International Journal of Civil Engineering (IJCE)
ISSN(P): 2278-9987; ISSN(E): 2278-9995
Vol. 5, Issue 1, Dec – Jan 2016, 47-54

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

INFLUENCE OF RICE HUSK ASH AND METAKAOLIN ON THE STRENGTH PROPERTIES OF TERNARY BLENDED CONCRETE WITH RECYCLED COURSE AGGREGATE

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ABSTRACT

Ternary blended concrete is developed by partial replacement of cement with metakaolin and rice husk ash. In the last decade the use of supplementary cementing materials has become an integral part of high strength and high performance concrete mix design. Rice husk ash is a by-product material obtained from the controlled combustion of rice husk which consists of non crystalline silicon dioxide with high specific surface area and high pozzolanic reactivity. Metakaolin helps to reduce the amount of calcium hydroxide, thus resulting in stronger and durable concrete. Another advantage of using SCMs is increase in durability of concrete which consequently results increase in resource use efficiency of ingredients of concrete which are depleting at very fast rate. Long term performance of structure has become vital to the economies of all nations. In the present experimental investigation an attempt is made to evaluate the workability and compressive strength of M20 concrete for 7 and 28 days curing period. Cement was replaced with rice husk ash at 0%, 5%, 10%, 15% & 20% and metakaolin of 5% was choosen for all trail mixes. Locally available demolished recycled coarse aggregate having the maximum size of 20 mm was used in place of coarse aggregate. A constant water binder ratio of 0.5 was adopted. The results summarizes that the concrete made with these trail mixes shows excellent fresh and hardened properties.

KEYWORDS: Compressive Strength, Metakaolin, Rice Husk Ash, Ternary Blended Concrete and Workability

INTRODUCTION

An investigation on the use of metakaoline and silica fume as supplementary cementing materials in enhancing the near surface properties of concrete. Metakaoline and silica fume mixtures, each with 10% replacement, were Prepared and tested for initial surface absorption, water absorption and sorptivity. Metakaoline and silica fume were found to enhance the overall near surface characteristics of the concrete. The inclusion of metakaoline and silica fume greatly reduced the initial surface absorption, water absorption and sorptivity of concrete in varying magnitudes. Generally, the curing method adopted had significant effects on the near surface properties of concrete incorporating metakaoline or silica fume [1].

Construction industry is one of the fastest growing sectors in India. Rapid construction activity and growing demand of houses has lead to the short fall of traditional building materials like bricks, cement, sand and wood. Demand of good quality of building materials to replace the traditional materials and the need for cost effective and durable materials for low cost housing has necessitated the researchers to develop variety of new and innovative building materials. Rice milling generates a byproduct known as husk and this husk is converted in to ash is known as rice husk ash. This RHA in turn contains around 85-90% silica. Silica is the basic component of sand which is used with cement for plastering and concreting. Few researchers have been studied the use of rice husk ash [2, 3].

Pozzolanic materials including silica fumes, fly ash, slag, rice husk ash and metakaolin have been used in recent years as cement replacement material for developing high strength concrete (HSC) with improved workability, strength and durability with reduced permeability. Metakaolin, which is a relatively new material in the concrete industry, is effective in increasing strength, reducing sulphate attack and improving air-void network. Pozzolanic reactions change the microstructure of concrete and chemistry of hydration products by consuming the released calcium hydroxide (CH) and production of additional calcium silicate hydrate (C-S-H), resulting in an increased strength and reduced porosity and therefore improved durability. Use of Metakaolin in construction industry as partial replacement of cement started in the 1960's and the interest in this material has considerably increased in recent years. Metakaolin has pozzolanic properties bringing positive effects on resulting properties of concrete. Pozzolanic properties cause chemical reaction of active components with calcium hydroxide (portlandite), which is formed as a product of cement hydration. This reaction leads to formation of binding phases of following types. Secondary C-S-H gel, C_4AH_{13}, C_3AH_6, and C_2ASH_8 thereby increasing strength [4]

The raw material in the manufacture of Metakaoline is kaolin clay. Kaolin is a fine, white, clay mineral that has been traditionally used in the manufacture of porcelain. Kaolins are classifications of clay minerals, which like all clays, are phyllosilicates, i.e. a layer silicate mineral. The Meta prefix in the term is used to denote change. In case of Metakaolin, the change that is taking place is dehydroxylization, brought on by the application of heat over a defined period of time. Dehydroxylation is a reaction of decomposition of kaolinite crystals to a partially disordered structure. The results of isothermal firing show that the dehydroxylation begins at 420 ^{0}C. At about 100-200 ^{0}C clay minerals lose most of their adsorbed water. The temperature at which kaolite loses water by dehydroxilization is in the range 500-800 ^{0}C. This thermal actvation of a mineral is also referred to as calcining. Beyond the temperature of dehydroxylization, kaolinite retains two dimensional orders in the crystal structure and the product is termed Metakaolin. Metakaolin is neither the by-product of an industrial process nor is it entirely natural. It is derived from naturally occurring mineral and is manufactured specially for cementing applications. Metakaolin is produced under carefully controlled conditions to refine its color, remove inert impurities, and tailor particle size such, a much high degree of purity and pozzolanic reactivity can be obtained. Metakaolin is white, amorphous, highly reactive aluminiumsilicate pozzolan forming stabile hydrates after mixing with lime stone in water and providing mortar with hydraulic properties. Heating up of clay with kaolinite $Al_2O_3.2SiO_2.2H_2O$ as the basic mineral component to the temperature of 500°C - 600°C causes loss of structural water with the result of deformation of crystalline structure of kaolinite and formation of an unhydrated reactive form so called metakaolinite. The chemical equations describing this process is $Al_2O_3.2SiO_2.2H_2O = Al_2O_3.\ 2SiO2 + 2H_2O$ (g) [5]

Rice husk can be burnt into ash that fulfils the physical characteristics and chemical composition of mineral admixtures. Pozzolanic activity of rice husk ash (RHA) depends on (i) silica content, (ii) silica crystallization phase, and (iii) size and surface area of ash particles. In addition, ash must contain only a small amount of carbon. RHA that has amorphous silica content and large surface area can be produced by combustion of rice husk at controlled temperature.

Suitable incinerator/furnace as well as grinding method is required for burning and grinding rice husk in order to obtain good quality ash. Although the studies on pozzolanic activity of RHA, its use as a supplementary cementitious material, and its environmental and economical benefits are available in many literatures, very few of them deal with rice husk combustion and grinding methods [6]. Rice husks are shells produced during the de 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 7 Rice husk constitute about 1/5 th of the 300 million metric tons of rice produced annually in the world. According to the report by Mehta 8 the current yearly production paddy rice is approximately 500 million tones that gives about 100 million tons of rice husk as a waste product from the milling. Rice husk is also not used for feeding animals since it is less nutritional properties and its irregular abrasive surface is not naturally degraded and can cause serious accumulation problems. Controlled burning of rice husk between 500 and 600 ^{o}C for short duration of about 2hrs yields ash with low 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. Both the crystalline and amorphous rice husk ash is used to manufacture a lime- rice husk ash mix or a Portland rice husk ash cement or the rice husk ash can be used as a Portland cement replacement in concrete [7,8].

MATERIALS USED IN THE PRESENT STUDY

Cement

Ordinary Portland cement Zuari-53 grade conforming to IS: 12269-1987 [9] was used in concrete.

The physical properties of the cement are listed in Table 1.

Table 1: Physical Properties of Zuari-53 Grade Cement

S No	1	2	3	4	5		
Properties	Specific Gravity	Normal Consistency	Initial Setting Time	Final Setting Time	Compressive Strength (Mpa)		
Values	3.15	32%	60 min	320 min	3 days	7 days	28 days
					29.4	44.8	56.5

Aggregates

Fine Aggregate

Natural sand from Swarnamukhi River in Srikalahasthi with specific gravity of 2.60 was used as fine aggregate conforming to zone- II of IS 383-1970[10] . The individual aggregates were blended to get the desired combined grading.

Recycled Coarse Aggregate

Locally available demolished recycled coarse aggregate having the maximum size of 20 mm was used in our work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested as per Indian Standard Specifications IS: 383-1970[10].

Table 2: Properties of Recycled Coarse Aggregates

S. No.	Characteristics	Value
1	Type	Uncrushed (natural)
2	Specific gravity	2.71
3	Total water absorption	1.2%
4	Fineness modulus	7.16
5	Grading zone	I

Water

Potable water was used for mixing and curing of concrete cubes.

SUPPLEMENTARY CEMENTING MATERIALS

Metakaoline

The Metakaoline was obtained from M/s. 20 Microns Limited, Baroda, India. The chemical composition of Metakaoline is shown in Table 5.

Table 3: Chemical Composition of Metakaoline

Chemical Composition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	SO_3	Na_2O	K_2O	LOI
Mass Percentage	52 to 54%	42 to 44%	< 1 to 1.4%	< 3.0%	0.1%	< 0.1%	< 0.1%	< 0.05%	< 0.4%	<1.0%

Rice Husk Ash

The rice husk was burnt under guided or enclosed place to limit the amount of ash that will be blown off. The ash was ground to the required level of fineness and sieved through 150µm sieve in order to remove any impurity and larger size particles. Tables 4 and 5 shows the physical and chemical properties of rice husk ash

Table 4: Chemical Characteristics of RHA

Sl. No.	Chemical Characteristics	RHA
	Silicon oxide (SiO_2)	86.85
	Aluminum oxide (Al_2O_3)	2.425
	Ferric oxide (Fe_2O_3)	0.41
	Calcium oxide (CaO)	0.4
	Magnesium oxide (MgO)	08 0.99
	Sodium oxide (Na_2O)	0.61
	Potassium oxide (K_2O)	2.93
	Sulphuric anhydride (SO_3)	0.23
	Loss on ignition (LOI)	8.05

Table 5: Physical Characteristics of RHA

Sl. No	Physical Characteristics	RHA
1	Fineness (m2/kg)	25,000
	90µ passing	100 %
	45µ passing	70 %
	Specific Gravity	2.10

Super plasticizer

VARAPLAST SP123 is a chloride free, superplasticisingad mixture based on selected synthetic polymers. It is supplied as a brown solution which is instantly dispersible in water and also it can provide very high level of water reduction and hence major increase in strength can be obtained coupled with good retention of workability to aid placement.

RESULTS AND DISCUSSIONS

In the present work, proportions for concrete mix design of M20 were carried out according to IS: 10262-2009 [11] recommendations. The mix proportions are presented in Table 6. The tests were carried out as per IS: 516-1959 [12]. The 150mm size cubes of various concrete mixtures were cast to test compressive strength. The cubes specimens after de-moulding were stored in curing tanks and on removal of cubes from water the compressive strength were conducted at 7days, 28days. The test results were compared with controlled concrete. The workability results are presented in Table.7.

Table 6: Mix Proportion of M20 Concrete

Trial Mix	Cement	Coarse Aggregate	Fine Aggregate	Water
Composition in Kg/m^3	383	1103	727	191.6
Ratio	1	2.87	1.898	0.5

Table 7: Workability Results of Concrete

Replacement of Metakaolin and Rice Husk Ash with Cement (%)	Workability (Slump in cm)
100% OPC	25
5%MK+ 5 % RHA	29
5%MK+ 10 % RHA	28
5%MK+ 15 % RHA	27
5%MK+ 20 % RHA	26

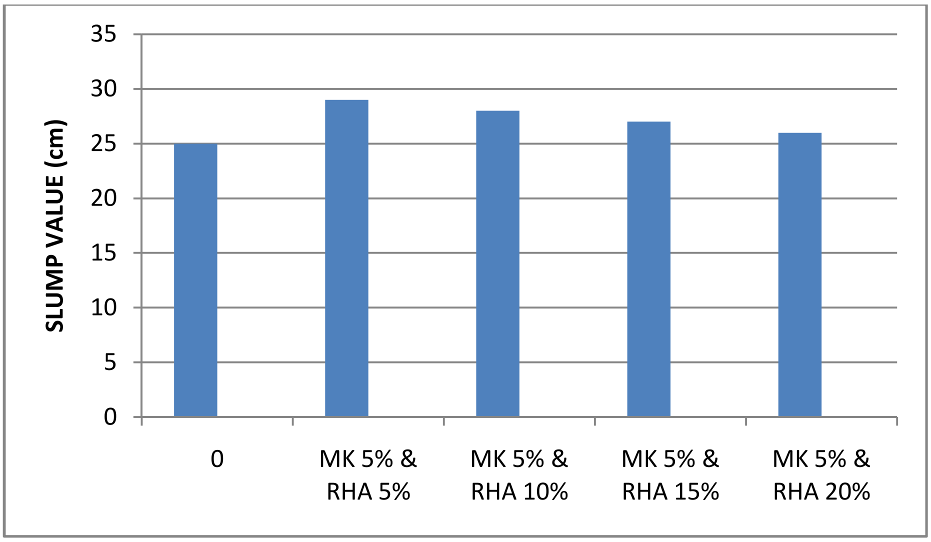

Figure 1: Variation of Slump of Concrete with Different Replacement Levels

Table 7: Variation of Compressive Strength for Different Trail Mixes

Percentage of Replacement	Compressive Strength N/mm^2	
	7 Days	28 DAYS
100% OPC	14.22	22.33
5%MK+ 5 % RHA	19.73	30.75
5%MK+ 10 % RHA	18.93	29.57
5%MK+ 15 % RHA	16.22	27.22
5%MK+ 20 % RHA	15.41	23.13

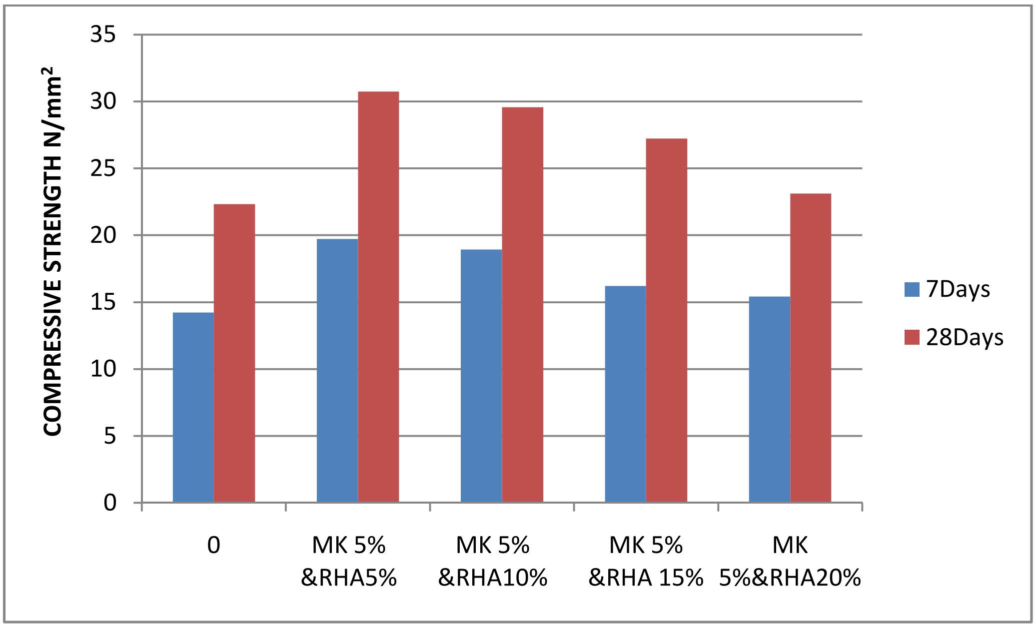

Figure 2: Variation of Compressive Strength of Concrete

CONCLUSIONS

In the present investigation as the w/c ratio is insufficient to provide the good workability, super plasticizers are necessary for the development of standard concrete.

The experimental results show that the maximum compressive strengths for seven and 28 days curing period achieved are 19.73 and 30.75 N/mm^2 respectively with 5% replacement of cement by rice husk ash and 5% metakaolin. Use of Recycled Coarse Aggregates in concrete can prove to be economical as it is non useful waste and free of cost and will eradicate the disposal problem of demolished aggregates.

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