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Study on Concrete Using Fly Ash, Rise Husk Ash and Egg Shell Powder

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Abstract*: Approximately, yearly concrete production is about 10 billion cubic meters. Cement is a very important constituent of concrete, and approximately 4180 million tons of cement were produced in 2014 globally. Production of one ton of cement releases approximately one ton of CO2 which makes up 7% of all CO2 emissions produced globally. Hence, there is necessity to use supplementary cementitious materials (SCMs) as partial replacement of cement and sand in concrete. Utilization of SCMs reduces the consumption of Ordinary Portland cement, and thereby reduces the energy consumption and greenhouse gas emissions associated with cement production. In this paper the basic aim is to review the research paper on the use of waste material in concrete.
Keywords*: Fly ash, Rice husk ash, Egg shell powder, Green concrete, sand replacement

I. INTRODUCTION

It is a pressing need today for the concrete industry to produce concrete with lower environmental impact, these-called green concrete. This can be achieved in three ways. The first one is by reducing the quantity of cements one tonne of cement saved will save equal amount of CO2 to be discharged into atmosphere. Secondly by reducing the use of natural aggregates whose resources are limited and are exhausting very fast. It is also achieved by utilizing maximum possible waste materials like fly ash, Ground Granulated Blast Furnace Slag, Rice husk ash and silica fume are some of the pozzolanic materials in concrete. This will reduce the requirement of landfill area and make system more sustainable. The World Bank has reported that by 2015 disposal of fly ash will require 1000 square kilometre area or one square meter of land per person. [12]

Fly ash is generally used as replacement of cement, as an admixture in concrete, and in manufacturing of cement. Concrete containing fly ash as partial replacement of cement poses problems of delayed early strength development. Concrete containing fly ash as partial replacement of fine aggregate will have no delayed early strength development, but rather will enhance its workability and strength. This higher workability and strength achieved gives scope for indirectly reducing the cement quantity in concrete. Earlier investigations in respect of development of strength of cement mortars with fly ash showed the 50% to 80% increase in 91 days' strength. For better packing of concrete more quantity of particle size less than 75 microns is highly desirable. This addition of finer particles will also increase the water requirement of the concrete mix. Addition of fly ash as replacement of sand fulfils this requirement of additional finer particles and improves workability and strength at same water content. [12]India is a major rice producing country, and the husk generated during milling is mostly used as a fuel in the boilers for processing paddy, producing energy through direct combustion and / or by gasification. About 20 million tons of RHA is produced annually. This RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped. Lots of ways are being thought of for disposing them by making commercial use of this RHA. Pozzolanic reaction of RHA consumes Ca(OH)2 present in a hydrated Portland cement paste, reduces susceptible to acid attack and improves resistance to chloride penetration. This reduces large pores and porosity resulting very low permeability. The pozzolanic and cementitious reaction associated with RHA reduces the free lime present in the cement paste, decreases the permeability of the system, improves overall resistance to CO2 attack and enhances resistance to corrosion of steel in concrete. [4]

India is in fifth position in the world annual egg production. About 1.61 million tons of egg shells are being waste annually by disposing it as a landfill, which attracts vermin due to attached membrane and causes problems to human health and environment. It is scientifically known that the eggshell is mainly composed of compounds of calcium. Calcium carbonate, (caco3), is the major composition of the eggshell, accounting for 93.70% of the total composition of the eggshell. Similarly, calcium carbonate (caco3), is the primary raw material in the production of cement. The produced OPC is composed of four main Calcium compounds in the forms of calcium silicates, (C2S), tricalcium silicate, (C3S), tricalcium aluminate, (C3A), and tetra-calcium alumina ferrite, (C4AF). It is, therefore, indicated that cement and eggshells have the same primary composition in calcium compounds. [23]

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II. LITERATURE REVIEW

Gemma de Sensale et al. (2005) study on the development of compressive strength up to 91 days of concretes with rice-husk ash (RHA), in which residual RHA from a rice paddy milling industry in Uruguay and RHA produced by controlled incineration from the USA were used for comparison. Two different replacement percentages of cement by RHA, 10% and 20%, and three different water/cementitious material ratios (0.50, 0.40 and 0.32) were used for experiments. The results are compared with those of the concrete without RHA, with splitting tensile strength and air permeability. He concluded that residual RHA provides a positive effect on the compressive strength at early ages, but the long-term behaviour of the concretes with RHA produced by controlled incineration was more significant. Result of compressive strength was increased with all water/cementitious ratios from 13% to 47% for 20% replacement of RHA produced by controlled incineration. [1]

Maisarah Ali et al (2015) introduced RHA as the micro filler in concrete mixtures. The replacement of RHA which is lighter as compared to the Ordinary Portland Cement results in decreasing density of cement fibre composite and less permeable concrete. 5% of RHA was used as cement replacement material for target strength of 50MPa. Microstructure properties of both mixes were analysed using FESEM. Higher silica contains in concrete cubes containing RHA led to the greater formation of calcium Silicate Hydrate (CSH) that contributed towards strength development to the concrete during curing. Water absorption of concrete with RHA replacement is lower than concrete without RHA. The compressive strength test of concrete with 5% RHA replacement is lower than without RHA replacement. However, the target compressive strength of is achieved. [2]

Malkit Singh et al (2016) studied on the Influence of bacteria on the properties of rice husk ash (RHA) concrete. They used concrete having 28-d strength of 32.8 MPa. RHA is replaced in proportion of (0%, 5%, 10%, 15% and 20%) by weight of cement. Bacterium Bacillus aerius (10^5 cells/mL) was mixed in water during making of concrete. Inclusion of bacterium in RHA concrete reduced its water absorption, porosity, and permeability at all ages, due to calcite precipitation, which in turn improves these properties. Results indicated that inclusion of bacteria in RHA-concrete enhanced its compressive strength at all ages. However, best performance was achieved with 10% RHA wherein 28-d compressive strength was 36.1 MPa, and with bacteria, it was 40.0 MPa. [3]

Satish H. Sathawane et al (2013) studied the effect of partial replacement of cement by Fly Ash (FA) and Rice Husk Ash (RHA) in combine proportion started from 30% FA and 0% RHA mix together in concrete by replacement of cement with the gradual increase of RHA by 2.5% and simultaneously gradual decrease of FA by 2.5%. Experiments were done on mechanical properties of concrete such as compressive strength, flexural strength, and split tensile strength. combination of 22.5% FA and 7.5% RHA gives compressive strength increased by 30.15% in compared with targeted strength flexural strength increased by 4.57% compared with control concrete at 28 days, split tensile strength decreased by 9.58% compared with control concrete at 28 days. Results suggest that Partial replacement of FA and RHA reduces the environmental effects, produces economical and eco-friendly concrete. [4]

Divya Chopra et al (2014) replaced cement content with rice husk ash (RHA) as supplementary cementitious materials (SCM's) in SCC and observed fresh flow (slump flow, V Funnel, U-box, L-Flow), mechanical strength (compressive and split tensile) and durability properties (porosity and rapid chloride permeability test) at 7, 28 and 56 d. Concrete specimens were prepared with 0%, 10%, 15% and 20% RHA replacing cement content. Conplast SP430 was used conforming to IS: 9103 (1999) as a high range water reducing admixture. An increase of about 25% strength at 7 d, 33% at 28 d and 36% at 56 d was observed with RHA content of 15% RHA when compared to control mix. Maximum split tensile strength was 3.8 N mm^2 at 28 d and 4.0 N mm^2 at 56 d for 15% RHA replacement. All the mixes were less porous as compared to the control mix at all ages and showed “low range” to “very low range” chloride penetration. [5]

Rafat Siddique (2003) conducted experimental investigation carried out to evaluate the mechanical properties of concrete mixtures in which fine aggregate (sand) was partially replaced with Class F fly ash. Fine aggregate (sand) was replaced with five percentages (10%, 20%,30%, 40%, and 50%) of Class F fly ash by weight. Tests were performed for properties of fresh concrete. Compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity were determined at 7, 14, 28, 56, 91, and 365 days. Compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity of fine aggregate (sand) replaced fly ash concrete continued to increase with age for all fly ash percentages. [10]

Baoshi et al. (1998) used bottom ash in amounts of 10– 40% as replacement for fine aggregate. Test results indicate that the compressive strength and tensile strength of bottom ash concrete generally increases with the increase in replacement ratio of fine aggregate and curing age. The freezing–thawing resistance of concrete using bottom ash was lower than that of ordinary concrete and abrasion resistance of bottom ash concrete was higher than that of ordinary concrete. [11]

Hwang et al. (2004) examined the effects of fine aggregate replacement on the rheology, compressive strength, and carbonation properties of fly ash and mortar. Rheological properties, compressive strength, and rate of carbonation of mortars of water to

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Portland cement ratio of 0.3, 0.4, and 0.5, in which the fine aggregate was replaced with fly ash at 25% and 50% levels. Test results showed that rheological constants increased with higher replacement level of fly ash and that, when water to Portland cement ratio was maintained, the strength development and carbonation properties were improved. [8]

Ghafoori et al. (1997) carried out investigations on a series of laboratory-made roller compacted concretes (RCC) containing high-calcium dry bottom ash as a fine aggregate. Concrete specimens of six different proportions (cement content of 188–337 kg/m3 and coarse aggregate content of 1042–1349 kg/m3) were prepared at their optimum moisture content and fabricated in accordance with ASTM C 1170 Procedure A. Specimens were tested for compression, splitting tension, drying shrinkage, and resistance to abrasion and rapid freezing and thawing. Based on the test results, they concluded that good strength, stiffness, drying shrinkage and resistance to wear, and repeated freezing and thawing cycles can be obtained with compacted concretes containing bottom ash. [24]

Y. Bai et al (2005) studied strength and drying shrinkage of concretes with the natural sand replaced with furnace bottom ash (FBA) at 0%, 30%, 50%, 70% and 100% by mass with fixed slump ranges. The results showed that, at fixed water–cement ratios, the compressive strength and the drying shrinkage decreased with the increase of the FBA sand content. However, at fixed workability, the compressive strength was comparable with that of the control concrete, while the drying shrinkage increased with the increase of the FBA sand content beyond 30% replacement level. Nevertheless, 30% of the natural sand can be beneficially replaced with the FBA sand to produce concrete in the compressive strength range from 40 to 60 N/mm2 without detrimentally affecting drying shrinkage properties of the concrete. [13]

Turhan Bilir et al (2015) studied the influence of fly ash as fine aggregate in mortar properties Flow ability, unit weight, ultrasound pulse velocity, compressive and flexural strengths, modulus of elasticity, stress–strain behaviour and free drying and restrained shrinkage tests were conducted on mortars produced. It was observed that the usage of fly ash as fine aggregate presents a new approach to consume high amount of fly ash without causing significant changes on properties of mortars when it was used at the ratio of 60–70%. FA usage significantly reduces unit weight which was desirable in point of reducing cross sections of structural elements and dead load. Reducing dead load was very important to lightening the earthquake damage and saving life. Weight loss is 36.6% when FA is used at the ratio of 100%. [6]

Shirish V. Deo et al (2015) explored the use of fly ash as replacement of sand is an economical solution for making green and denser concrete. M45 concrete mix (control mix) was designed as per Indian Standard concrete mix design method (IS 10262: 1982) and its comparative performance was verified with respect to minimum voids method and maximum density method for partial replacement of sand with fly ash along with the addition of super plasticizer dose to enhance the workability and strength. For the designed mix five alternative cases were studied. The compressive and the flexural strength of concrete mixes with partial replacement of sand by fly ash was found to be 15% higher without super plasticizer and 28% higher respectively with super plasticizer. They concluded that fly ash could be very conveniently used as partial replacement of sand in structural concrete where its proportion and replacement of sand could be efficiently done by using minimum voids method for higher compressive strength, flexural strength and workability and lower voids at lower cost. [12]

Papadakis (1999) used a typical low calcium fly ash as additive in mortar replacing, part of volume either of Portland cement or aggregate. In either case, 10%, 20% and 30% addition to the cement weight was done. A very important finding was that when the compressive strength of mix in which aggregate was replaced by fly ash were like that of control mix at 3 and 14 days, but were higher from 28 days and later. The strength increase is due to higher content of calcium silicate hydrate (C-S-H; the main carrier of strength in hardened cement) due to reaction of CH produced from cement hydration with active silica of fly ash. [22]

Jayasankar et al. (2010) conducted an experimental study on properties of concrete by substituting rice husk ash, fly ash and egg shell powder to cement in concrete. M20, M25 and M30 mix design was used with 5%, 10%, 15% and 20% variation of egg shell powder, rice husk ash and fly ash to cement and in the combination of ESP +fly ash, ESP + RHA, fly ash + RHA, fly ash + RHA + ESP. It was observed that M20 and M25 cubes was taking equal load compared to conventional concrete but M30 grade concrete's load carrying capacity was slightly decreased. Therefore, they concluded that RHA, ESP and Fly ash mixed cubes when added with grades above M25 may results in the decreased strength level. [19]

Chatterjee (2011) reported that about 50% of fly ash generated is utilised with present efforts. He also reported that, one may achieve up to 70% replacement of cement with fly ash when high strength cement and very high reactive fly ash is used along with the sulphated naphthalene formaldehyde super plasticizer. He reported improvement in fly ash property could be achieved by grinding and getting particles in sub microcrystalline range. [16]

Filho et al. (2013) based on their study on high volume fly ash concrete with and without hydrated lime, they reported that, to maintain the same compressive strength of reference concrete at 91 days, concrete containing 50% of fly ash, must have reduced

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water to cementitious ratio. Moreover, they concluded that use of fly ash changed density and amount of calcium hydroxide in concrete were reduced. [18]

Homnuttiwong (2012) investigated compressive strength, water permeability and abrasion resistance of high volume fine fly ash and fine ground palm oil fuel ash concrete. They replaced up to 70% Portland cement type I by fine fly ash (FFA) and fine ground palm oil fuel ash (GPA). They reported that FFA was more reactive than GPA. Their results also confirmed that compressive strength, water permeability and abrasion resistance were comparable with normal concrete due to increase in pozzolanic activity of FFA. [17]

Doh Shu Ing and Chin Siew Choo (2014) carried out an investigation on egg shell powder as potential additive to concrete. In this investigation, five different percentages of egg shell powder with respect to cement was added into concrete mix of grade M25. Based on the investigation they came across the conclusion that water cement ratio of 0.4 produces medium workability, ESP as filler in concrete had improved the compressive strength of concrete and maximum strength was obtained at 10% replacement. Flexural strength of concrete was improved with addition of ESP to concrete compared to control concrete mix. ESP has an addition to concrete had improved the resistance to failure under bending and water absorption was reduced at initial stage. [21]

Dr Sowmya N et al. (2015) conducted an experimental study on properties of Egg Shell Concrete with Partial Replacement of Cement by Fly Ash. Two wastes are used as a partial replacement of cement and various properties like workability, compressive strength, split tensile strength and flexural strength were determined. Egg shell powder are varied up to 12.5% (0%, 2.5%, 5%, 7.5%, 10% and 12.5%) and fly ash is added to optimum egg shell powder content cement concrete from 0% to 30% (0%, 5%, 10%, 15%, 20%, 25% and 30%).out of this 7.5% of egg shell powder replacement gives highest compressive strength and Split Tensile Strength. Fly ash percentage are varied from 0% to 30% with 7.5% off egg shell powder. The combination of ESP + FA showed the reduction in compressive strength compared to egg shell concrete mixes beyond 5% replacement of fly ash to optimum egg shell content concrete. [23]

Hanifi Binici et al (2015) evaluated the feasibility of the use of industrial egg shell waste for the protection of buildings against external radiation effects. Towards that end, the radiation absorbing property of mortars made of cement, sand and egg shells was extensively studied. During their investigation, the possible decrease in the quality of mortars like 90-day sulphate resistance and the 7, 28 and 90 day compressive and flexural strengths were also investigated. The results showed that egg shells as an additive decreased the compressive and flexural strengths of the mortars for all the samples with different additive percentages of egg shells for all ages. However, the mix proposed satisfies the minimum compressive strength requirements of the Turkish standards. The linear absorption coefficient increased in the samples with increasing egg shell ratio, i.e., mortars with egg shells had low radioactive permeability. Hence, egg shells may be used in regions where radiation is effective. Such concrete can easily be used in walls for radiation shielding. [2]

III. CRITICAL REMARKS

Following critical remarks can be drawn from the literature review:

The increase in compressive strength of concretes with residual RHA is better justified by the filler effect (physical) than by the pozzolanic effect.

The RHA concrete shows less porosity in the interfacial transition zone (ITZ) due to the filler effect of this natural fibre. The microcracks observed in matrix and along interfacial transition zone in concrete with RHA replacement is lower.

The higher content of Calcium Silicate Hydrate from the reaction of silica from RHA with calcium hydroxide making the concrete denser.

Water absorption of concrete with RHA replacement is lower than concrete without RHA. The workability of concrete had been found to be decrease with increase RHA in concrete.

RHA increased the SSD of mortar, slightly decreased filling and passing abilities and significantly increased plastic viscosity and segregation resistance of SCHPC. RHA also eliminated the bleeding of mortar and SCHPC.

Compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity of fine aggregate (sand) replaced fly ash concrete specimens were higher than the plain concrete at all the ages.

The usage of FA as fine aggregate in the mixture reduces workability.

The cost per N/mm2 was lower without and with super plasticizer making the partial replacement of the sand with the fly ash ecoomical.

Abrasion resistance was found to increase with increase in fly ash content as replacement of fine aggregate.

Egg shell powder can be used as a cement replacement up to 10% by weight of cement.

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egg shells may be used in regions where radiation is effective. Such concrete can easily be used in walls for radiation shielding

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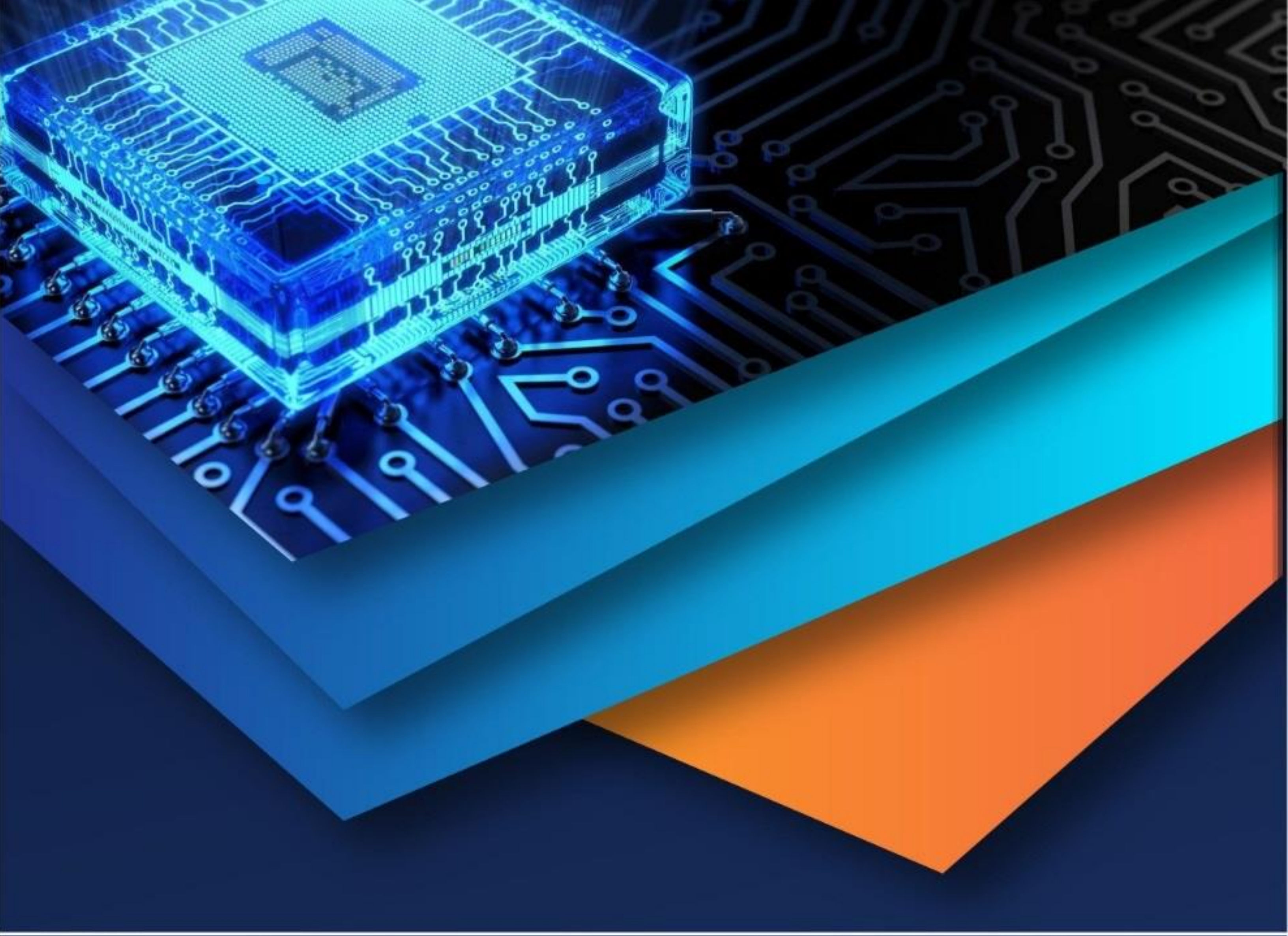

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