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Study on Performance of Ash Based Cementry Matrix

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ABSTRACT: This research is aimed at examining the feasibility of Rice Husk Ash as supplementary cementitious material. In this search, the main variables are the proportion of rice husk ash (0%, 4%, 6%,7%, 8%, 9% and 12%) and cement content. Parameters kept constant are the amount of fine aggregates, coarse aggregates, water, SP content, w/b ratio. The primary aim of this study is to explore the feasibility of using rice husk ash as supplementary cementitious material in SCC by examining its fresh properties, mechanical properties i.e. compressive strength, splitting tensile strength. The test results revealed that the fresh properties were significantly influenced by rice husk ash content. All the results were in range as per code specified. Mix 20RHA showed minimum workability. The increase of about 25% strength at 7 days, 33% strength at 14 days and 36% strength at 28 days were observed with increase oh RHA content from control mix (ORHA) to 15RHA.

KEYWORDS: Rice Husk Ash, Concrete, Compressive Strength

I.INTRODUCTION

In the early era, construction work was mostly carried out with assist of mudstone from industry. Fly ash is a by-product of burned coal from power station and rice husk ash is the by-product of burned rice husk at higher temperature from paper plant artificial fibers are commonly used nowadays in order to improve the mechanical properties of concrete. In the last few years the use of waste material as a replacement of cement in the cement mortar and concrete become very popular in our country. Use of waste products like Rice Husk Ash (RHA), Fly Ash, and Blast Furnace Slag etc. helps in saving the environment because their disposal requires large amount of money and land. Rice husk ash is a waste that is obtained from the separating the paddy from its cover and then burning it. It is used as a replacement of cement in cement mortar and also in cement concrete. The main aim of this project is to check the effects of adding Rice Husk Ash (RHA) in the Ordinary Portland Cement, and to check what is the optimum amount of RHA that can be used in cement mortar without any kind of compromise in the strength of mortar. So this project is a study of performance of cement mortar by based replacement of cement with the Rice Husk Ash. The maximum amount of replacement of Rice Husk Ash in cement is also calculated in this project. Effects of RHA on setting time of mortar is also computed Extensive hard work are being taken globally to utilize natural waste and by –product as supplementary cementing materials to improve the properties of cement concrete. Rice husk ash (RHA) and Fly ash (FA) with using Steel slag is such materials. RHA is by-product of paddy industry. Rice husk ash is a highly reactive pozzolonioc material produced by controlled burning of rice husk. FA is finely divided produced by coal-fired power station. Fly ash possesses pozzolonioc properties similar to naturally occurring pozzolonioc material. The detailed experimental investigation is doing to study the effect of partial replacement of cement by RHA with using in concrete

A. Fly Ash

Residue obtained from the combustion of powdered coal collected by the mechanical dust collector or electrostatic precipitator or separator from the flue gases of thermal plant is called as fly ash.Fly ash is the most widely pozzolanic material in the world.

A.1 Fly Ash Contains

Carbon content in fly ash should be as low as possible.

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Table 1.1: Various Contents of Fly Ash with their Percentage

Sr. No.	Content Name	Percentage
1	Oxides of silicon (SiO_2)	30-60 %
2	Oxides of calcium (CaO)	1-7 %
3	Oxides of aluminum Al_2O_3	15-30 %
4	Un burnt fuel (Carbon)	Up to 30 %
5	Oxides of magnesium (MgO)	small %
6	Oxides of sulphur (SO_2)	small %

A.2 Characteristic of Fly Ashes Connected by Different Collectors

1. Fly ash collected by Electrostatic precipitator (ESP Causes with specific surface 350 to 500 m^3/kg. ESP fly ash collected in chamber I & II is coarse with non spherical surface (particles) showing longer ignition are called as coal ash & not fly ash & not suitable for use as a pozzolana& does not reduce water demand.
2. Fly ash collected by cyclone separator is comparatively coarse and may contain longer amount of un-burnt fuel.

A.3 Effects of Fly Ash

1. Effect of Fly Ash on Fresh Concrete

i. Reduces water demand for desired slump.
ii. Reduces heat of hydration when used as a replacement of cement upto some %age.
iii. Also reduces bleeding & drying shrinkage due to low water content.

A.1:. Effect of fly Ash on Hardened Concrete

i. Due to slower reactivity of fly ash, Initial strength of concrete is less. But on later stage, strength increases and final strength may be greater than concrete without fly ash.
ii. It makes the structure of concrete dense resulting in reduced water permeability & gas permeability.
iii. Fly ash mixed concrete should be coined for longtime as its slower reactivity. So enough moisture required for long time needed for the reaction.

A.2. Effect of Fly Ash on Concrete's Durability

i. One aspect is that due to addition cementitious property of fly ash results in dense structure & gives more resistance to corrosion of reinforcement.
ii. Second aspect is that pozzolanic reactivity reduces the calcium Hydroxide (content) which results in reduction of passivity to steel reinforcement and can produce corrosion in reinforcement.
iii. Both concrete with fly ash and without fly ash, depth of carbonation is same take same concrete compressive strength.
iv. It helps in reducing alkali aggregate reaction became addition of fly ash reduce the expansion due to reduced water permeability due to dense structure of concrete.
v. Hence it improves long term strength & durability & reduces heat of hydration. It is an indispensible mineral and mixture per high performance one.

A.3 High fly Ash Concrete

1.3.1 Advantage of Fly Ash in Concrete

i. Use of fly ash concrete reduces thermal cracking. This is useful advantage of fly ash for durability of Concrete as thermal cracking reduce the water tightness. (Heat of Hydration is important not only in mass concrete such as massive dams. But also in those structure where thickness is greater than 600 mm which produces enough heat of hydration to cause thermal cracking.)

ii. Low permeability to CO_2 & Chloride Ion in HVFA concrete. Since high permeability to CO_2 and chloride ions are responsible for carbonation & corrosion in steel.
iii. Results in improved mechanical properties.

1.3.2 High volume Fly Ash → HVFA Concrete
HVFA concrete is a concrete which incorporate 50 to 60% of fly ash.

1.3.3 Properties of HVFA Concrete
1. **Effects of HVFA on Fresh Concrete**
i. Flow ability with slump 180 mm to 220 mm
ii. Reduction in water content
iii. Slump may be reduced to zero without super plasticizer for roller compacted concrete applications.
iv. Doses of super plasticizer may vary.
v. Bleeding is reduced as after negligible due to low water content and setting time is increased. Increased Setting time is due to lower cement content, lower water content and high content of super plasticizer.
vi. Heat of hydration is reduced to 15°C to 25° C which is less than heat of hydration is conventional Concrete.

2. **Effect of HVFA on Hardened Concrete**
i. Curing should be done for longer period as reaction takes place for longer period which requires enough moisture for longer period.
ii. Excellent Mechanical & durability properties of HVFA concrete.

C.Cement Mortar
Cementmortarisamixtureofcementandsandwithspecificamountofwater.Cementmortaris generallyusedinplastering,bindingthebuildingblockwhichcanbebricks,stonesandanykind of concrete masonryunits.

D. Mineral Admixture
Mineral admixtures are also called supplementary cementing materials. They are used when special performance is needed i.e. increase in strength, water reduction, impermeability, low heat of hydration etc. mineral admixtures are result in cost and energy savings. Environmental damage and pollution is control by the use of the mineral admixtures in concrete. About 6%-7% of co_2 emission is occur from the production of the cement which can be reduced by the use of the mineral admixtures In our project the different mineral admixture that we used are fly ash (FA), rice husk ash (RHA), Steel slag. These mineral admixtures are replaced partially by the 30 % of the total cement.

E. Different Mineral Used are
i. Fly Ash
Fly ash is also known as flue-ash, is one of the residues generated in combustion and comprises the fine particles that rise with the flue gases. Ash that does not rise is called bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants and together with bottom ash removed from the bottom of the furnace is in this case jointly known as **coal ash**. Depending upon the source and makeup of the coal being burned, Constituents depend upon the specific coal bed makeup, but may include one or more of the following elements or substances found in trace quantities (up to hundreds ppm): arsenic, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with dioxins and PAH compounds.
In the past, fly ash was generally released into the atmosphere, but air pollution control standards now require that it be captured prior to release by fitting pollution control equipment. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43% is recycled,[3] often used as a pozzolana to produce hydraulic cement or hydraulic plaster or a partial replacement for Portland cement in concrete production.

ii. Rice husk ash
RHA, produced after burning of Rice husks (RH) has high reactivity and pozzolonioc property. Indian Standard code of practice for plain and reinforced concrete, IS 456- 2000, recommends use of RHA in concrete but does not specify quantities. Chemical compositions of RHA are effected due to burning process and temperature. Silica content in the ash increases with higher the burning temperature. As per study by Houston, D. F. (1972) RHA produced by burning

rice husk between 600 and 700°C temperatures for 2 hours, contains 90-95% SiO_2, 1-3% K_2O and < 5% un burnt carbon. Under controlled burning condition in industrial furnace, conducted by Mehta, P. K. (1992), RHA contains silica in amorphous and highly cellular form, with 50-1000 m2/g surface area. So use of RHA with cement improves workability and stability, reduces heat evolution, thermal cracking and plastic shrinkage. This increases strength development, impermeability and durability by strengthening transition zone, modifying the pore-structure, blocking the large voids in the hydrated cement paste through pozzolonioc reaction. RHA minimizes alkali-aggregate reaction, reduces expansion, refines pore structure and hinders diffusion of alkali ions to the surface of aggregate by micro porous structure. the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO).

II. Literature Review

Following are the some of the studies which were conducted on ricehusk ash as a replacement of cement, ricehusk andricehusk ash:

GODWINA. AKEKE (2012) said in his research an experimental study was conducted on cement concrete to investigate the effects of ricehusk ash on the properties of concrete by replacing the cement partially with RHA.According to there portof the researcher the compressive strength and workability test suggest that the RHA can be used upto25% of the weight of the cement. The results of spilt tensile strength it was concluded that there was no major increase in the tensile strength with the addition of RHA. The flexural strength studies indicate that rice can be used up to10-25%. By using RHA in concrete enhances th equal it ies that make adurable and good structural concrete for long term and short term.

JAYANTIRAJPUT et. al. (2013) shows the results obtained from their study show that the RHA produced from agro waste can be used as partial replacement of ordinary Portland cement in cement mortar pastes. From the test results it can be concluded that if approximately 10%ofcement is replaced by RHA,there is not any kind of noticeable decrease in the compressive strength of the cement mortar. Thus the RHA can be used as partial replacement of cement where it is available easily.

HWANG CHAO-LUNG et al, (2011) founded that compression strength and electrical resistance of rice husk concrete. In this project, they added different proportions of ground rice husk ash such as 10%, 20%, 30% by the replacement of cement. The compressive strength of concretes with up to 20% ground RHA added attain values equivalent to that control concrete after 28 days. Finally they found two this project, compressive strength of RHA concrete and electrical resistance of RHA concrete After 91 days of curing, the electrical resistance of all RHA concrete becomes higher than 20 k X-cm. Similarly, for all RHA concrete samples, the UPV are all higher 3660 m/s after 91 days of curing. The strength efficiency of cement in ground RHA concrete is much higher than that of the control concrete.

V. RAMASAMY, (2011) has studied about the strength and durability properties of concrete with partial replacement of cement by rice husk ash. The paper presents the experimental investigation conducted on Rice Husk Ash (RHA) concrete to evaluate the compressive strength and to study its durability properties. In the preparation of rice husk concrete, cement was replaced at various percentage levels such as 5%, 10%, 15% and 20%. Besides control concrete was also prepared for comparison purpose. Two grades of concrete, namely M30 and M60, were prepared. The strength of the concrete increased with the levels of percentage of replacement of 10% at which the increase in strength was 7.07% at 90 days compared to normal concrete.

SATISH D. KENEL et al, (2011) they have studied on the strength studies of concrete with partial replacement of cement by fly ash and rice husk ash with different proportions. The detailed experimental investigation done to study the effect of partial replacement of cement with RHA and FA on concrete. In this paper I started proportion form 30% FA and 0% RHA mix together in concrete by replacement of cement ,last proportion taken 0% FA and 30% RHA, with gradual increase of RHA by 1% and simultaneously gradual decrease of FA by 1%. They prepared cubes, cylinders, prisms. Finally they found compressive strength, spilt tensile strength, flexural strength of fly ash and rice husk of concrete.

C.MARTHONG, T.P.AGRAWAL (2012) have found strength studies by addition of fly ash to the partial replacement of cement. The utilization of fly ash in concrete as partial replacement of cement is gaining immense importance today, mainly on account of the improvement in the long-term durability of concrete combined with ecological benefits. Three grades of ordinary Portland cement (OPC) namely: 33, 43 and 53 as classified by Bureau of Indian Standard (BIS) are commonly used in construction industry. This paper reports a comparative study on effects of concrete properties when OPC of varying grades were partially replaced by fly ash. The main variable investigated in

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this study is variation of fly ash dosage of 10%, 20%, 30% and 40%. The compressive strength, durability and shrinkage of concrete were mainly studied.

HARDJITO AND RANGAN (2005) worked with fly ash based Concrete and found that the Concrete has a comparable compressive strength and lower modulus of elasticity to that of PC concrete for up to 90 days of their investigation. However, the splitting tensile strength of Concrete was found to be higher than the values recommended by Australian Standard (2009) for PC concrete.

A. Conclusion from Literature

From literature main concluded points areas follow:-

i. Incaseofconcretericehuskashcanbeusedupto20%-25%withoutcompromisingthe strength of concrete.
ii. Therewillbeenhancementinthemechanicalpropertiesofcementmortarandconcrete.
iii. By using ricehuskash initial setting time will be increased.
iv. Addition of ricehusk ash will result is decrease in porosity.
v. Ricehusk ash can added up to 6%-14% in case of cement mortar.

III. Material Use

In every project material and materialistic properties playsa prominent role in determining the properties of final product. Following materials were used in this project:

i. Cement
ii. Sand
iii. Controlled burned ricehusk ash
iv. Uncontrolled burnedricehusk ash

A. Cement

Cement plays an important role in cement mortaritactasabinder. In this project Ordinary Portland cement (OPC) confirming to IS 8112(1989) was used .Manufacturer cement is AMBUJA CEMENT and
The cement was bought from Channo.There is specification provided manufacturer ordinary Portland cement (OPC) OFgrade43.

B. Sand

Sand is a material which exists naturally; it is generally granular in form. Sand constitutes of very fine rock and minerals. Sand provides mass to the mix and also helps in filling the gaps which are present in the mix. Composition of sand depends on the environment and the rock type that is found in the surrounding. Sand is obtained by crushing the stones in crushers and it can also be obtained from rivers. Sand for project was bought from Satgur Stone Crusher, Mubarakpur.Sand was washed thoroughly and the dried. After washing the sand was sieved and then used.

C. Uncontrolled Burned RiceHusk Ash

Ricehusk was burned in uncontrolled conditions.Ricehusk was collected in a pan and burned for 120min.An average uncontrolled temperature was found out to be 450degreeCelsius. Source of ricehusk was Indian Acrylics Limted,Bhawanigarh.After collecting the ricehusk,it was burned in a pan with the help of silica sand. After doing the burning process the ash was collected and sieved. The percentage of ricehusk ash was4%, 6%, 7%, 8%, 9%,12%, lately it was 4%, 8%, 12%. For more accurate results 6, 7&9%were added to it.

D. Controlled Burned Rice Husk Ash

This type of ricehusk ash is obtained by burning the ricehusk in controlled conditions. Generally ricehusk is burnt below800 °C burning husk at this temperature provides ash containing silica mainly in a morphous form. Recently,Nairetal.reported an investigation on the pozzoloniocactivity of RHA by using various methods in order to verify the effect of incineration temperature and burning duration.Hestated that the samples burntat 500°Cor700°C and burned for more than 12 hours produced ashes with high reactivity with no significant amount of crystalline material. The short burning durations(15-360minutes) resulted in high carbon content for the produced RHA even with high incinerating temperatures of 500°C to 700°C. The source of the ricehusk ash was Indian Acrylics Limted, Bhawanigarh.After sieving the ash it was used. The percentage of ricehusk ash was 4%, 6%, 7%, 8%, 9%, 12%.

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IV. Procedures

i. Test performed on cement.
ii. Test performed on sand.
iii. Test performed on ricehusk ash.
iv. Casting of mortar cubes
v. Test performed on mortar cubes.
vi. To determine the mechanical property i.e Compressive Strength of concrete by using mineral admixtures.
vii. To correlate the mechanical property and compressive strength of concrete by using the rice husk.
viii. Mix design of M30

A. Tests Performed on Cement

A.1 Finess Test

IS90 micronsieve was used for finding whether the cement is fine or not. According to Indian standards if the cement retained on 90micron sieve is more than10% then the cement is not desirable for use, and this valueis5%for rapid hardening cement. In this test 200grms of cement was taken for sieving and percentage of material retained on the 90 micronsieve was found out to be 8%which was under the limits provided by Indian standards.
Percentage weight retained =16/200*100 = 8%

A.2Normal Consistency of Cement

It is defined as percentage of water by weight of cement which produces a consistency allowing a plunger of 10mm dia.To penetrate upto a depth of 5mm to7mm above the bottom of vicat's mould. Apparatus used to find the consistency of cement is same as that of initial and setting time testi.e.vicat'sapparatus only difference lies in the plunger diameter. Normal consistency gives the percentage of water to be added for a good mixture. Procedure of finding consistency is as follows: Take 400grms of cement add 100 gms of water and keep on increasing the water to obtain the desired depth of the plunger. The normal consistency of the cement came out to be33%Normal consistency=weight of water/weight of cement×100 Normal consistency=(132/400)×100 =33%

A.3 Initial setting time

Initial setting of cement is defined as per iodelapsing between the time when the water is added to the cement and the time at which needle of 1mmsq. Section fails to pierce the test block to a depth of 5-7mm from the bottom of the mould Take 400 grams of cement,add112 ml of water, make a paste of it and start the stop watch as soon as the water is added to the cement, time taken to mix cement and water or the time taken to make a proper paste should not be more than3min. Place the paste in the mould and smoothen the surface place the needle on the mould just in contact with the surface of cement mortar and allow the free fall of needle. Note down the time when the needle shows the reading 5-7mm from the bottom.
Water required = (0.85*33/100)400=112ml

A.4 Final Setting Time

It is determine donthe same test sample used for initial setting.init1 mm dia.Need leisre placed by a needle with annul arattachment of 5 mm dia.Final setting time is determined as the period elapsing between the time when the water is added to the cement and the time when the test needle makes an impression on the test block while the attachment fails to make it on the first attempt the attachment will be able to make an impression so keep on repeating the steps of making an impression. And note down the time when internal circle fails to make its impression on the block. In this test final setting time came out to be 195min.

A.5 Casting of Mortar Cubes

Mortar of 1:3 was prepared. Which contain one part of cement and 3 parts of sand. Quantity of material for one cube was calculated 800grms which contain 200grms of cement and 600grms of sand. Quantity of water was calculated using consistency of cement. Water required for casting one cube of mortar=(P/4+3)%of total material where P is the consistency of cement. Water required= (33/4+3)%*800=90ml.Cement sand and water were hand mixed and the mix was placed in the cube sinthreelayers in each layer 25blows of tamping rod were given for proper compaction. To eliminate further more air voids the cube was given vibration on the vibration machine. On an average 1min vibration was given. After vibration mortar cubes were allowed to set for 24 hours and after 24hourssettingthe mortar cubes were placed in water tank for curing.

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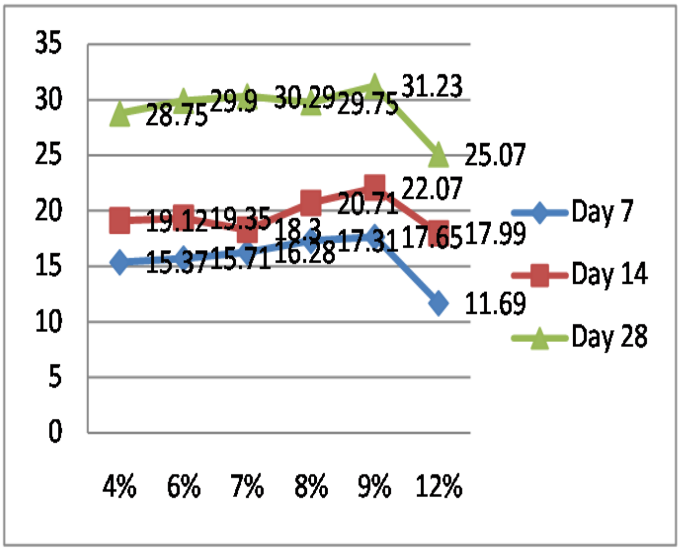
v. Experimental Techniques and Procedures

A. Results Obtained by Testing Cubes with Controlled RHA(7, 14,28Days)



Graph5.1GraphofCompressivestrengthof mortarusingcontrolledburntRHA

Graph shows that from4%-9% there is a rapid increase in the compressive strength of the mortar. After increasing the percentage upto12% there is a decrease in the compressive strength of the mortar.

B.Results Obtained by Testing Cubes with Un-Controlled RHA(7, 14,28days)

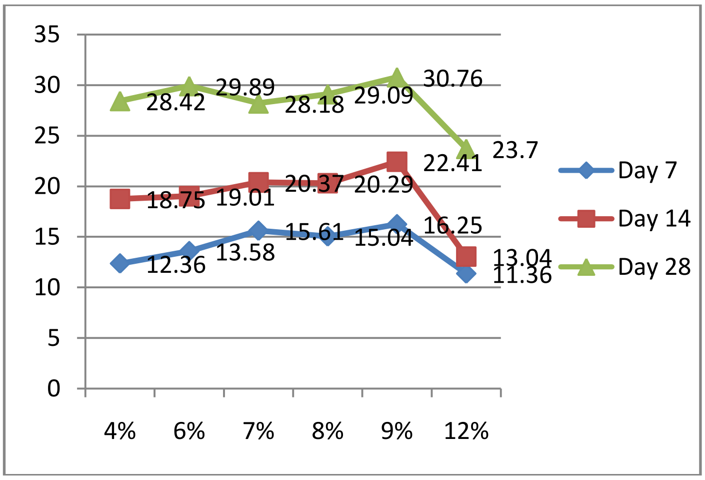


Figure5.2:Graph of Compressive strength of mortar using uncontrolled burnt RHA

Using uncontrolled ash upto 9% gives good values of compressive strength.Butany kind of increase in percentage of ash after 9% strength will be reduced.

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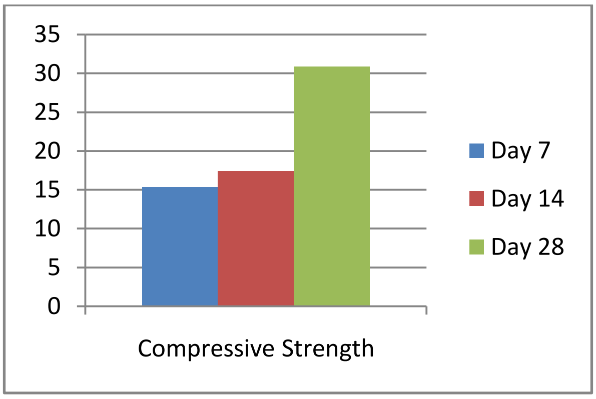
c. Compressive Strength of Standard Mortar(1:3)



Graph5.3:Graph compressive strength of standard mortar

D.Results Obtained From Initial and Final Setting Time

D.1Result Obtained by Adding Controlled RHA

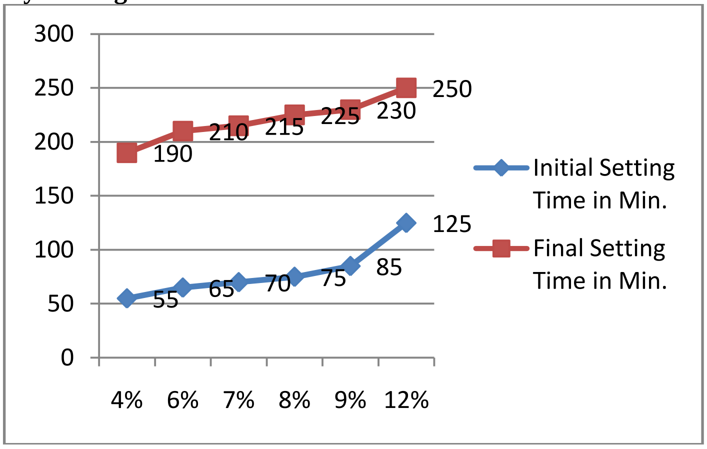


Figure5.4Graphofsetting time of mortar using controlled burnt RHA

D.2 Result Obtained by Adding Uncontrolled RHA

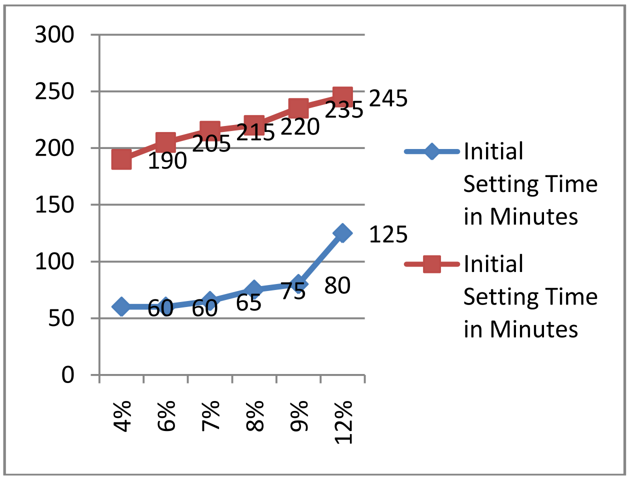


Figure5.5Graphofsetting time of mortar using controlled burnt RHA

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There is an increase in initial setting time with increase in ricehuskash.This effect of ricehusk ash can used in an effective way when mortar mix has to be transported to along distance. As when cement mix has to be transported to along distance an add mixture has to be added to increase its initial setting time therefore by adding ricehusk ash with increase in compressive strength, economy can be obtained as it will be reduce the cost of adding admixture for increasing initial setting time.

VI. Conclusion

A. Sustainability of RHA

Results obtained by the use of controlled burned ash are somehow better than that of results obtained from the uncontrolled burned ash. However the results does not differ that much. The difference between the results obtained were 1-2Mpain most of the samples.Theuseof uncontrolled RHA is also not suitable because burning of ricehusk is not easy and also more cost&time will be consumed. But for better results and for saving time use of controlled burned ash is more preferable.

B. Effect on Compressive Strength

Using ricehusk ash upto an optimum level of 9%results in good compressive strength of cement mortar.Firstly there was a rapid increase in strength of the mortar when percentage varied from 4%-9%,after9% when 12%ricehusk ash was used a down fall in the strength was observed. Using ash upto9% will give good results without compromising compressive strength.

C. Effect on Setting Time

Initial setting time in creased with the increase in percentage of ash whether that's burned under controlled condition or burned under uncontrolled condition. In case of final setting time, it is not affected by the lower percentages of the Ash but as soon as percentage increases final setting time also increases. So both initial and final setting time will be enhanced by adding RHAand increase will depend solely on percentage of RHA added.

D. Summary

The main 0bjective of this study was to study the behavior of concrete and changes in the properties of concrete with steel slag aggregates by replacing the use of natural aggregates. Steel slag is a byproduct and using it as aggregates in concrete will might prove an economical and environmentally friendly solution. The demand for aggregates is increasing rapidly and so as the demand of concrete. Thus, it is becoming more important to find suitable alternatives for aggregates in the future.

A through literature review was conducted to study and investigate the properties of steel slag aggregates. The results showed that it has properties similar to natural aggregates and it would not cause any harm if incorporated into concrete. A comparison was made between concrete having natural coarse aggregates and concrete with various percentages of steel slag aggregates replaced by volume. The results of this research were encouraging, since they show that using steel slag as coarse aggregates in concrete has no negative effects on the short term properties of hardened concrete. Fly ash and Rice husk ash is found to be superior to other supplementary materials like slag, and silica fume. RHA used in this study is efficient as a pozzolonioc material; it is reach in amorphous silica. Due to low specific gravity of RHA which leads to reduction in mass per unit volume, thus adding it reduces the dead load on the structure. Used of Fly ash and Rice husk ash helps in reducing the environment pollution during the disposal of excess Fly ash and Rice husk ash. Cement is costly material, so the partial replacements of these materials by Rice husk ash reduces the cost of concrete.

The study of the research program can be summarized as follows:

1. Compressive strength, flexural strength and splitting tensile strength for steel slag aggregates concrete were more to conventional concrete. The strength may be affected with time and so long term effects on hardened properties of concrete require further investigation
2. The slight improvement in strength may be due to shape, size and surface texture of steel slag aggregates, which provide better adhesion between the particles and cement matrix.
3. Proper care should be taken during the aging of steel slag and during the stockpiling of steel slag.

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4. Split tensile strength decreases as we decreases the % of fly ash and increases the % of RHA
5. Flexural strength increases as we decreases the % of fly ash and increases the RHA
6. We get the maximum split tensile strength and flexural strength when we use the steel slag along with the FA, RHA as a partial replacement of cement.
7. Average compressive strength increases as we increases the % of the fly ash and decreases the % of Rice husk ask maximum compressive strength is occur when we add steel slag along with fly ash and rice husk ash
8. Up to 20% RHA content, strengths of RHA concrete is not much different than the control. Further increase of RHA content decrease the compressive strength due to high water content required to maintain similar workability.

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