage of sewage sludge ash content.
- Flexural strength was increased by the addition of sewage sludge ash and GGBS content.

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