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A Review Paper on Strength and Durability Characteristics of Self Compacting Concrete Containing Induction Furnace Steel Slag as Fine and Coarse Aggregate

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INTRODUCTION

GENERAL

Self-Compacting Concrete (SCC) is a special type of concrete that does not require any vibration effort for placing the concrete in structures with congested reinforcement, restricted and compact areas. It can flow under its weight and achieve full compaction even in the presence of congested reinforcement. In its fresh state, it shows properties like high fluidity, self-compacting ability, and segregation resistance which produces a uniformity in the quality of concrete resulting in improved reliability and durability of reinforced concrete structures.

A key factor for a successful formulation of SCC is the clear understanding of the role of various constituents in the mix and their effects on the fresh and hardened properties. A successful SCC must show high fluidity for flow under self-weight, high segregation resistance to maintain uniformity during flow, and sufficient passing ability so that it can flow through and around reinforcement without blocking or segregation. SCC is usually proportioned with one or more mineral and chemical admixtures. Superplasticizers are added to provide better workability and Viscosity Modifying Agents (VMA) are used to improve segregation resistance of SCC.

But making it only with conventional constituents arise some severe environmental issues. Waste valorization technique becomes an essential strategy to establish an eco- friendly and clean environment. Every year the volume of solid waste generation is also reaching new heights, which is explained through the following statistics. Production of 1 ton of crude steel generates about 1 ton of solid waste [Grubeša et al.,2016]. Annually, the large-scale steel-producing industries discard about 29 million tons of slag [Mohapatra et al.,2007]. From 2010 onwards, the worldwide annual steel production exceeded 1500 million tons. Recently the world steel association (WSA) labeled China, Japan, and India as the three major countries that are currently producing> 0.1 billion tons of steel/year and generate a large volume of slags. Effective transformation of agricultural and industrial by-products into useful concreting material plays a significant role to overcome the sustainability issues in the field of construction, and it also safeguards the environment from the toxic solid wastes discarded from industries.

Cassava peel is an agricultural or industrial waste derived as a by-product from the processing of cassava through either at the industrial or domestic level of production. Due to the gross underutilization of this industrial/agricultural waste, they are indiscriminately deposited on our landfill posing a lot of environmental challenges. Thus, processing of the cassava peel into CPA becomes very necessary to encourage its re-use and recycling as an important construction material that possesses pozzolanic properties (Ofuyatan et al., 2018; Owolabi et al., 2015). Cassava peel possesses up to 20 % to 35 % of the cassava tuber's total weight, especially when processed by hand- peeling. These agricultural waste materials are subjected to controlled incineration to obtain ash products referred to as CPA (Mbadike et al., 2016). Salau and Olonade (2011) studied the pozzolanic potential of CPA and their results showed that CPA possesses pozzolanic reactivity when it is calcined at 700^0C for 90 minutes. At these conditions, CPA contained more than 70 percent of combined silica, alumina, and ferric oxide.

OBJECTIVES OF THE STUDY

The objectives of the present study are as follows:

1. To develop a mix design for SCC containing conventional aggregates (control mix) and containing combinations of IFS and conventional aggregate.
2. To obtain optimum replacement % of CPA (by weight of cement) with reference to strength characteristics of cement-CPA mortars.
3. To evaluate the fresh, mechanical and durability properties of SCC containing-

a) Manufactured sand as fine aggregate and crushed stone as coarse aggregate. (SCC 0/0)

b) IFS as fine aggregate and crushed stone as coarse aggregate. (SCC 100/0)

c) M-sand as fine aggregate and IFS as coarse aggregate. (SCC 0/100)

d) IFS as both fine and coarse aggregate. (SCC 100/100)

e) IFS as both fine and coarse aggregate along with optimum content of CPA as mineral admixture. (SCC 100/100/10CPA)

The replacement of natural aggregates with Induction Furnace Slag (IFS) and the partial replacement of cement with an agricultural waste named Cassava Peel Ash (CPA) in the concrete would lead to the conservation of natural resources and will also solve the problem of disposal of solid waste resulting into cost effective economy in concrete production.

Induction Furnace Slag

Induction furnace slag (IFS) is the solid waste discarded from the induction furnace, which is used in metal casting foundries. An induction furnace is an electricity-based furnace that produces high temperatures in the metal bodies and melts them by inducing the eddy currents on them. In India alone, there are more than 600 units of induction furnaces, and each induction furnace unit discards about 15,000 tons of slag per annum.

IFS can be used as concrete material, but limited research is conducted on utilizing IFS as a concrete ingredient. Utilizing 30% of IFS as a fine aggregate enhanced the compressive strength of the mortar and concrete by 7% and 24%, respectively [John, et al., 2013]. 22% reduction in compressive strength was reported when coarse aggregate was completely substituted with IFS [Rezaul et al., 2017]. Replacing the recycled coarse aggregate with IFS particles in recycled aggregate concrete (RAC) resulted in an 8% and 11% reduction in the compressive and split tensile strength, respectively [Ahmad et al., 2018].

Till now, studies were not conducted on utilizing IFS as a complete replacement for both fine and coarse aggregate in a special concrete-like SCC. The possibility of improving the properties of concrete containing IFS aggregate with the usage of agro- waste mineral additions was also not attempted.

Cassava Peel Ash (CPA)

Industrial and agricultural wastes such as Fly ash, Silica fume, Ground Granulated Blast Furnace Slag (GGBFS), rice husk ash, etc. are also being used as a partial replacement for cement due to the presence of an adequate quantity of reactive silica. The presence of reactive silica seems to be very beneficial in concrete because it leads to the formation of secondary C–S–H in later ages and it also reduces the formation of calcium hydrates in the concrete. High C–S–H formation and low C–H formation is a typical hydration behavior of high strength and highly durable concrete self-compacting concrete (Chandru et al., 2017).

SCOPE OF THE STUDY

The investigation aims to study the strength and durability properties of the SCC containing IFS-slag as a replacement for aggregates. Compressive strength study is also carried on mortar specimens containing cassava peel ash as a partial replacement for cement to evaluate the optimum content of CPA.

SUMMARY

The chapter discusses a special type of concrete named SCC. Emphasis is made on the use of industrial and agricultural solid waste as a replacement for conventional concrete materials. A brief introduction about the availability and occurrence of IFS slag and CPA is provided. The scope of the study along with the objectives of the study and organization of the thesis was described.

LITERATURE REVIEW

In the previous chapter, we discussed SCC and assorted reasons which compile us to use industrial and agricultural waste as a source to produce concrete. This chapter aims in describing in detail the various study conducted in relevance with the current research classified under some of the major headings, namely, replacement of concrete aggregates by steel slags, information related to the mix design, fresh properties, strength properties and durability properties of SCC, and literature relevant to use of CPA as a partial replacement to cement in concrete.

FIELDS OF LITERATURE REVIEW

The relevance of literature reviewed in connection with the current study is classified under some of the major headings as

STEEL SLAG AS AGGREGATE

Manso et al. (2006) researched the behavior of EAF slag concrete under test conditions like internal expansivity of the slag, its chemical reactivity with cement, and resistance to environmental agents. The results show that the performance of EAF slag concretes is like that of more traditional concrete in terms of its strength and slightly less so in terms of its durability. The study found that the High porosity of EAF slag is an obstacle in making concrete resistant to freezing and the leaching test showed a substantial cloistering effect of concrete on the toxic products present in EAF slag.

Pellegrino and Gaddo (2009) study aimed to investigate the opportunity to substitute natural aggregates with Black/Oxidizing EAF slag. A proper series procedure should be adopted for material preparation of EAF to achieve the chemical and physical stabilization necessary for safe use in concrete production. The slag must be stored and aged outdoors in advance and exposed to natural moisture or forced spraying for various weeks, to allow any feasible expansion and breaking up for both short- and long-term hydration Compressive and tensile strength, elastic modulus, and durability characteristics of concrete containing EAF slag as aggregate were experimentally investigated. The study reports that EAF slag is suitable to replace traditional natural aggregates in conglomerates, even in high percentages and for medium sizes (to 2–4 mm size) but proper treatment should be provided to EAF slag before use.

Ramesh et al. (2013) studied to obtain low-cost building materials using industrial wastes (welding and furnace slags). The objective of the study is to use these wastes in low-cost construction with adequate compressive strength. Different fine aggregate replacements have been studied by substituting 5%, 10%, and 15% of slag. The waste material was substituted for replacement of fine aggregates and for the preparation of concrete blocks. In this project, we have followed Indian standard methods and arrived at the mix design for M25 grade concrete. Experimental studies were conducted only on plain cement concrete. The preliminary studies were conducted by mixing the slag with the cement concrete cubes of standard sizes. The building material specimens were analyzed for compressive strength as per IS code. For the test and other specifications, it can be concluded that the welding and furnace slags can increase the strength of the concrete. The optimum compressive strength of concretes after 28 days has been found to be 41 N/mm^2 for 5% welding slag and 39.7 N/mm^2 for 10% furnace slag replacements. The results show that 5% of welding and 10% furnace slags replacement with sand is very effective for practical purpose.

Faleschini et al. (2015) investigated the feasibility of using Black/Oxidizing Electric Arc Furnace slag (EAF) as coarse aggregate to produce High Performance Concrete (HPC). Various experimental mixes have been produced, fully replacing natural coarse aggregates with EAF slag, varying the cement dosages and the water/cement ratios, and they have been characterized through a mechanical and microstructural campaign. For some mixtures also durability has been evaluated, through a study about chloride ingress into concrete matrix. Results indicate that total replacement of coarse aggregate with EAF slag improves concretes mechanical properties, including compressive, tensile strength and elastic modulus. Accordingly, in this work, the production of HPC with EAF slag was possible, maintaining relatively high *w/c* ratios (higher than 0.4), and without using mineral additions, commonly used to achieve high strength. The shape and the texture of EAF slag significantly improve the tensile strength of EAF-concretes, due to the better bond of these aggregates with the cement- paste. The density of EAF concrete is sensibly higher than conventional concrete, thus leading it to be suitable in high density concrete applications. The evaluation of possible expansive compounds as free MgO and CaO could be a topic of further studies when dealing with potential application of metallurgical slag in concrete.

Valcuende et al. (2015) aimed to study shrinkage evolution with age in self- compacting concretes (SCC) in which part of the fine aggregate was replaced by granulated blast furnace slag (GBFS) as sand. Seven types of SCC were made with a w/c ratio of 0.55 and different slag contents. The results show that replacing sand by GBFS gives rise to mixes with higher pore volume but with slightly finer porous structure (smaller median pore and threshold diameters). At early ages slag SCCs have similar compressive strength to that of the reference concrete, although in the long term their strength increases because of slag reactivity. We also observed that the higher the slag content, the higher were both autogenous and drying shrinkage and consequently also total shrinkage. In comparison with the reference concrete, the increase in total shrinkage was found to be of the order of 4% and 44% when 10% and 60%, respectively, of the sand was replaced by slag. Replacing sand by the type of slag used in this research gives rise to mixtures with higher total pore volume and slightly finer pore structure, with smaller median pore size and threshold diameter. The SCCs with slag show a higher autogenous shrinkage, due to their higher concrete deformability, the higher self-desiccation generated by the slag hydration, and the chemical shrinkage caused by the slag reactivity. This increase is on average 11% and 33% when sand is replaced by 10% and 60% slag, respectively. Due to higher autogenous shrinkage and drying shrinkage, the SCCs containing slag show higher total shrinkage. The increase is on average 4% and 44% when the sand replaced by slag is 10% and 60%, respectively.

Ozbakkalogu et al. (2016) studied the effect of slag size and content on the behavior of normal and high strength concrete incorporating air-cooled blast furnace slag as coarse aggregate. It has been shown that the size of coarse aggregates has a significant effect on the properties of both normal- and high-strength SACs. An increase in the coarse aggregate size (i.e., from 10 to 20 mm) leads to an increase in the 28- day compressive strength (i.e., up to 7.4%), elastic modulus (i.e., up to 2.9%), and splitting tensile strength (i.e., up to 9.3%). An increase in the coarse aggregate size also leads to a decrease in the slump of concrete (i.e., up to 6.2%). Results show that in both NSC and HSC mixes, SACs exhibit lower workability and mechanical properties compared to those of the companion NACs. On the other hand, mechanical properties of normal-strength SACs are close to those of control mixes (i.e., 22.8% lower *f'c*, 20.8% lower *Ec* and 19.3% lower *fst* at 100% replacement). Likewise, high-strength SACs with *SA%* of 50% exhibit relatively close mechanical properties to those of companion high-strength NACs (i.e., 15.9% lower *f'c*, 12.4% lower *Ec* and 16.2% lower *fst*). Depending on the application, these properties can be sufficient and hence both the normal-strength SACs with up to 100% slag aggregates and high-strength SACs with up to 50% slag aggregates can serve as a feasible alternative to conventional concrete in certain structural applications. It should also be noted that the natural coarse aggregates used in this study had extremely high mechanical properties and the use of weaker aggregates would lead to different observations on the relative performance of SAC and NAC.

İsa Yüksel (2017) reviewed usage of steel slag in construction industry for sustainable development. Use of by-products from the steelmaking process can play an important role in achieving sustainable development. The available literature suggests that the use of iron and steel industry slags as mineral admixture or partial replacement of cement improves the microstructure of the concrete as well as its mechanical and durability characteristics. This paper reviews utilization of steel slag (SS) in the construction industry by considering current and probable future utilization fields, advantages of SS usage, and problems associated with its use. Strength and durability evolution of concretes or mortars containing SS in different ratios as aggregate or cement replacement material, combined use of ground granulated blast furnace slag with SS, and some new fields of utilization of SS are also addressed. Improvements in and results of SS utilization in cement and concrete are discussed by addressing its beneficial effects. This article could help researchers to understand the recent developments in evaluation of SS in the construction industry.

Saxena and Tembhurk (2018) studied the impact on fresh and hardened properties of the concrete when natural coarse aggregate is replaced with steel slag aggregate and wastewater is reused during the making of concrete. This study was focused on the replacement of ingredients of concrete with recycled material and wastewater to compensate for the increasing demand for natural resources. The result from the research shows that 50% replacement of basalt aggregate with steel slag aggregate indicates improvement in compressive strength, flexural strength, and modulus of elasticity of concrete by 33%, 9.8%, and 22% at the age of 28 days respectively.

Therefore, this study shows the possible reuse of steel slag as coarse aggregate and wastewater in concrete.

Ahmad and Rahman (2018) reported that porosity and water absorption decreased for concrete when up to 50% Recycled aggregate (RA) is replaced by IFS, but the values increased when a higher replacement ratio is adopted. This shows that equal proportions of IFS and RA make the internal structure of concrete more uniform throughout its volume with fewer pores. Compressive strength and split tensile strength were also found to be maximum at 50% replacement of RA by IFS. This increase is due to the formation of a compact mix in the concrete matrix that was uniform in nature throughout the volume of concrete which is evident from the lowest pore spaces. Modulus of elasticity was found to increase for all mixes containing IFS compared with 100% RA concrete. As RA was replaced by IFS, the average bulk density and specific gravity of combined aggregate enhanced, which was one of the reasons for the increase in modulus of elasticity of RAC when RA is replaced by IFS.

Devi and Subathra (2018) studied the durability properties of concrete containing a combination of steel slag and ceramic waste as a replacement for aggregates. Decrement in weight and compressive strength was observed for M20 grade concrete subjected to acid attack and chloride ion penetrability was found to be moderate in all mixes. Also, lesser water absorption and sorptivity were observed than the reference mix. Fine aggregate replacement by fine steel slag of 21% in combination with 2% coarse ceramic waste has very good resistivity to chloride ion penetration and capillary absorption. The loss in weight and decrease in compressive strength is observed in all the percentage of replacement proportion mix for M20 grade concrete when it is being subjected to acid attack by H2SO4 and HCl. It is observed that only very little percentage of loss in compressive strength is seen in FSCS and FSFCCS1 than CM, when the specimens are subjected to HCl immersion. Greater reduction in compressive strength is seen in mix FSCS, when immersed in H2SO4. Fine aggregate replacement by fine steel slag of 21% in combination with 2% coarse ceramic waste has very good resistivity to chloride penetration and capillary absorption. This percentage of replacement of waste aggregates can be used instead of normal aggregates for better durability characteristics.

Guo et al. (2019) found that the addition of Basic Oxygen Furnace (BOF) slag as a replacement for fine aggregate has a positive effect on the toughness of concrete. It also concludes that the use of steel slag in normal strength concrete is more advantageous than that in high strength concrete in terms of compressive strength. Superior compressive strength and toughness of NSSC can be obtained when the steel slag content is approximately 20% or 80%. However, superior compressive strength and toughness of HSSC can be obtained when the steel slag content is 30%. The compressive strength of normal-strength SSC (NSSC) exhibited an inverse W- shaped trend with increasing steel slag content. The addition of steel slag has a slight effect on the compressive strength of high-strength SSC (HSSC). The trend of the compressive strength of HSSC with steel slag content also fluctuates, but not like that of NSSC. The use of steel slag as a fine aggregate in concrete mixtures has a positive effect on toughness and the ultimate expansion ratio; hence, adding steel slag to concrete will improve the energy absorption capacity. These findings illustrate that SSC with an optimal steel slag content can exhibit better compressive behavior compared with normal concrete, and steel slag is a more environmentally friendly alternative for use in the compression of concrete structures.

Baalamurugan et al. (2019) utilized Induction furnace slag (IFS) as a replacement for coarse aggregate in concrete. The concrete blocks of size 150 × 150 × 50 mm were cast and the effect of density, compressive strength, linear attenuation coefficient, Gamma Attenuation Factor (GAF), and Half Value Layer (HVL) has been explored. Gamma attenuation measurements were carried out using NaI (Tl) based gamma detector. Gamma-ray source ^{60}Co emitting two gamma energies 1.17 and 1.33 MeV was used for radiation measurements. The result of this present study shows that 50% of IF steel slag replacement increases the density (2.81 g/cm^3) and compressive strength (29.11 N/mm^2). The Linear attenuation coefficient (0.1953 cm^{-1}–0.2236 cm^{-1}) and GAF (0.6343–0.6710) is higher at 50% replacement of IF steel slag than conventional concrete. HVL values were also having a positive impact on 50% replacement of IF steel slag (3.10 cm) in concrete than conventional concrete (3.55 cm). The partial replacement of IF steel slag as coarse aggregate in concrete is effective in gamma shielding.

Devi et al. (2020) studied the durability of concrete containing steel slag as a replacement for 30% coarse and 40% fine aggregate under various exposure conditions. UPV test found that the quality of steel slag concrete is better than the conventional concrete in all exposure conditions and the acid resistance test reported that the weight loss is lesser for steel slag concrete than conventional concrete for all exposure conditions. The steel slag specimen subjected to very severe exposure conditions performed better under the RCPT test than conventional concrete by 5.8%. The sorptivity coefficient is similar for extreme and severe conditions, whereas, for moderate and very severe conditions, steel slag concrete performs better with lesser capillary action than conventional concrete.

Yang et al. (2020) studied ASR potential of nickel slag fine aggregate in blast furnace slag-fly ash geopolymer and Portland cement mortars. Utilizing nickel slag as aggregates in concrete production proposes an economic option for recycling this industrial by-product, and meanwhile preserves the natural rock aggregate resources. Thus, there is an urgent need to further explore the potentially alkali-silica reaction (ASR) nature. This study investigates the ASR of high-magnesium nickel slag (HMNS) fine aggregate in the fly ash-blast furnace slag geopolymer and Portland cement (PC) mortars. No obvious ASR product is observed in the mortars with HMNS fine aggregate, which exhibit lower ASR expansion than the mortars with ASR reactive sand. In the geopolymer mortars, the reactive Al species initially dissolved from HMNS promote the formation of aluminum-containing alkalis silicate gel layer covered on the surface of HMNS grains. This provides a diffuse barrier to protect the inner silica against further attack of alkalis, and consequently mitigates the deleterious ASR. In the PC mortars, the pozzolanic reaction of HMNS improves the consumption of portlandite in the pore solution to reduce the alkalinity and calcium content, resulting in a suppression to the ASR degradation. The accelerated mortar bar test shows that HMNS is dependable for the utilization without deleterious ASR expansion risk.

Chandru and Karthikeyan (2021) used IFS slag as a replacement for coarse aggregate to produce SCC and investigated its fresh and mechanical properties. GGBFS and Silica fume was used as a partial replacement for cement in SCC and different mixes were designed accordingly. Their mechanical properties were evaluated through compressive strength, splitting tensile strength, modulus of rupture, elastic modulus, and pull-off bond strength tests. Due to the low relative density of IFS aggregate, better flowability and passing ability were observed in SCC with IFS aggregate. The hardened density of the IFS aggregate SCC was 5% – 6% lesser than the natural aggregate SCC. Due to the porous microstructure, the SCC produced with IFS aggregate showed a 9% –14.5% reduction in cube compressive strength, 11.3% – 16.8% reduction in cylinder compressive strength, 16% – 18% reduction in splitting tensile strength, 20 – 22% reduction in flexural strength, 13% - 16.3% reduction in pull-off bond strength and 10% – 13.6% reduction in elastic modulus in comparison with the natural aggregate SCC. Due to environmental benefits and satisfactory mechanical performance shown by the SCC mixes containing IFS coarse aggregate, the study concludes that replacement of IFS slag as aggregate in concrete is adaptable and is an effective slag valorization technique.

Chandru et al. (2021) aimed to study the durability characteristics between ternary blended self-compacting concrete containing normal crushed stone and induction furnace slag (IFS) as coarse aggregate. Two series of blended (silica fume + ground- granulated blast furnace slag) SCC mixtures were made, one with normal coarse aggregate and the second with IF-Slag aggregate. For comparing the performance of these two series of blended SCC mixtures, the following tests such as water absorption, coefficient of water absorption, the volume of permeable pores, rate of capillary absorption, rapid chloride permeability, electrical resistivity, and ultrasonic pulse velocity were conducted. The experimental results showed that the performance of SCC made with IF-Slag coarse aggregate was inferior to the SCC made with normal coarse aggregate. The inclusion of mineral additives improved the microstructure of the binder matrix through their pore refinement effect, which was noticed from the SEM images. Maximum improvement was achieved in the blended mix SCC-10/40, in which the absorption, coefficient of absorption, permeable pore volume, and sorptivity values were reduced by around 28%, 40%, 27%, and 44% respectively. It also increased the electrical resistance as well as chloride ion penetration resistance of both the series of SCC mixtures.

Mark et al. (2021) studied the effect of induction furnace slag on the strength and durability properties of self-compacting concrete as supplementary cementitious material. The materials utilized include 42.5R Portland cement, induction furnace slag as an SCM ranging from 0 to 50 % by cement weight at 10 % interval, river sand, granite, water, and superplasticizer. The fresh properties were evaluated for filling

ability, passing ability, and segregation resistance, the strength characteristics measured include compressive strength, splitting tensile strength, flexural strength and Schmidt/rebound number. The oxide compositions and microstructural analysis of SCC were investigated using x-ray fluorescence analyzer (XRF) and scanning electron microscopy equipped with energy-dispersive x-ray spectroscopy (SEM-EDS), respectively. Empirical correlations were statistically analyzed using MS-Excel tool. The filling ability characteristic was determined via both the slump flow test and the T50cm slump flow time test. Moreover, the passing ability characteristic was determined using L-Box test. The segregation resistance characteristic was determined using V-funnel at T5minutes test. The results of the fresh properties showed a reduction in the slump flow with increasing IFS content. On the other hand, the T50cm slump flow increased with increasing IFS content. Furthermore, the L-Box decreased with higher IFS content. On the contrary, the V-funnel at T5minutes increased with greater IFS content. The strength test results revealed that the strength properties increased to 20 % IFS, with a value of 66.79 N/mm^2 compressive strength at 56 days, giving a rise of 12.61 % over the control.

Mohammed et al. (2021) worked on IFS slag as a replacement of brick aggregate in concrete for varying mix design parameters including W/C ratio, cement content, and fine aggregate to total aggregate volume ratio. Concrete mechanical properties were assessed, UPV test was conducted on concrete and aggregate-matrix interfaces were assessed using SEM analysis. The test results showed that For any level of partial replacement of brick aggregate by IFS aggregate, concrete exhibits 6–15% higher compressive strength, 3–11% higher Young's modulus, and 9–15% higher splitting tensile strength in comparison to 100% brick aggregate concrete. The rate of increase relies on the W/C ratio, cement content, and f/a ratio. However, the maximum compressive strength, Young's modulus, and splitting tensile strength of concrete can be obtained for 50% replacement of brick aggregate by IFS aggregate. Any level of IFS replacement provides better mechanical strength to concrete than the brick aggregate. The ultrasonic pulse velocity (UPV) through concrete increases with the increase of IFS replacements due to a denser ITZ along the rough-textured IFS aggregate and cement matrix interface. Relationships between normalized stress and strain, Young's modulus, and compressive strength, splitting tensile strength and compressive strength, and compressive strength and UPV have been proposed for concrete with 100% brick aggregate, 50% IFS replacement, and 100% IFS aggregate as coarse aggregate. Results concludes optimum replacement ratio concerning compressive and tensile strength is found at 50%, workability is increased by replacement of brick aggregate by IFS aggregate and the absorption capacity of brick aggregate is much higher than that of IFS aggregate.

CASSAVA PEEL ASH (CPA)

Ogunbode et al. (2012) studied the strength properties of Laterized concrete (LATCON) made with Cassava peels ash (CPA) an agricultural waste at varying levels of replacement to Ordinary Portland cement (OPC) up to 40%. The Strength properties, namely compressive strength, initial surface absorption and density were measured in the laboratory on 375 100x100x100mm cube specimens with the view of establishing the percentage of the ash and laterite that can be used in the cement matrix and fine aggregate compositions respectively. The best strength performance was obtained at 30% of cement replacement while the laterite (lat.) will perform better at 30% fine aggregate replacement for concrete production which was comparable to normal concretes (i.e., Control). It is therefore concluded that the CPA/OPC LATCON has sufficient strength and adequate density to be accepted as structural concrete.

M. A. Salau (2012) investigated the behavior of Cement-Cassava peel ash blended concrete on structural strength characteristics by varying CPA content between 5 to 25% by weight of cement at 5% intervals. Water binder ratios (w/b) of 0.5, 0.55, 0.6,

0.65 and 0.7 were used to produce the blended concrete of mix 1:2:4. The workability results showed that as CPA content was increased, the water-binder ratio (w/b) required to achieve workable blended concrete also increased, and 0.7 was suggested as an appropriate optimum w/b. The Compressive strength and flexural strengths increased with age but got reduced with an increase in CPA content in the mix especially when more than 15% CPA is used. Strength Activity Index (SAI) indicated the late strength development in concrete containing CPA when replaced up to 15% by weight of cement. Regression analysis of models showed a quadratic relationship between compressive strength and curing age for up to 15% CPA replacement. The study recommended maximum use of 15% CPA with a water binder ratio of 0.70 to produce cement-CPA blended concrete of appropriate strength.

Villamizar et al. (2012) studied the effect of the addition of coal-ash and cassava peels on the engineering properties of compressed earth blocks. A series of test compressed earth blocks were made using a clay-rich soil, without coal-ash and stabilized with coal- ash, in a Cinva-Ram hydraulic machine. The use of cassava peels as novel organic materials was also introduced in the preparation of the compressed earth blocks. The objective of this study is to investigate the effect of the addition of coal-ash and cassava peels on the engineering properties of compressed earth blocks. The samples were tested for flexion, compression, and absorption to observe their performance. Results show that the compressive and bending tests reveal that the compressed earth blocks stabilized with coal-ash produced the best results using a dose less than or equal to 5%. However, doses greater than 5% generate more flexible and fragile compressed earth blocks. Adding cassava peels to the clayed soil increases the required water content for extrusion (apparent plasticity).

Uysal et al. (2012) researched the effect of mineral admixtures on properties of SCC. the benefits of limestone powder (LP), basalt powder (BP) and marble powder (MP) as partial replacement of Portland cement are established. Furthermore, LP, BP and MP were used directly without attempting any additional processing in the production of self-compacting concrete (SCC). The water to binder ratio is maintained at 0.33 for all mixtures. The examined properties include workability, air content, compressive strength, ultrasonic pulse velocity, and static and dynamic elastic moduli. Workability of the fresh concrete is determined by using both the slump-flow test and the L-box test. The results show that it is possible to successfully utilize waste LP, BP and MP as mineral admixtures in producing SCC. Due to its observed mechanical advantages, the employment of waste mineral admixtures improved the economic feasibility of SCC production on a unit strength basis.

Agbenyeku et al. (2014) studied the effect of partial substitution of cement with an agricultural waste (CPA) on the compressive strength of laterised concrete (LATCON) was investigated. Physical and chemical tests on CPA and laterite revealed them to have satisfactory characteristics for concrete production. A total of 192 cubic specimens of 100 mm dimensions were cast and cured by complete submergence in water for 7, 14, 21 or 28-day hydration periods, adopting a 28-day targeted strength of 25 N mm -2 as the control. The ordinary portland cement/CPA and sand/laterite replacement ratios ranged from zero to 30% with a view to determining the best compositions matrix. The concrete with 100% brick aggregate, 50% IFS replacement, and 100% IFS aggregate as coarse aggregate. Results concludes optimum replacement ratio concerning compressive and tensile strength is found at 50%, workability is increased by replacement of brick aggregate by IFS aggregate and the absorption capacity of brick aggregate is much higher than that of IFS aggregate.density and compressive strength performance decreased with increase in the CPA and laterite content. However, gradual strength development in the CPA-LATCON was observed as the hydration period increased. The 28-day density and compressive strength of standard concrete was 2 385 kg m^{-3} and 27.05 N mm^{-2}, whereas those of the 10% CPA + 10% laterite sample (i.e., the best replacement matrix) were 2 322 kg m^{-3} and 25.57 N mm^{-2}, respectively. The strength of the CPA-LATCON (25.57 N mm^{-2}) was higher than the targeted strength of 25 N mm^{-2} after hydration for 28 days, which makes it suitable as a building material. As such, it can be adopted in the construction of simple foundations and masonry units as a reliable alternative to the scarce and expensive conventional materials for prime cost reduction in rural housing and development without compromising standards.

Daud et al. (2014) compared Pineapple Leaf and Cassava Peel by Chemical Properties and Morphology Characterization. This study conducted for the chemical composition by analysed by TAPPI Test method, Chlorination method and Kuchner-Hoffner method. All chemical components analyse; Cellulose (Kuchner-Hoofner), Holocellulose (Chlorination method), Hemicellulose (Chlorination method), Hemicellulose, Ash content (T211-om-93), Lignin content (T222-om-98) and Sodium Hydroxide soluble (T203-om-88). The scanning electron microscopy (SEM) was used to observe and determine the morphological characteristic of both crops. The result indicates that pineapple leaf more suitable for becoming an alternative fibre than cassava peels. Pineapple leaves have a high Holocellulose content (85.7%), cassava peels 66%, followed by Cellulose pineapple leaf (66.2%), cassava peels (37.9%). However, hemicellulose content in pineapple leaf (19.5%) less than cassava peels (37.0%). Lignin content of pineapple leaf is lower (4.2%) compared to cassava peels (7.52%) in this study. From SEM images, cassava peel contained abundance fibre such as hemicellulose and cellulose that is held by the lignin in it and Pineapple leaves give a condensed composition of fibre structure. The chemical compositions and morphology study of pineapple leaf and cassava indicate pineapple leaf have a high percentage to be used as an alternative pulp in paper making industry, promoting the green technology. However, cassava peels make some of properties that can also be through for the paper industry.

Raheem et al. (2015) researched the effect of CPA as an alternative binder in cement concrete. This study partially replaced cement with CPA varying from 0 to 20% with an interval of 5% and concrete was designed with a mix ratio of 1:2:4. Test results showed that the compressive strength of the concrete increased with an increased curing age but decreased as the percentage of CPA increased. As CPA content increases, water-binder (w/b) to achieve workable concrete also increases. It is suggested that an optimum w/b ratio of 0.7 may be appropriate. It showed CPA replacement of 5%, 10%and 15% in concrete with OPC have no significant loss in strength compared to the control sample with 100% cement and hence, could be acceptable in most concrete work.

Bello et al. (2015) This research is aimed at assessing the impact of Cassava Peels Ash (CPA) on the stabilization of lateritic soil deposit found within Osogbo Local Government Area in Osun State, Nigeria. This project was carried out to study the characteristics of Cassava Peels Ash (CPA) stabilization on lateritic soil. Preliminary tests were performed on three samples, L1, L2, and L3 for identification and classification purposes followed by the consistency limit tests. Geotechnical property tests (compaction, California bearing ratio (CBR), and Unconfined Compression Test) were also performed on the samples, both at the stabilized and unstabilized states by adding 2, 4, 6, 8 and 10% Cassava Peels Ash (CPA) by weight of sample to the soils. The results showed that the addition of CPA improved the strengths of the samples. Optimum moisture contents (OMC) reduced to 14.58, 18.40 and 16.00% at 6, 4 and 6% CPA additions in samples L1, L2 and L3 respectively while maximum dry density (MDD) increased to 1470, 1410 and 1440 kg/m^3 at 10, 4 and 2% CPA additions in samples L1, L2, and L3. The unsoaked CBR values of samples increased from 7.89 to 19.40% at 8% CPA stabilization for sample L1, for sample L2, it increases from 5.80 to 27.02% at 10% CPA stabilization and for sample L3 at the natural state, it increases from 14.50 to 18.20% at 4%. The shear strengths of samples L1, L2 and L3 also increased from 123.70 to 590.58 kN/m^2 at 2% CPA stabilization, 293.48 to 297.67 kN/m^2 at 10% CPA stabilization and 153.99 to 554.02 kN/m^2 respectively. It was therefore concluded that Cassava Peels Ash has a good potential for stabilizing lateritic soil.

Ofuyatan et al. (2018) investigated the effect of partial replacement of CPA with ordinary Portland cement at 5, 10, 15, 20, and 25% by weight of cement and subjected to compressive strength, tensile strength, durability, porosity, water absorption, slump, compact factor, and shrinkage tests. The results showed that partial replacement of 10 and 15% gave compressive strength comparable to the control mix with 0% replacement and optimum replacement is found to be 10%. It was found that durability and sulphuric acid resistance improved considerably at 10% replacement of cement with cassava peel ash. Slump values and specific gravity were found to decrease as the CPA content increased and it was concluded that concrete with CPA can be used for light construction works where high strength is not a major requirement but where durability is a major concern.

Baenla et al. (2019) assessed the replacement of low reactive volcanic ash by ashes of an agro-waste matter (cassava peel) within the range of 0–30% by mass in geopolymer synthesis. Due to its high amorphous phase content (72% by mass), cassava peel ash partially replaced low reactive volcanic ash during alkali activation of volcanic ash. This led to positive effects on the obtained products. Thus, when used alone, volcanic ash showed low reactivity in alkaline medium, thereby making the handling of geopolymers possible after 3 days, compressive strength of 3.0 MPa (specimens aged 28 days) and abundant efflorescence on specimens exposed to atmospheric air of the laboratory. Conversely, gradual replacement of volcanic by cassava peel ash allowed to get geopolymer pastes with reduced initial setting time (64%) and specimens aged 28 days with significant increase of compressive strength (733%). This behavior was attributed to additional reactive phase brought by the replacement of volcanic ash. Also, replacement of volcanic ash by cassava peel ash (≥20% by mass) led to compact enough products and homogeneous distribution of Na+ ions over the structure of alkali activated specimens along with reduction of magnitude of efflorescence. Lessening of efflorescence resulted among other to the presence of arcanite (K2SO4) in the replacement which helped to embed unreacted Na+ ions through the formation of aphthitalite (K3Na(SO4)2). After 28 days of immersion in 5% by mass of sulphuric acid, the surface of all specimens remains structurally intact. Hence, cassava peel ash behaves as an additional precursor that brings synergistic effect to volcanic ash during alkaline activation.

Ogbonna et al. (2020) studied the effects of CPA on the mechanical properties of concrete by replacing 0 to 40% of OPC with CPA to reduce the quantity of cement consumption for construction works. The chemical composition showed CPA contained Fe2O3, Al2O3, and SiO2 which produced a total sum of 81.83%, indicating a good pozzolanic behavior. The maximum modulus of elasticity response of 31.72GPa was obtained at a 90-days curing period for the 0%-replacement while at 5%- replacement produced the best CPA-cement blended concrete with a modulus of elasticity response of 31.12GPa at 90-days curing period. It was found that 5%- replacement produced the best durability performance from the result while the durability performance of CPA-concrete tends to decrease as the replacement ratio increases.

Ogunbode et al. (2021) investigated the effects of kenaf bio-fibre (KBF) and cassava peel ash (CPA) on the physical, mechanical, and microstructural properties of concrete. The CPA was characterized by microstructural studies such as X-ray diffraction (XRD), scanning electron microscopy (SEM) and X-ray spectroscopy (EDS). The KBF (length, L = 5 cm) and five (5) volume fractions from 0 to 1.0% (Δ% = 0.25%) were used with Portland cement (CEM 1). Next, five concrete mixtures were also cast using 10% CPA as a replacement for CEM 1. The results revealed that the inclusion of KBF in concrete and blending CPA with CEM 1 reduced the slump values with no major improvement of the compressive strength. However, blending CPA with CEM 1 and inclusion of KBF in concrete improved the VeBe time of the fresh concrete and the tensile and flexural strengths of the hardened concrete. The SEM results showed that KBF serve as bridges between the cracks and enhanced the load transfer capability of the concrete matrix. Overall, the study demonstrated that the utilization of KBF and CPA in concrete is a technically feasible and environmentally friendly approach to waste valorisation and sustainable construction.

Osuide et al. (2021) determined the suitability of Cassava Peel Ash (CPA) as a partial replacement of cement in concrete in a bid to devise more economical construction measures while preserving strength and protecting the environment. Tests to determine the chemical composition of the CPA, specific gravity, and sieve analysis of the aggregates in accordance with BS 812 standards and slump test of the concrete were carried out. In the experiments, 0-50% with 5% increment of CPA was used as partial replacement of cement in concrete. The concrete was batched by weight with a ratio of1:2:4. Compressive strength test was conducted on the samples at interval of 7 days and some of the results obtained in N/mm^2 were 10.50, 16.00, 16.50, 19.50 for 0 %,9.50,15.50, 15.60, 18.00 for 5 %, 6.80, 13.40, 14.10, 15.00 for 30 %, 5.90, 12.00, 13.50,14.20 for 40 %, 5.50, 11.70, 12.9,13.70 for 45 %, 5.30, 11.20, 12.00, 13.10 for 50 % partial replacement conducted for 7, 14, 21 and 28 days curing respectively. The graph plotted showed that compressive strength of the concrete increased with increase in length of curing but decreased as the percentage of cassava peel ash was increased. However, the strength remained in the allowable range of workability for concrete in line with the British standard. Also, it was found out that the entire mix was suitable since the results were within the acceptable limits as concrete strength made with varying amounts of cassava peel ash did not fall below half of the original strength of the concrete made with zero percent CPA. This alternative use of cassava peelings will in the long run reduce cost of construction, attract higher economic value to cassava peels and increase the economic return of the farmers and preserve the environment.

INFERENCES FROM THE LITERATURE REVIEW

The inferences drawn from the literature study conducted are as follows:

- Slag to be used in concrete is required to be passed through a series of treatments to make it chemically and physically stabilized.
- SCC produced with IFS as coarse aggregate showed porous microstructure which caused a reduction in strength performance of concrete in comparison to natural aggregate SCC.
- Improved strength characteristics were found when 50% IFS aggregate was used as a replacement for basalt aggregate.
- EAF slag when used as fine aggregate behaves like traditional concrete in terms of strength and slightly less so in terms of durability.
- Fresh and mechanical properties were found to be enhanced when 50% IFS aggregate is used in place of brick aggregate.
- CPA possesses good pozzolanic behavior due to the presence of Fe_2O_3, Al_2O_3, and SiO_2 which produced a total sum of 81.83% composition.
- Partial replacement at 10% of CPA by weight of cement depicted comparable strength to the control mix.
- Partial replacement at 5% of CPA by weight of cement was found to perform best for durability tests and tends to reduce with an increase in CPA%.
- Water-binder ratio required to achieve workable blended concrete increases as an increase in %CPA content and was 0.7 was suggested as optimum w/b.

SUMMARY

This chapter describes in detail the various studies conducted on concrete to determine the fresh and mechanical properties of concrete containing steel slag as aggregates. Research works related to the use of CPA as a partial replacement for cement are also studied. Inferences obtained from the literature survey have been summarised at the end.