Sustainable Materials for Green Buildings

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Abstract-Concrete is by far the most widely used construction material worldwide. First, it consumes huge quantities of virgin materials. Second, the principal binder in concrete is cement, by these production the greenhouse gas is increased which causes effects the global warming and climatic changes. Many structures suffer from lack of durability which has an adverse effect on the resource productivity of the industry. The supplementary cementing materials like natural materials, by-products or industrial wastes are used. The fly ash concrete system addresses all sustainability issues, its adoption will enable the concrete construction industry to become more sustainable. In order to eradicate problem of causing cracks due to hydration, the materials which improves suitability of concrete different cheaper materials are used. As concrete is the most demanded material and use of cement is huge as such, different replacing material should be used in order to achieve properties of the concrete safely within standards. The study has been undertaken to investigate the effects, on the properties of concrete, by replacing cement (up to 40% by weight) with fly ash, rice husk ash , ground granulated blast furnace slag(GGBS), by replacing fine aggregate (up to 30% by weight) with fly ash , rice husk ash. This is on the results of the compressive strength of concrete under water curing after 7 days and 28 days. There appears to be little difference in the performance of the fly ash, rice husk ash and ground granulated blast furnace (GGBS) used in this investigation. The use of these materials in concrete has been associated with the increased compressive and flexural strengths, reduced permeability, and increased resistance to chemical attack, increased durability, reduced shrinkage, making concrete denser, Enhanced workability of concrete.*

Keywords: *fly ash, rice husk ash, ground granulated blast furnace blast (GGBS), Compressive strength*

Introduction

Energy conservation in the building industry is a world-wide concern, by taking this into consideration the engineers and scientists have taken this as challenge and exploring the ways of producing building materials with minimum energy unit.

Flyash

Fly ash is a by-product of coal-fired from thermal power plants, it is approximately 80 million tons every year, and its percentage utilization is less than 10% during last few years [1]. It increases the durability when used as replacement of cement, as an admixture in concrete and increases the strength of the concrete [2].There is advantage in adding fly ash to concrete products cured at normal atmospheric conditions or in the autoclave at high temperatures and pressures. Recently, fly ash has been increasingly used in the concrete industry. In some cases, large volume of (>40%) fly ash is used to achieve desired concrete properties and lower the cost of concrete production. This limits the wide use of high-volume fly ash concrete by engineers. As fly ash is more complex than silica, however, and contains CaO, $A1_20_3$, Fe_20_3 and other impurities, its composition is dependent on the source and operational conditions at each power plan**.** Different approaches are used to accelerate the pozzolanic reaction, these approaches include (i) mechanical treatment (grinding), (ii) accelerated curing and autoclaving, and (iii) chemical activating. Chemical activating involved using alkali activation and sulfate activation. However, alkali activation used in concrete may lead to alkali–silica reaction, and sulfate activation may decrease the durability of concrete due to the large ettringite contents. If the materials show high pozzolanic activity, the heat produced during hydration is higher [2].

It is well known that the service life of a concrete structure is strongly dependent on its material transport properties, which are controlled by the microstructure characteristics of concrete. It is generally recognized that the incorporation of pozzolanic materials as a partial replacement for Portland cement in concrete is an effective means for improving the properties of concrete[3].Concrete containing fly ash as partial replacement of fine aggregate will have no delayed early strength development, but rather will enhance its strength on long-term basis[1].The size of the pores of crystalline hydration products, make the microstructure of concrete more uniform and improve the impermeability and durability of concrete. These improvements can lead to an increase in the service life of a concrete structure.

Rice husk ash

Rice husks is an agro-waste material which is is obtained by the combustion of rice husk or shells produced during the husking of paddy rice. 1000 Kg of paddy rice can produce about 200 Kg of husk, which on combustion produces about 40 Kg of ash. Rice husk constitute about 1/5th of the 300 million metric tons of rice produced annually in the world. According to the report by Abhilash Shukla [5], 100 million tones of rice husk as a waste is formed from the milling. The burning of rice husk ash (RHA) is not to be done in between 500 and 600^0 C in short duration i.e., 2hrs cause it yields un burnt carbon and anamorphous silica. When rice husk is burnt in an uncontrolled manner, the ash, which is essentially silica, is converted to crystalline forms and is less reactive[5].so this materials is used as a highly reactive pozzolanic material and used as replacement in concrete. This leads to a significant improvement on strength and durability of normal concretes [6].Rice husks contain organic substances and 20% of inorganic material. The most important property of RHA that determines the pozzolanic activity is its amorphous phase content.

Research in India and the United States has found that if the hulls or straw are burned at a controlled low temperature, the ash collected can be ground to produce a pozzolan [5].Since the end of the 1960s, extensive research has been carried out on the preparation, properties and applications of RHA in pastes, mortars and concretes and many papers and patents have been published on this subject. Although high quality RHA has been produced by many researchers under controlled conditions, the use of this material is still limited in many countries due to its sensitivity to burning conditions. Research on producing RHA can be incorporated to concrete and mortars are not recent. In 1973, Metha investigated the effect of pyroprocessing on the pozzolanic reactivity of RHA. Since then, a lot of researches have been developed to improve the mechanical and durability properties of concrete Costenaro and Libório, Payá .

RHA contains a high amount of silicon dioxide. The results show that adding percentage over 12% of RHA, the expansion is reduced in acceptable levels.by this paper, the RHA obtained by uncontrolled combustion was added to concrete.Acid treatment has been found to decrease the degree of crystallization of silica and carbon in rice husks [7]. educing the sensitivity of the pozzolanic activity of the rice husk ash to burning conditions.) Rice husk is also not used for feeding animals since it is less nutritional properties. The characteristics of the typical rice husk produce in India has organic amorphous silica (made of rice husk ash) with silica content of above 85%, in very small particle size of less than 25 microns, which is used for making green concrete, high performance concrete, refectories, insulators, flame retardants etc.

Ground Granulated Blast Furnace Slag

Ground Granulated Blast Furnace Slag (GGBS) is a byproduct of the steel industry which is commonly used in combination with portland cement in concrete. Concrete made with ggbs has many advantages, including improved durability, workability and economic benefits. The drawback in the use of ggbs concrete is that its strength development is considerably slower under standard 20 -C curing conditions than that of portland cement concrete, although the ultimate strength is higher for the same water–binder ratio.By these GGBS is not used in any application where high early age strength is required. However, hydration of ggbs is much more sensitive to temperature than portland cement and there is evidence that at higher early age temperatures, the strength development of ggbs concrete is significantly enhance [8]. Blast furnace slag is defined as "the non-metallic product consisting essentially of calcium silicates. When the iron ore, which is made up of iron oxides, silica, and alumina, comes together with the fluxing agents, molten slag and iron are produced. The molten slag then goes through a particular process depending on what type of slag it will become. Air-cooled slag has a rough finish and larger surface area when compared to aggregates of that volume which allows it to bind well with Portland cements as well as asphalt mixtures. GGBS is produced when molten slag is quenched rapidly using water jets, which produces a granular glassy aggregate.In the construction of large structural concrete elements where heat dissipation is slow, there can be a significant rise in temperature within the first few days after casting due to the exothermic reaction of the binder. This leads to higher early age strengths, which can only be determined by temperature matched curing. Cubes or cylinders cured at 20 -C would underestimate the strength in the structure.

Table-1
Chemical composition of materials

			Sl	MATERIAL	Author	SiO_2	Al_2O_3	Fe_2O_3
		1.43	CEMENT	Gengying Li(2004)	19.5	4.4	6
	0.48	2.12	FLYASH	Gengying Li(2004)	53.9	28.5	
1	3.56	-	RHA	Jayasankar R. (2010)	92.99		
0.1	0.31	-	GGBS	S.J. Barnett (2006)	3		

Pozzolanic reaction

A pozzolanic reaction occurs when a siliceous or aluminous material get in touch with calcium hydroxide in the presence of humidity to form compounds exhibiting cementitious properties . In the cement hydration development, the calcium silicate hydrate (C-S-H) and calcium hydroxide ($Ca(OH)_2$, or CH) are released within the hydration of two main components of cement namely tricalcium silicate (C3S) and dicalcium silicate (C2S) where C, S represent CaO and SiO_2. Hydration of C3S, C2S also C3A and C4AF (A and F symbolize Al2O3 and Fe2O3) respectively, is important. Upon wetting, the following reactions occur

$$2(3CaO\text{-}SiO_2) + 6H_20 \rightarrow 3CaO.2SiO_2.3H_20 + 3Ca\ (OH)_2 \quad (1)$$

$$2(2CaO.SiO_2) + 4H_20 \rightarrow 3CaO.2SiO_2.3H_20 + Ca\ (OH)_2 \quad (2)$$

$$3CaO.A1_203 + 31H_20 + 3CASO_4 \rightarrow 3CaO.\ A1_203.\ 3CaSO_4.\ 31\ H_20 \quad (3)$$

$4CaO.Al_2O_3.Fe_2O_3 + 10H_2O + 2Ca(OH)_2 \rightarrow 6CaO.Al_2O_3.Fe_2O_3.12H_2O$ (4)

The C-S-H gel generated by the hydration of C3S and C2S in equations (1) and (2) is the main strengthening constituent. Calcium hydroxide and Ettringite ($3CaO.3CaSO_4.31H_2O$, equation 3) that are crystalline hydration products are randomly distributed and form the frame of the gel-like products. Hydration of C4AF (equation 4), consumes calcium hydroxide and generates gel-like products. Excess calcium hydroxide can be detrimental to concrete strength, due to tending the crystalline growth in one direction.

It is known that by adding pozzolanic material to mortar or concrete mix, the pozzolanic reaction will only start when CH is released and pozzolan/CH interaction exist. In the pozzolan-lime reaction, OH- and Ca 2+ react with the SiO_2 or Al_2O_3-SiO_2 framework to form calcium silicate hydrate (C-S-H), calcium aluminate hydrate (C-A-H), and calcium aluminate ferrite hydrate:

Tobermorite gel:

$SiO_2 + Ca(OH)_2 + H_2O \rightarrow CaO.SiO_2.H20$ (5)

Calcium aluminate hydrate:

$Ca(OH)_2 + H_2O + Al_2O_3 \rightarrow aO.Al_2O_3.Ca(OH)_2.H_2O$ (6)

Calcium aluminate ferrite hydrate:

$Ca(OH)_2 + Fe_2O_3 + Al_2O_3 + H_2O \rightarrow Ca(OH)_2.Al_2O_3.Fe_2O_3.H_2O$ (7)

The crystallized compound of C-S-H and C-A-H, which are called cement gel, hardened with age to form a continuous binding matrix with a large surface area and are components responsible for the development of strength in the cement paste Pozzolan-lime reactions are slow, generally starting after one or more weeks. The behavior of the delay in pozzolanic reaction will result in more permeable concrete at early ages and gradually becomes denser thanplain concrete with time. This behavior is due to two reasons: Firstly, pozzolan particles become the precipitation sites for the early hydration C-S-H and CH that hinders pozzolanic reaction. Secondly, the strong dependency of the breaking down of glass phase on the alkalinity of the pore water which could only attain the high pH after some days of hydration. Pozzolan can partially replace cement in mortar or concrete mix without affecting strength development. The effect of the pozzolanic reaction produces more cement gel (i.e. C-S-H and C-A-H) reducing the pore size, blocks the capillary and produces denser concrete thus making it stronger and more durable [9].

Compressive strength of fly ash

The compressive strength of fly ash concrete mixes with 10%, 20%, 30%, 40%, and 50% fine aggregate replacement with fly ash, was higher than the control mix at all ages. Compressive strength of all mixes continued to increase with the increase in age. However, the rate of increase of strength decreases with the increase in fly ash content. This trend is more obvious between 40% and 50% replacement level. However, maximum strength at all ages occurs with 50% fine aggregate replacement. This increase in strength due to the replacement of fine aggregate with fly ash is attributed to the pozzolanic action of fly ash. In the beginning (early age), fly ash reacts slowly with calcium hydroxide liberated during hydration of cement and does not contribute significantly to the densification of the concrete matrix at early ages. Concrete with fly ash shows higher strength at early ages because inclusion of fly ash as partial replacement of sand starts pozzolanic action and densification of the concrete matrix and due to this strength of fly ash concrete is higher than the strength of control mix even at early ages.

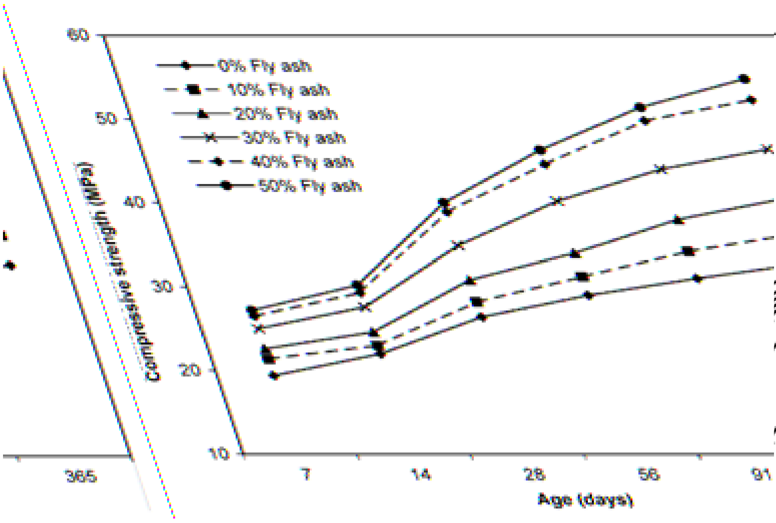

Fig-1: compressive strength Vs age

For 3 days and 7 days compressive strength, no fly ash concrete achieved maximum strength. Up to curing period of 14 days, compressive strength is seen to decrease with the increase in fly ash content when compared with no fly ash mortar.28 days compressive strength test result of the specimens up to 50% replacement level were very similar with OPC mortar strength. 28 days strength for the 60% fly ash replacement mortar was lower by 28% when compared with no fly ash mortar. After 90 days, maximum compressive strength was obtained for 30% and 40% replaced mortar specimens with an increase in strength of 10% and 14% respectively as compared to OPC mortar. Cement normally gains its maximum strength within 28 days [10].During that period, lime produced form cement hydration remains within the hydration product. Generally, this lime reacts with fly ash and imparts more strength. For this reason, mortar made with fly ash will have slightly lower strength than cement mortar up to 28 days and substantially higher s trength within 90 days. Fly ash retards the hydration of C_3S in the early stages but accelerates it at later stages.

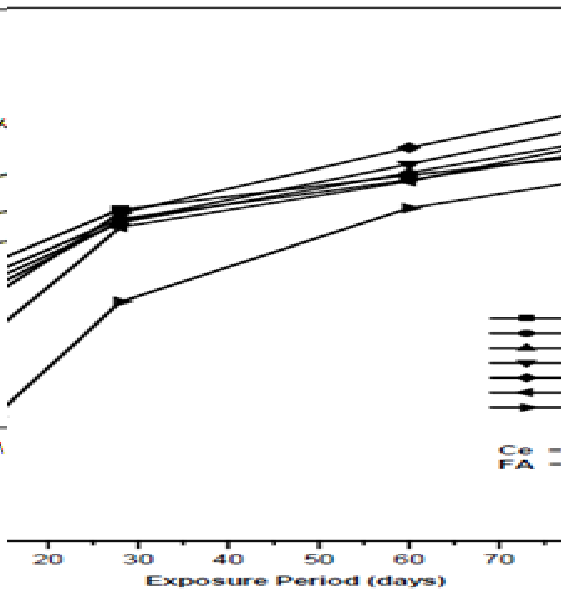

Fig:-2: compressive strength – exposure time relation for cement: fly ash mortars

Compressive Strength of RHA

Addition of RHA as partial replacement of cement increases the compressive strength of concrete, but the optimum replacement level of cement by RHA to give maximum long term strength enhancement has been observed between 10% to 30%. The addition of RHA causes an increment in the compressive strength due to the capacity of the pozzolan of fixing the calcium hydroxide, generated during the reactions of hydrate of cement. All replacement levels of RHA are in percentage by weight of the total binder material [7]. An increment of 25% in axial compressive strength was obtained when added 5% of RHA for 28 days.

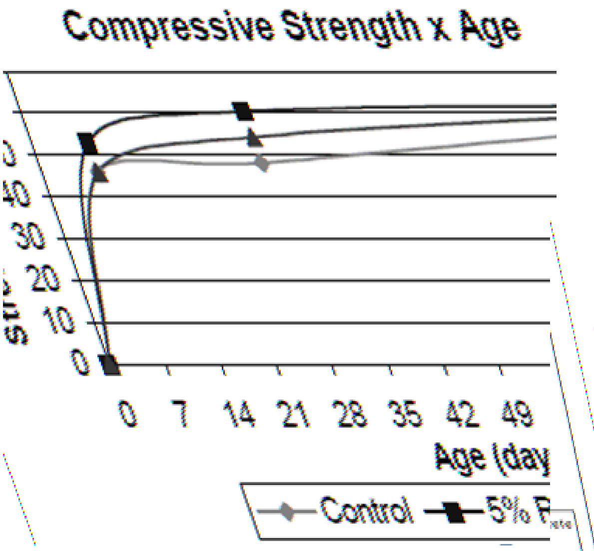

Fig – 3: compressive strength Vs age

Where as in mortar for curing time of 3, 7 and 28 days shows that the compressive strength of OPC mortar is higher than the others but at later age (90 days), the samples having 10%,15% and 20% RHA show better result than the OPC one. For 30% replacement level compressive strength at all test time was lower than the OPC samples. The increase in strength may be due partially to the pozzolanic reaction and the presence of reactive silica in RHA as reported by many researchers [11], [12], [13], [14].

COMPRESSIVE STRENGTH AT DIFFERENT AGES

mple	RHA	Strength (psi)		
		3	7	28
D	(%)	days	days	days
A0	0	1450	2137	3557
A10	10	1150	2062	3579
A15	15	1126	1994	3491
A20	20	1217	1868	3326
A25	25	1042	1806	319
A30	30	979	1575	25

The mixes containing 20% rice husk ash have the highest compressive strength than the others. In addition water to binder ratio has more impact on normal concrete rather than self-compact concrete. Moreover, by increasing the amount of replacement, water to binder ratio rises up.

Concrete mixes at 10% rice husk ash level showed 3 to 10% increase in compressive strength. Rice husk ash levels of 15 to 20% showed reduction in compressive strength in all ages.

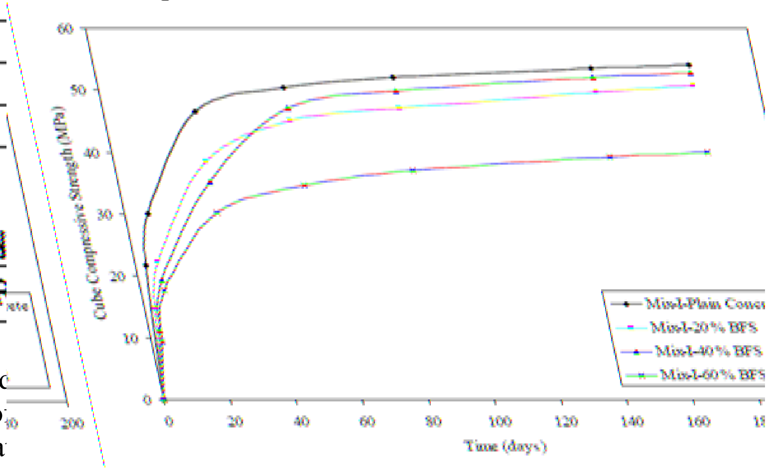

Fig – 4: compressive strength of plain and GGBS concrete

Compressive strength of GGBS

The variation of cube and cylinder compressive strength of ordinary concrete and concrete containing GGBFS with time is shown in Figure. Figure shows that the compressive strength increases with the time at a decreasing rate. The pattern of strength development is same in all the mix. At the age of 28 days the cube compressive strength of GGBFS concrete mixes with cement replacement of 20, 40 and 60 percent was observed to be 83, 75 and 65 of the plain concrete for Mix-I respectively. However, at the age of 180 days this variation of cube compressive strength development of GGBFS concrete with the cement replacement of 20, 40 and 60 percent is increased as 93, 97 and 74 percent for Mix-I with the Plain concrete strength.[16]. 40 percent replacement seems to be the optimum replacement in the present investigation. This strength development of GGBS concrete can be explained by the hydration process according to Regourd [17] and Roy and Idorn [18].

Conclusion

The employment of fly ash, rice husk ash and GGBS in cement and concrete has gained considerable importance because of the requirements of environmental safety and more durable construction in the future. The use of fly ash as partial replacement of cement in mortar and concrete has been extensively investigated in recent years. This literature review clearly demonstrates that fly ash is an effective pozzolan which can contribute the properties of concrete. Fly ash blended concrete can improve the compressive strength as of concrete. A 25 - 35 % fly ash replacement provides the most optimal (best possible) strength results. Beyond 35 % fly ash replacement, the rate of gain of compressive strength decreases but maintains its strength value above the desired design strength. Replacement of cement with high lime fly ash reduces the rate of strength development/ gain, beyond the optimal limits obtained for 25 – 35 % fly ash mixes. After burning rice husk contributes 20% of its weight to Rice Husk ash [19]. According to Tashima RHA is a high pozzolanic material. [20]. Rice husk ash blended concrete can improve the compressive strength as of concrete. Adding RHA to concrete, a decreasing in water absorption was verified. A reducing of 38.7%, for 10% of RHA at 28 days, was observed when compared to the control sample. An increment of 25% in axial compressive strength was obtained when added 5% of RHA for 28 days. Ground granulated blast furnace blended concrete can improve the compressive strength as of concrete. The compressive strength of OPC concrete shows higher strength than the GGBFS based concrete for all replacement (in percent) and at all ages. Incorporating 40% GGBFS is highly significant to increase the compressive strength ofconcrete after 56 days than the 20 and 60% replacement. Among GGBFS based concrete 40% replacement is found to be optimum. Finally, this literature search showed that the properties of concrete are enhanced when the substitution of Portland cement was done by fly ash.

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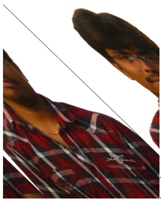
Author's Profile



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