Partial Replacement of Cement Material in Ethiopia: A Review

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Abstract - *Concrete is a composite material which is predominantly used all over the world. It is obtained by mixing cementing materials, aggregates and water in required quantities. At present, the construction industry and its sectors of the world have high and limitless demands for using concrete material to build various infrastructures. The worldwide production of cement has greatly increased, due to this production environmental pollution increases with emission of CO_2 gas and ecological degradation. Different researchers investigated on alternative material that can partially replace cement. So, this relies on great concern about the environment impact to produce the concrete which balances the demand of it. Therefore the aim of this study focuses on reviewing alternate cement replacement material in concrete production in Ethiopia.*

1. INTRODUCTION

Concrete is basically a mixture of two components: aggregates and cement paste. The paste, comprised of Portland cement and water, binds the aggregates (usually sand and gravel or crushed stone) into a rock like mass as the paste hardens because of the chemical reaction of the cement and water. Due to high development and depletion of concrete making material, searching for alternative concrete making material is the major issue. There are different locally available wastes that can partially replace cement such as glass waste, marble dust powder, ceramic waste, quarry dust, GGBS, Fly ash, RHA, CKD, BSFC, Silica fume, Silt, Clay, Sewage Sludge Ash and different Sludge etc. as partial substitution at place of concrete ingredients, it may prove more economical than traditional concrete and question of damping of such waste produced by different industries is also get solved (Patel1 et.al, 2015). The use of construction and demolition glass waste increases the compressive strength up to 30% replacement and water absorption percentage decreases when glass powder content increases in cement [13]. Partial replacement of cement with up to 10% Hypo Sludge increases the compressive strength and above 10% decreases the compressive strength [1].

2. Literature Review

[2] Investigated on effects of partial substitution of Portland cement clinker with limestone addition on the physical and chemical properties of cement paste and hardened mortar in two ranges of blain fineness values. The laboratory test results revealed that up to 15% replacement of clinker by fine limestone powder having blain fineness values in the range of 4000 to 4500 cm2/gm result in comparable compressive strength to similar mixes produced using 100% ordinary Portland cement. It also satisfied the standard compressive strength of high early strength of cement (42.5 MPa) as per EN 197-1 standard requirements. Furthermore, it was found that 25-35% limestone addition by weight results in slightly lesser compressive strength values than the 28th day's standard compressive strength requirement. Therefore the authors concluded that increasing in fineness of the limestone filler addition in Portland cement clinker results in relative increase of rate of hydration and faster development of the early age strength while decreasing slightly the consistency and the setting times.

[3] Demissew, Fufa, & Assefa (2019) investigated the suitability of coffee husk ash (CHA) as a partial replacement for ordinary Portland cement (OPC) in conventional concrete production. Coffee husk were collected from different coffee treatment centers and grounded to determine the physical and chemical properties by atomic absorption spectrophotometer method. The study proposed six different concrete mixes with CHA replacement 0, 2, 3, 5, 10, and 15% of the OPC were prepared for 25MPa conventional concrete with water to cement ratio of 0.5 and 360 kg/m3 cement content. The study resulted on, up to 10% replacement of OPC by CHA achieved advanced compressive strength at all test ages, i.e. 7, 14, and 28 days of age using compressive test machine. Generally according to Demissew, Fufa, & Assefa (2019), the compressive strength increased with curing period, but decreased with increased amount of CHA. The compressive test showed that more percentage replacement caused less degree of strength for the same ages of specimen. In the reveries, aged specimens resulted better strength for the same replacement percentages. Therefore, 10% of CHA replacement is the optimum ratio for C-25 concrete production.

[4] Geremew (2017) studied bagasse ash as a Partial Substitute of Cement on Concrete Rigid Pavement. Systematic experiments were conducted for replacement ratios of 5%, 10% and 20% by volume of cement. The percentage of replacement which yielded a relatively better response with respect to the mentioned properties was selected as an optimum percentage of replacement. The experimental study showed that strength enhancement was seen in concrete mixes that were prepared with bagasse ash amount of 5% and 10% replacement by volume. Moreover; the pozzalanic nature of the bagasse ash was not inhibiting the early age strength development. The use of bagasse ash in concrete rigid pavement has showed certain technical advantages and as per the findings the material can substitute cement up to 10% (by volume). This finding was obtained using the

bagasse ash which did not pass through any treatment or modification except being sieved with a 300μm sieve. Generally, Replacement of cement by up to 10% in concrete production was found to enhance the compressive strength by 1.23%, flexural tensile strength by 8.65% at 28 days.

[5] Danbala, Quezon, & Kebede (2019) conducted to examine the suitability of calcined termite hill clay powder as a cement replacing material in the production of C-25 grade concrete. The termite hill clay sample was collected from Bokuluboma vicinity and the chemical composition of the material investigated. Results revealed that calcined termite hill clay powder found pozzalanic and can partially replace cement. It has shown that up to 11.3% replacement of the ordinary Portland cement by CTHCP, the cubes achieved a target mean compressive strength of C-25 concrete grade. Generally the study revealed that calcined termite hill clay powder found pozzalanic and can partially replace cement. It has shown that up to 11.3% replacement of the ordinary Portland cement by CTHCP, the cubes achieved a target mean compressive strength of C-25 grade concrete at 28th day.

[6] Hailu & Dinku (2012) investigated the application of bagasse ash in concrete production. For the study bagasse ash collected from the wonji sugar factory and grounded until the particles passing through 63μm sieve size reach about 85% and specific surface area about 4716cm2/ gm. The study used four different C-35 concrete mix with bagasse ash replacement of 0%, 5%, 15% & 25% of the Ordinary Portland cement prepared with water to cement ratio of 0.55 and cement content of 350 kg/m^3 for control mix. The oxide composition test indicate that, the bagasse ash from wonji factory can be classified as N pozzalana as prescribed by ASTM 618. The replacement of OPC by bagasse ash up to 10% resulted in better compressive strength than the control mortar with 100% OPC. However, the replacement of PPC with bagasse ash resulted in lower compressive strength than the control mortar even a lower replacement. Moreover, all of the mortar containing OPC and bagasse ash satisfy the ASTM C-618 minimum pozzalanic index requirement i.e. 75%. Generally the author concluded that 10% replacement of bagasse ash results in better or similar concrete properties and further environmental and economic advantages can also be exploited by using bagasse ash as a partial replacement of cement material.

[7] W/amanuel, Quezon, & Busier (2018) investigated on effects of varying dosage replacement of cement content by animal bone powder in normal concrete mix production. The bone samples collected from seka waste disposal site of Jimma town, approximately 10km from the bus station where a quantity of waste animal bones can be found. After cleaning and drying, the bone samples burned in the Furnace. The average required energy to burn the animal bone obtained at a temperature of 340°C. The burnt bone was allowed to cool before grinding in a hammer mill and sieving. There were six proportions prepared to start from 0% (as control specimen), 5%, 10%, 15%, 20% and 25% dosage increment by weight of bone powder, and evaluated the normal concrete strengths of C-25 grade concrete. The laboratory test results indicated the chemical analyses of bone powder composed similar compounds of oxide in cement but slightly lesser in content based on ASTM C-150. Likewise, the effects of replacing animal bone on the properties of cement such as consistency and setting time remained within the acceptable limits of the Standard Specifications. On the other hand, the results of compressive, flexural tensile, and the split tensile strengths significantly declined from the control specimen during the dosage increment of the replacement made. Therefore, the optimum dosage of bone powder indicated 10% by weight to replace cement content in normal concrete mix production. Concrete strength partially replaced the cement by ABP of varying percent dosage, it was seen that the combination of ABP and cement strongly affected the workability of the fresh concrete. The test results indicated that as the replacement percent dosage of ABP increased, the workability tends to decrease significantly. Therefore, the optimum dosage of animal bone powder (ABP) to replace cement for normal concrete strengths is 10% by weight.

[8] Assefa & Dessalegn (2019) studied on production of lightweight concrete using Corncob Ash as replacement of cement in concrete. Corncob was collected from agricultural farmers and burned in furnace at a temperature of 850°C. The burned ash powder was sieved in order to remove coarser material and replacement of cement was done by 5%, 10%, 15%, 20%, 25%, 30%, and 35% with corncob ash. For each replacement, including control, 3 samples were prepared based on ASTM standards. After curing for 7 and 28 days in curing tank, the weight and compressive strength of samples were checked. Based on the experimental result, as the percentage of corncob ash increase, the weight of cubes decreased and 15% and above corn cob ash replacement makes concrete cubes lightweight. The compressive strength was also decreasing as the amount of replacement increase. However, up to 15% replacement, compressive strength is found within the range of concrete grade requirement. Generally, as the replacing percentage of corn cob ash increased, the slump value, the unit weight and compressive strength of C-25 grade of concrete is slightly decreased. Replacing of cement with corn cob ash up to 15% is acceptable with a compressive strength of 28th day which is 25.18 MPa and is greater than 99% of the 28th day by 1% increment. The slump value of 26.0mm which is within the limit and the density of the concrete at the 28th day curing is 1834.07kg/m3, which is in the range of light weight concrete. In order to make concretes produced by replacing corncob ash lighter in weight, some admixtures can be added to enhance the compressive strength and workability and hence corncob ash amount can be increased.

[9] Kebede (2019) conducted laboratory analysis on property of banana leaf ash for cement replacement. Banana Leaf Ash (BLA) was obtained by collecting sun dried banana leafs from Horizon plantation PLC at Gojeb Agricultural development and burnt in the furnace to change sun dried

leaf into ash. The chemical composition of Banana leaf ash was tested in the geological survey of Ethiopia and the materials used in the mix are banana leaf ash, ordinary Portland cement, fine aggregate, coarse aggregate and water. The replacement percentages of banana leaf ash used are 0, 5, 10, 15 and 20. The compressive strength of the hardened concrete was tested at 7th, 14th and 28th days of curing. From the laboratory result conducted, the banana leaf ash contains major oxides such as calcium oxide, silica, iron oxide and aluminum oxide, which are found in the ordinary Portland cement and the alkali (Na2O and K2O) content found in the ash is very low compared to OPC. The slump result was 70mm in the controlled mix and this value reduced with different replacement percentage of banana leaf ash. The compressive strength was 32.26N/mm2 at 28th day without replacing the ash and with 5 and 10 percent replacement the strength was increased and for 15 and 20 percent banana leaf ash replacement, the compressive strength was reduced. For all percentage of replacement, the 7th and 14th days of compressive strength was lower than the controlled mix. Based on the results conducted, the chemical contents found in banana leaf ash satisfies the pozzalanic property and used as a binding material to partially replace cement. The alkali content is very low in the ash and this helps to control alkali silica reaction in the concrete. Increasing the replacement percentage of banana leaf ash reduces the workability of concrete. Therefore the study concluded that the optimum percentage replacement is 10% and it also increases the compressive strength of concrete.

[10] Kumar & Lemessa (2017) studied on behavior of concrete with agro and industry waste as a replacement for constitutive materials. The replacement of these raw materials of concrete by waste products decrease cost, reduce energy consumption and decrease environment pollution as well as protect the environment from industrial and agro wastes such like municipal waste, coal mine, lime sludge, ground nut shell ash, quarry dust, iron tailing, marble dust, rice husk, lime stone, Hazardous waste, zinc tailing, jute fiber, rice wheat straw, etc., ground nut shell ash can used as filler material and reduce the voids content in concrete material. In this investigation the workability and strength features of M20 grade concrete with 50% quarry dust replacement for river sand and 5% and 10% ground nut shell ash for cement at 28 days is done using IS mix design method. The concrete compressive strength made of 50% quarry dust and 10% GSA is more than that of the control concrete. When the tensile, split and flexural strength is concerned, control concrete is more workable than the concrete with 50% quarry dust and 10% GSA replaced. Finally the surface hardness replaced concrete is more or less same to that the control concrete because when ground nut shell ash mixed with cements and quarry dust, it forms like a gel and make a concrete hard. Therefore, the experimental results showed that the use of quarry dust with ground nut shell ash in concrete improved strength characteristics.

[11] Kumar, et.al (2019) investigated on the effects of tobacco waste ash and waste glass powder as a partial replacement of cement on strength characteristics of concrete. WGP (size 80 µm) and TWA at percentage of 5, 7.5, 10, and 12.5 respectively as replacing cement. The strength characteristics of this new type of concrete are compared with that of the conventional concrete. After mixing, casting, and curing in water for 7, 14, and 28 days respectively, with respect to the experimental results of compressive, flexural and split tensile strength tests values of the specimens were assessed. The experimental results reveal that the compressive and split tensile tests values of the specimens increases by adding at 10% of WGP and 10% of TWA, whereas flexural strength test values increases at the 12.5% of WGP and 12.5 % of TWA. The test results showed that the partial replacement of the waste glass powder and tobacco waste ash combination can be a good substitute for cement. Apart from the strength, the new type of concrete helps to recycle the wastes of glass and tobacco, and thereby protecting the environment and reduce the construction cost.

[12] Reta & Mahto (2019) investigated on concrete produced by partial replacement of cement with Coffee husk ash. CHA was obtained and used to replace cement partially in specified ratios of 5%, 10%, 15%, 20% and 25%. Compressive strength test was carried out on the cubes. The 28 days' compressive strength for 5% replacement was 21.32KN/m2, 10% replacement was 20.67KN/m2, 15 % replacement was 11.48KN/m2, 20% replacement was 8.81KN/m2 and 25% replacement was 7.17N/mm2 respectively. The initial and final setting time of PPC-CHA at 10% replacement was observed to be 168 minutes and 305 minutes respectively. The density of PPC-CHA was also observed to decrease with increasing CHA replacement. The specific gravity of CHA was 2.03. The study concluded that CHA can be used as partial replacement for cement in concrete production as well as for walls of building units and other mild construction works, and replacement is up to 10% for cement as strength produced in making concrete.

[11] Kumar, et.al 2019 analyzed experimental studies on strength of concrete by partial replacement of cement and coarse aggregate with silica fume and road demolition waste. The study focused on the compression, split tensile and flexural strength properties of M20 grade concrete. The composite concrete contains different percentage of Silica Fume and road demolition waste, and they were used as partial replacement for cement and coarse aggregate respectively. The Silica fume is added to the concrete with the percentage of 0%, 5%, 10%, 15% and 20% by the weight of cement and 0%, 10%, 20%, 30% and 40 % of road demolition waste was replaced instead of coarse aggregates. Concrete specimens casted are cubes, cylinders and beams. After completion of curing process, the concrete specimens are tested at 28 days and the final test results are recorded, analyzed and discussed. The strength achieved due to the addition of Silica fume and road demolition waste is compared with the conventional concrete. The experimental

results reveal that the compressive strength, split tensile strength and flexural strength test values increases by adding at 10% of Silica fume and 20% of Road demolition.

3. CONCLUSIONS

From the above literature review the following conclusions are drawn:

 The waste materials coffee husk, banana leaf ash, bagasse ash, bone powder, corncob ash , municipal waste, coal mine, lime sludge, ground nut shell ash, quarry dust, iron tailing have pozzalanic property and can partially replace cement in the range (10-15%) in normal concrete production the optimum percentage replacement of the material is 10%. And if the percentages value of the material increase the compressive strength becomes decreasing.

 All the researchers analyzed only their pozzalanic property their effect on compressive strength and percentage of replacement but the durability case is not investigated. Therefore further studies would focus on durability and accessibility of materials.

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