To study the effect of varying proportion of rice husk ash on the properties of fly ash based geopolymer mortar: A Review

Vinay Bajad[1], Dr. Sanjay Sharma[2], Jasvir Singh Rattan[3]

[1]M. E. Scholar, [2]Professor, [3]Senior Technical Assistant, Civil Engineering Department, National Institute of Technical Teachers Training and Research Chandigarh, India

Abstract: Due to the wide use of cement mortar and cement concrete the cost of building materials increasing very quickly in some parts of the world also in developing country like India so only the industries, business cooperation, government and few individuals can afford it. This rising cost can however be reduced by use of alternative building materials that are locally available and cheap. Some industrial and agricultural waste products may be used as building material. There are different wastes available in large quantities that have properties to make concrete and mortar such as fly ash, rice husk ash, blast furnace slag etc. i.e. geopolymer mortar and geopolymer concrete.
The study begins with a detailed literature review on fly ash, rice husk ash, its chemical properties its bonding with mortar or cement and its feasibility in the construction industry focusing firstly on the nature of the scope of the construction industry and the most activities that involve cement mortar and cement concrete operations. Here we will talk about strength of Fly ash and RHA both with cement blending and without cement, environmental impact of cement and its reductions with using Fly ash and RHA.

Keywords: Fly Ash, Rice Husk Ash (RHA), Geopolymer Mortar, Environmental Impact.

I. INTRODUCTION

Mortar comes from Latin mortarium meaning crushed. Cement mortar becomes hard when it cures, resulting in a rigid aggregate structure. However, the mortar is intended to be weaker than the building blocks and the sacrificial element in the masonry, because the mortar is easier and less expensive to repair than the building blocks. Mortars are typically made from a mixture of sand, a binder, and water. Due to the wide use of cement mortar and cement concrete the cost of building materials increasing very quickly in some parts of the world also in developing country like India so only the industries, business cooperation, government and few individuals can afford it. This rising cost can however be reduced by use of alternative building materials that are locally available and cheap. Some industrial and agricultural waste products may be used as building material. There are different wastes available in large quantities that have properties to make concrete and mortar such as fly ash, rice husk ash, blast furnace slag etc. i.e. geopolymer mortar and geopolymer concrete.
The cement has other disadvantages also such as the total production of Carbon Dioxide in world is major concern these days and out of that total carbon dioxide 5-7% of it is produced in manufacturing of the cement. The cement also has disadvantage of Sulphate and alkali attacks. There is another problem in country is waste material. These problems with cement or cement mortar can be reduced if somehow, we reduce use of cement which can be done by using waste products of smaller size that will not only reduce use of cement and help nature but also being small in size it will also reduce Sulphate attacks in mortar as well as in concrete.

Geopolymer is a term originally coined by French researcher Joseph Davidovits to describe a class of ceramic materials formed from aluminosilicates. Geopolymers have been known to provide enhanced physical performance to traditional cementitious binders but with the added advantages of significantly reduced greenhouse emissions, increased fire and superior chemical resistance. Geopolymer cement mortar is inorganic polymer composites which are prospective mortar with potential to form a sustainable element of an environmentally sustainable construction by replacing of supplementing the conventional concrete. Fly ash is generally finely divided residue ash particle resulting from the combustion of coal in the furnaces which blows along with flue gas of the furnace. Theses ash are collected with the help of electric precipitators and termed as fly ash. Fly ash is the most widely used Pozzolanic material all over the world. In UK it is termed as pulverized fuel ash i.e. PFA. Although it is a residue of coal but it contain chemical components like silicon dioxide, Aluminium oxide, iron oxide in major quality and apart from these substance reactive silica, magnesium oxide, sodium oxide, calcium oxide, titanium, lead oxide are also found in major quantity which marks fly ash suitable to be used in combination with cement in the production of concrete.
Rice husk is a byproduct of agricultural waste generated in rice mills. During milling of paddy 80% weight found out as rice and remaining 20% weight received as husk. This husk is used as fuel in industries to generate steams and other purposes. This husk contains about 75 % organic fickle matter and the remaining 25 % of the weight of this husk is converted into ash during the firing process, this ash is known as rice husk ash (RHA). Typically, RHA contains 80 – 90% of amorphous silica, 1-2 % Potassium oxide (K_2O) and remaining being sunburn carbon. The RHA can be blended with ordinary Portland cement to produce concrete. In this present study, Ordinary Portland cement was replaced by rice husk ash at different percentage to find out the suitable percentage of rice husk ash with the help of compressive and split tensile strength.

II. RESEARCH AND STUDIES ON FLY ASH BASED GEOPOLYMER MORTAR

Relevant research work and studies are reviewed here:

R.putra jaya et al. [1] (2016) demonstrates their results of an experimental study taken out on geopolymer mortar containing varying proportions of OPC and rice husk ash. The mortar was subjected to saturated Ca(OH)2 and seawater solution. They prepared three samples at different temperature's i.e. 1000°c white, 800°c grey, 600°c pink with varying proportions of of rice husk ash by 10, 15, 20, and 30% by wt. of OPC binder. Water to binder ratio is 0.45. Samples of size 50.6 mm3 are prepared and cured for 24 hrs. Compressive strength test at 7,28,150 days, FITR spectroscopy test and X-ray diffraction test were performed. White sample with 15% RHA shows higher compressive strength in both saturated Ca(OH)2 and seawater solution. The strength of mortar was found increase as C-S-H increases with the limited amount of Ca(OH)2 available to react with admixture

Zhang and Malhotra [2] (1996) This paper shows results on physical and chemical properties of rice husk ash (RHA), and deals with the properties of fresh and hardened concrete using RHA. The properties of fresh concrete investigated included workability, bleeding, setting time, and autogenously temperature rise, and those of the hardened concrete included compressive, splitting tensile, and flexural strengths, modulus of elasticity, drying shrinkage, resistance to chloride ion penetration, resistance to freezing and thawing cycling, and salt- scaling resistance. The test results shows that the RHA is good Pozzolanic material and can be used as a supplementary binder material to produce high-performance concrete. Although it requires a higher dosage of the super plasticizer and the air-entraining admixture compared with those of the control concrete and the silica fume concrete. The RHA concrete had excellent resistance to chloride ion penetration, and the charge passed in coulombs were below 1000 both at 28 and 91 days. The compressive strength of the concrete containing up to 15 percent of the RHA was higher than that of the control Portland cement concrete. The strength of the concrete increased with decreasing W/(C+RHA). The maximum temperature for the RHA concrete was reached 2 to 3 hours earlier than for the control and silica fume concretes. The RHA concrete had higher compressive strengths at ages up to 180 days compared with that of the control concrete, but lower values than those of the silica fume concrete. The RHA concrete showed excellent performance under freezing and thawing cycling with a durability factor of 98. The resistance of the RHA concrete to deicing salt scaling was similar to that of the control concrete and marginally better than that of the silica fume concrete.

Rukzon and Chindaprasirt [3] (2010) Studied the strength and carbonation resistance of mortar made with Portland rice husk ash cement by some accelerated short-term techniques in 5% carbon dioxide. Three fineness of rice husk ashes, viz., original rice husk ash 'RAO', medium rice husk ash 'RA1' with 15–20% by weight retained on a sieve no. 325 and fine rice husk ash 'RA2' with 1–3% by weight retained on a sieve No. 325. Ordinary Portland cement was partially replaced with RAO, RA1, and RA2. Compressive strength, porosity, and carbonation depth were determined. The result shows that with RA2 the water requirement decreases to a lesser extent as compared to that of the RA0 and RA1. RA2 results in mixes with low porosity and high strength of mortar. With increase in the replacement level of all rice husk ashes, the depth of carbonation increased. Carbonation depth in case of RA2 was less than RAO and RA1. The carbonation depth increased with a decrease in compressive strength and with an increase in amount of water requirement. From the test and the analytical results, it can be concluded in general that the replacement of Portland cement Type I with rice husk ash decreases the compressive strength and increases the carbonation of mortar in comparison with OPC mortar. It was found that the carbonation depth decreases with the increases the compressive strength.

Muthadhi and Kothandaraman [4] (2013) In this paper, four concrete mixtures were considered to identify the effect of RHA on performance characteristics of the concrete. RHA was added as partial replacement of ordinary Portland cement from 10 to 30%. The properties investigated include compressive strength, chloride permeability, water absorption, and sorptivity of RHA blended concrete. Based on the results, it was found that RHA addition up to 20% in partial replacement of ordinary Portland cement lead to increased compressive strength of concrete compared with that of reference mixtures. However, the durability of RHA concrete was on the higher side for all doses compared with the reference mixtures. Rice husk ash proves to be highly reactive Pozzolanic, which contributes to higher strength and improved performance characteristics. Performance characteristics of RHA-blended mixtures show significant improvement up to the 30% RHA level. At the 30% RHA level, the mixtures attained strength comparable to that of respective reference mixtures and showed improved resistance to performance characteristics. Hence, 30% of ordinary Portland concrete can be replaced with rice husk ash without affecting strength and durability properties. Considering the maximum strength, cost effectiveness, and performance characteristics, 20% replacement of cement by RHA addition is found to be the optimum dosage in concrete making.

Shatat [5] (2013) describes an experimental study carried out to investigate the effects of metakaolin and rice husk ash on the hydration behavior and mechanical properties of blended cement. This study shows a positive effect on mechanical properties with use of rice husk ash and metakaolin. The samples consisting blends of cement with 5–10% rice husk ash and 20– 15% metakaolin showed higher compressive strength than the sample with constitutes no amount of rice husk ash. These blends results in the optimum combination for achieving maximum effect. At the early ages of hydration rice husk ash acts as filler whereas at later ages it acts as pozzolana. Increasing rice husk ash content makes a dilution effect, requires higher water demands and forms a layer of rice husk ash particles around anhydrous cement grains which delays the hydration of cement. Accordingly, it is recommended to use the pozzolanic cement mix containing 75 wt% OPC, 20–15 wt% MK and 5–10 wt% rice husk ash, respectively instead of OPC and control cement for general construction purposes. In addition, the utilization of rice husk ash in construction purposes solves the problem of its disposal thus keeping the environment free from pollution.

P. J. Patel et al. [6] (2013) studied Effect of High-Performance Concrete Incorporating Alccofine and Fly ash on compressive and flexural Strength. They achieved very good compressive strength at 90 days. Highest compressive strength achieved was 78.58 N/mm2 for M2 mix more than the targeted strength. In all mix proportions strength achievement up to 7 days is excellent and is comparatively less in 7 to 28 days, but is high between 28 to 56 days because of fly ash. Compressive strength at 28 days is 1 to 12 % less than acceptable standards of Compressive strength as per Table-2, clause 6.2.1 of IS 456-2000. After testing, they concluded that they achieved for all proportions the acceptable flexural strength and by test of beam the maximum flexural strength obtained was of 7.02 MPa in M4 mix (fly ash-20% and alccofine-10%).

Venkatanarayanan and Rangaraju [7] (2015) The effectiveness of unground low-carbon rice husk ash (URHA) as a Pozzolanic and the effect of grinding the URHA to finer fractions for use in Portland cement system were investigated. The properties investigated include the setting time and calcium hydroxide depletion of rice husk ash (RHA) pastes; microstructure and flow behavior of RHA mortars; strength and durability of RHA concretes. Results from this investigation suggested that the URHA and ground RHA (GRHA) mixtures performed better than the control mixtures in all tests conducted except water demand and setting time. The URHA mixture revealed denser microstructure compared to the control mixture. From the studies conducted with URHA mixtures, the addition of URHA in Portland cement mixture at the studied replacement levels increased its normal consistency, initial setting time, final setting time, calcium hydroxide depletion, compressive strength, split tensile strength and flexural strength compared to the control mixtures. From the studies conducted with GRHA mixtures, the addition of GRHA at 7.5% and 15% replacement levels substantially improved all properties of Portland cement mixtures investigated. However for certain properties such as compressive strength, modulus of elasticity and water absorption, significant improvements were not observed beyond 7.5% replacement level of GRHA. The optimum replacement level of RHA evaluated based on flow behavior is substantially higher for GRHA mortars (18%) than for URHA mortars (7%), indicating the beneficial effects of grinding the RHA.

Karim et al. [8] (2013) The aim of the study is to fabricate a new non-cement binder (NCB) using slag, palm oil fuel ash (POFA) and rice husk ash (RHA). To activate these materials, sodium hydroxide (NaOH) was used at 2.5%, 5.0% and 7.5% by weight of NCB. Four different mix ratios of the slag, POFA and RHA were designed to fabricate the NCB. Mortar-prisms of NCB were cast using water-to-binder ratio of 0.5 and 0.6 with required super plasticizer. Mortar specimens were immersed in a water bath at 25 ± 2 C for curing. NCB was tested for its consistency, setting time, flow, flexural and compressive strengths. XRD, SEM and FTIR analyses of NCB mortars were also obtained. The results revealed that the consistency, setting time, flow and strength of NCB-paste/mortars are greatly influenced by the mix proportion and fineness of constituent materials of NCB, and NaOH doses. NCB-mortar containing 42% slag, 28% POFA and 30% RHA with 5% NaOH achieves the highest compressive strength of 40.68 MPa and a flexural strength of 6.57 MPa at 28 days. From the FTIR analysis, NCB-mortars are observed to have silica–hydrate bond with sodium or other inorganic metals (i.e., sodium– silica–hydrate–alumina gel). Therefore, NCB could be fabricated from the aforementioned materials. When slag, POFA and RHA are used in NCB as substitute of cement, the demand of cement is reduced. Therefore, these wastes can be properly disposed by their successful utilization as a non-cement binder.

Sunil Suthar et al. [9] [2013] investigated the Effect of Alccofine & Fly ash accumulation on the properties of High performance Concrete. Indeed ternary cementitious mingle of alccofine, fly ash, and Portland cement proposes significant advantages over binary mixtures and even higher improvement over plain Portland cement. The presence of alccofine enhances the early age performance of concrete while fly ash refines the hardened concrete properties as its strength starts increasing with respect to time. The combination of class F fly ash and alccofine is balancing. Such mixes are in better-quality to plain Portland cement concrete with respect to durability. The presence of fly ash enhances long-term strength improvement of silica fume concrete. Alccofine increase the density which results in the increase strength of concrete. The Fly ash will balance the increased water demand due to presence of silica fume. The accumulation of 8% alccofine to various fine aggregates replacement results in high compressive strength in comparison to 10% silica-fume. This ternary system of alccofine mix concrete illustrates high compressive strength than all other silica-fume concrete mixtures. The optimum value of alccofine is 8%and for fine aggregates is 20% for high strength concrete.

Yatin H Patel et al. [10] (2013) studied consequence of Alccofine and Fly Ash accumulation on the strength and Durability of the High Performance Concrete. In this study, investigations on the effect of local Alccofine as additional cementing materials and filling materials on the strength and durability of concretes. Compressive strength achieved by using Alccofine (8%) + Fly Ash (20%) is 54.89Mpa, 72.97 Mpa, at 28 and 56 days respectively. It helps to reduce voids as its particle size is smaller than cement, which gives higher packing effect so there is increase in strength. Because of more compactness and less permeability of concrete effect of sulphate attack gets reduced. As there is conversion of leachable calcium hydroxide into insoluble non- leachable cementanious manufactured item. Hence, this pozzolanic stroke results in impermeability of concrete. Also, there is reduction in the susceptibility of concrete to attack by magnesium sulphate by the removal of calcium hydroxide. Also because of this property of compactness and lower permeability, effect of alkali gets minimized because of more fineness of mineral admixtures such as Alccofine. Due to its pour filling and pore refining of particle property it is feasible to make M70 concrete having RCPT value lower than 500 coulombs. In Alccofine, RCPT value is lower as per observations

Hwang and Huynh [11] (2016) This study combines various proportions of class-F fly ash (FA) and residual rice husk ash (RHA) with an alkaline solution to produce geopolymers. All of the geopolymer samples were cured at 35 C and at 50% relative humidity until the required testing ages. The effects of the RHA content (0–50%) and of the concentration of the sodium hydroxide (NaOH) solution (8–14 M) on the compressive strength development of the samples were then investigated. X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) were used to examine the microstructural properties of the samples. Further, scanning electron microscopy (SEM) coupled with energy dispersive spectrometer (EDS) was used to characterize sample surface morphologies and compositions. Results found that the samples prepared with a NaOH concentration of 10 M and a RHA content of 35% exhibited the highest compressive strength and that increasing the NaOH concentration and RHA content beyond these values exhibited decreasing compressive strength. The compressive strength of all of the geopolymer samples increased with curing age. Chemical analyses found that the major crystalline phases presented in the resulted geopolymer were quartz, mullite, and cristobalite. Additionally, minor zeolite phases were also detected in all geopolymer samples. Through SEM observation, the geopolymers with 10 M NaOH concentration and 35% RHA showed a denser structure relative to the other samples. The use of FA and RHA as a constituent ingredient in cement is not only cost effective but also facilitates the safe disposal of these solid wastes.

Sai [12] (2017) Shows the results on experiment done on samples made with replacement of cement with rise husk ash (RHA) partially which is an environmental threat is being introduced to concrete mix to reduce the land damage. Concrete mix with different percentages of RHA (i.e., 0%, 5%, 10%, 15%, 20% & 25%) the grade used is M 25 and strength of 7 days and 28 days are determined. Results shows that cement can be replaced with RHA up to range of 0- 15%. It is clearly shown that RHA has the prospective to be used as partial replacement material for cement as it has Pozzolanic properties. The problem of disposal of RHA is reduced. The greenhouse gas emissions can be reduced up to a major extent by replacing OPC with RHA in concrete.

Tulashie et al. [13] (2017) This study investigates the compressive strength of ordinary Portland cement mortar prisms with rice husk ash (RHA). Pit sand–cement, and sea sand- cement mortar prisms were separately prepared using cement-sand mix ratio 1:3, and RHA composition of 0–44.44%. The optimum strength of the pit sand cement mortar prisms after 1, 2, 7, and 28 days was recorded at 11.11% RHA by the mass of the cement. However, the compressive strength of the sea sand-cement mortar prisms with 11.11% RHA decreased on the 7th and 28th day. Thus the inconsistencies in the compressive strength indicate that, sea sand is not a good candidate for constructions. From the results of this study, the highest compressive strength of the pit sand-cement mortar prisms was achieved at 11.11% rice husk additive, indicating 8.4% and 21.2% improvement on the 7th and 28th day. Conversely, 22.22% rice husk ash addition also showed significant improvement (12% and 17.3%) in the compressive strength at 7, and 28 days old. The results suggest that a range of 11.11–22.22% rice husk ash by mass of cement can be incorporated into ordinary Portland cement together with pit sand to enhance the compressive strength. However, the compressive strength decreased at 33.33%, and 44.44% rice husk ash composition, implying that higher ash composition may not be desirable for compressive strength hence the ash must be added in modulation. The results of this study will motivate the cement and construction industries to partly add rice husk ash to ordinary Portland cement to enhance the compressive strength of mortar structures, and also avoid the use of sea sand as a construction material due to its adverse effects on compressive strength, and use pit sand for mortar constructions instead of sea sand.

Mayooran et al. [14] (2017) This study analyzes the feasibility of using high-carbon content rice husk ash waste generated from open air burning of rice husk, as secondary raw materials in the manufacture of cement blocks. Solid masonry blocks having the size of 215 mm × 105 mm × 65 mm, were cast with the mix proportion of 1:5 cement and sand. Blocks were manufactured with two types of rice husk ash (RHA); low-carbon content RHA and high- carbon content RHA. Cement blocks, at four different RHA replacement levels of 5%, 10%, 15% and 20% were prepared for low and high-carbon RHA as partial cement replacement. Testing was included for workability (water/binder ratio and setting time), strength (compressive, flexural bending and splitting tensile) and durability (water absorption, sorption, acid attack resistance and alkaline attack resistance). Results from this test results indicate that the workability, mechanical and durability characteristics of low-carbon RHA cement blocks slightly better than that of high carbon RHA cement blocks. However, both RHA replacement cement blocks satisfy the limit recommended by standards. Low-carbon RHA and high-carbon RHA replacement modified the bulk density and dry density of the cement blocks, making them lighter. Bulk density and dry density decrease more with the addition of low-carbon RHA than with high-carbon RHA. .Durability against alkaline attack and the acid attack was not much affected by the addition of RHA compared with control mortar. The incorporation of high-carbon RHA to cement mortar demonstrated its feasibility to be used in cement blocks production, mainly due to the reasonable performance of the properties studied. In addition, the economic and environmental benefits encourage using high carbon RHA in cement block production.

Christopher, Bolatito and Ahmed [15] This paper presents a comprehensive and up to date review of the work of numerous researchers on structure and properties of concrete containing rice husk ash (RHA) as partial replacement of ordinary Portland cement. Some of the findings are: (i) controlled incineration is required to produce RHA with structure that can result in structural concrete, (ii) the use of RHA resulted in increased water demand, (iii) up to 10% cement replacement with RHA will result in strength development comparable to the control specimens, and (iv) the use of RHA in concrete result in impervious RHA-concrete microstructure to agent of degradation like, Sulphate attacks, chloride ingress, etc., as well as good shrinkage properties, and thus produce durable concrete when used. Only rice husk ash produced to be amorphous and porous, usually obtained at burning temperature of between 600 and 700 0C (by using appropriate incineration method) has potential for use in structural concrete because of the Pozzolanic tendencies of such RHA. The compressive strength of concrete containing RHA depend on the water-cement ratio, but at least up to 10% cement replacement with RHA will result in strength development comparable to the control specimens. The impervious RHA-concrete microstructure to agent of degradation like, Sulphate attacks, chloride ingress, etc., as well as good shrinkage properties, makes it to produce durable concrete when used.

S. Detphan and P. Chindaprasirt [16] studied the burning temperature of rice husk, the RHA fineness and the ratio of FA to RHA. Strength and density of geopolymer mortar samples containing RHA/FA mass ratios of 0/100, 20/80, 40/60, 60/40 were tested. Sodium hydroxide (NaOH), sodium silicate and heat were used as activators. All geopolymer mortars were made with a sand to solid binder (FA+RHA) mass ratio of 2.75. Size of samples was 50mm3 . Fly ash and ground RHA with 1-5% 1%-5% retained on No.325 sieve are suitable source materials for making geopolymer, and the obtained compressive strengths are between 12.5-56.0 MPa and are dependent on the ratio of FA/RHA, the RHA fineness, and the ratio of sodium silicate to NaOH. Sodium silicate/NaOH mass ratio of 4.0, delay time before subjecting the samples to heat for 1 h, and heat curing at 60ºC for 48 h results in higher strength fly ash-rice husk ash geopolymer mortar. Based on the results it can be concluded that combination of RHA and FA can be used to produce geopolymer mortar. Optimum burning temperature is 690°C to produce reactive RHA. The bulk density of the mortar is reduced with an increase in RHA content. The strength of geopolymer mortars slightly decreases with an increase in RHA content as a result of the increase in SiO2/Al2O3 ratio and the increased water requirement of the mixes. The lower strengths are compensated with a reduced bulk density of mortars with high silica content.

III. CONCLUSIONS

Based on the various research carried out by many researchers, it may be concluded that:

• From various research papers, it has been concluded that Rice Husk Ash can be used as a replacement for Fly Ash in Geopolymer Mortar.

• The solution of sodium silicate and sodium hydroxide activates the Calcium Silicate Hydrate gel coexists with the NASH gel (sodium aluminosilicate hydrate gel), leading to a high strength Geopolymer Mortar.

• Various influencing parameter on geopolymer mortar are alkaline solution concentration , sodium silicate to sodium hydroxide mass ratio , curing temperature , curing time , aggregate shape etc.

• Compressive strength increases with increase in concentration of NaOH from 8M to 16M. Increase in compressive strength was observed with increase in curing time . However when curing time was increased from 48hr to 72hr, there was not much variation in compressive strength.

• The compressive strength increases with increase in air curing time from 7 days to 28 days.

• The rice husk ash improve physical and chemical properties of structure i.e. reduction of carbonation, heat of hydration resistant to Sulphate attack etc.

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