USE OF GREEN MATERIALS IN BUILDING CONSTRUCTION

FINAL YEAR PROJECT UG 2013

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This is to certify that the

Final Year Project Titled

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Has been accepted towards the partial fulfillment

of

the requirements

for the award of degree of

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ABSTRACT

Rice Husk Ash was selected as a green material. Two types of RHA were considered and one of them was selected for this study. The RHA was characterized and its effect on the properties of cement, especially strength and shrinkage were studied. Four formulations containing 0, 10, 15 and 20 percent of RHA were prepared for flexure, compression and shrinkage test. All formulations were prepared at their standard consistency. The results indicate that the RHA used in our study was not an effective pozolanic material and had an adverse effect on the strength and shrinkage properties of the cement formulations due to its increased water demand and large particle size.

Dedication

We dedicate this research to our families

Acknowledgement

All praises be to Allah Almighty and powerful. The authors of this thesis acknowledge gratefully appreciate our project advisor Engr. Abdul Basir Awan for his kind guidance and support throughout this research work. During the course of this research we faced many problems regarding availability of material and research papers. We express sincere gratitude to MSc students' engr. Abdul Mujeeb Khan Niazi and engr. Ali Janjua for providing help and encouragement in this regard.

Our profound thanks to Dr, Rao Arslan and Dr. Sayed Ali Rizwan for kind assistance in clearing basic concepts and providing kind guidance regarding the direction of research.

Our thanks are due to the lab staff for creating healthy environment in lab and assistance in our research. We are grateful to NICE administration for financial assistance and maintaining overall healthy environment for our research.

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CHAPTER 1

1 INTRODUCTION

1.1 Green Materials

A green material is supposed to be made with renewable rather than non-renewable products; this suggests that the recycling and resources available in abundance are of utmost importance when considering a green material. Building and Construction industry worldwide consumes over 3 billion tons of raw materials which makes up for about 40 percent of total use of raw materials. This further enhances the concept of using green materials to conserve and save up on the already dwindling resources that are available to us

Green materials and building promote sustainability which means that carbon emissions and the overall effect that harmful gasses have on the environment is reduced to a great extent. Sustainability has two parts to its definition in terms of green building materials, first one suggests the idea of not using the already dwindling non-renewable natural resources and maintaining their availability as they exist, we can guarantee this by finding other alternatives and with recycling the existing products that are going to waste for example saw dust, broken glass or Rice Husk Ask, can be used productively, secondly it suggests that the harmful gasses are kept minimal and the material that has negative effects on the environment is recycled and reused.

Use of green material can have many advantages depending on the way the whole idea of green buildings is implemented:

- They help preserve the environment as using the wasted products that would otherwise contaminate the environment and the raw materials that release less or no harmful gasses will help keep the environment at a healthy level
- They also help conserve energy which means using wasted products would help in reducing the energy required in producing raw products for traditional materials
- They also ensure reduced initial and replacement costs over the lifespan of the building since less energy is being utilized, and initial cost is also reduced as we use SRMs

1.2 Waste Products

Disposing waste has huge impact on the environment and can cause serious health complications. Most of the time the waste generated is dumped into landfills, in dug up holes, or incinerated. Which generates a lot of harmful gasses like methane which is a combustible and also contributes to the degeneration of the environment as a greenhouse gas. Recycling and reusing these wasted products can have a positive effect on the amount of greenhouse gasses and degeneration of the environment.

Recycling materials like paper, glass, wood, plastic etc. can help preserve the environment. And since the construction industry uses about 40 percent of the raw materials being consumed globally recycling or reusing wasted materials in this industry can help contribute towards a healthy society to a great extent.

1.3 Secondary Replacement Materials (SRMs)

These materials generally require less energy when being consumed as a binder in cement. SRMs are supposed to partially replace cement having almost the same binding properties as cement. This is required because the use of cement proves to be very hazardous for the environment, if we consider 1 ton of concrete being produced with 14 percent cement about

180 KGs of Carbon Dioxide is produced which is a greenhouse gas. Generally these materials contain no cementitious properties on their own but once they are mixed up with cement and water they produce compounds that would rather prove to have a cementitious effect. These products can also be industrial by-products. Some of the SRMs are Rice Husk Ash, Silica Fumes, Fly Ash, and Limestone Powder. These products can have a positive or a negative effect on the properties of the cement i.e. permeability, strength, water demand, temperature size, freeze-thaw property, chemical attack resistance, stability and microstructure. SRMs are mostly used with Super plasticizers as they help control the water demand or rather other properties having major effects.

1.4 Research Focus and Objective

The research was focused on selecting an adequate material that would prove to be cheap and available in abundance in the market considering the regional significance on this research. Materials that were considered included RHA, Fly Ash, Silica Fumes, Saw dust, Seaweed, Broken glass. The materials were studied in detail for adequate selection of the most suitable material that would prove to have less carbon emissions into the environment and have a cost benefit as well.

The objective of this study is to choose a suitable green material and study its immediate effects on the properties of concrete and to see if it’s a viable material to be used in the construction industry.

1.5 Materials Considered

1.5.1 Seaweed

According to a study conducted by *C. Dove* from the *University of Starthclyde, UK* Seaweed can be used as an alternate in producing bricks. Since the bricks used are produced by burning in kilns which results in very harmful gasses being emerged into the environment. To make bricks a green material we use Sea weed, which contains Alginate.

Alginate can have different properties depending on where it has been extracted from (specific region of plantation) but it can be tailored to the specific requirements.

Alginate acts as a gelling material in general and since it is available in abundance it contributes to being a green and a sustainable material. When the alginate polymer is added to soil it forms ionic bridging with the calcium contained in the soil increasing the strength of bricks.

The point of significance is that bricks produced with seaweed are not produced by burning, rather they are bound together by the seaweed itself.

1.5.2 Saw-Dust

According to a study conducted by Olubenga Joseph Oyedepo in 2014 **Saw-Dust** can be used as a replacement for fine aggregate in concrete. It is a by-product obtained from wood working industry. It also proves to be cheaper than sand since there is not a lot of demand for sawdust otherwise in the market.

Sawdust concrete is light weight and gives sufficient **Heat Insulation** and **Fire ratings**. When tested for flexure strength it was determined that a concrete containing 25 percent sawdust at 7 days had 1.15 N/mm sq to 1.67 N/mm sq at 28 days. Sawdust has achieved the compression strength of 3000 psi at 28 days.

A phenomenon that's proved to be different than regular concrete is that the failure of sawdust concrete is more like that of a wood, where the fibers try to hold it together. In concrete sawdust helps in gaining the type of structure where it prevents the concrete from total failure upon application of tensile forces.

1.5.3 Broken Glass

For coarse aggregate **Broken Glass** can be used to produce similar or rather better results. Glass is a 100 percent recyclable material, where most of it goes to waste in landfills

Glass concrete has great potential but **alkali-silica reaction (ASR)** might occur in the concrete causing deterioration. Certain suppressants can be used to mitigate this effect, like white Portland cement which has a very low alkaline content

If colored glass is used compression strength of about 40 MPa can be achieved at 28 days.

Another issue with using glass in Pakistan is that it requires a working **recycling system**. This, unfortunately, is not present in Pakistan.

CHAPTER 2

2 LITERATURE REVIEW

2.1 Cement Chemistry

ASTM C-150 defines Portland cement as hydraulic cement (cement that not hardens by reacting with water but also forms a water-resistant product) produced by pulverizing clinkers consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulphate as an intern ground addition.

The setting and hardening properties of concrete are determined by chemical reaction caused after the contact arises between water and cement. The rate of heat of hydration of cement plays an important role in determine concrete strength and durability. On coming in contact with water, Hydration of cement starts. Hydration of cement is defined as "dissolution –precipitation process between binder grains and water".

Major constituents of OPC are tricalicum silicate (C3S), dicalcium silicate (C2S), Tricalicum aluminate (C3A) and Tetra calcium Aluminoferrite (C4AF). These constituents react with water to form hydration products such as main hydration product of C-S-H (Calcium Silicate Hydrate), portlandite (CaOH2), Ettringite (CASH, Calcium Sulfoaluminate hydrate) and calcium monosulphoaluminate C4ASH12). (Lothenbach, B., & Winnefeld, F. 2006).

2.2 Secondary Raw Materials

Waste products or by products of industry. SRMs are not like cement in nature but can be used as partial replacement of cement. Also enhance the properties of concrete. This increases efficiency of industry and reduces production of cement. During lime stone calcination, OPC pastes and mortars are responsible for emission of CO_2. (Lothenbach, B., & Winnefeld, F. 2006).

2.3 Rice Husk Ash

2.3.1 Introduction

Rice is a heavy staple in the world market as far as food is concerned. It is the second largest amount of any grain produced in the world. Rice husk is extremely prevalent in East and South-East Asia because of the rice production in this area.

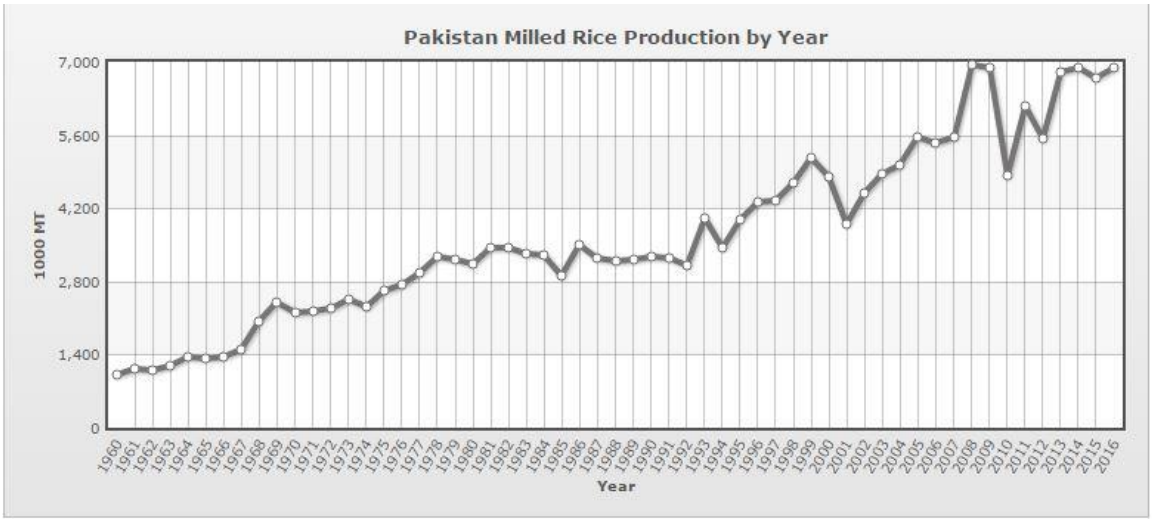


Figure 1. Rice Production

1 MT= 1000 kilograms United States Department of Agriculture

6500 (1000 MT) is Pakistan last five year average production.

2.3.2 Ash

Rice husk ash (RHA) is a by-product from the burning of rice husk.

The rice husk ash is a highly siliceous material that can be used as an admixture in concrete if the rice husk is burnt in a specific manner.

During the burning process, the carbon content is burnt off and all that remains is the silica content.

2.3.2.1 Burning at too high temperature

If the rice husk is burnt at too high a temperature or for too long the silica content will become a crystalline structure due to Cristobalite and Quartz.

2.3.2.2 Burning at too low temperature

If the rice husk is burnt at too low temperature or for too short period of time the rice husk ash will contain huge amount of un-burnt carbon.

2.3.2.3 Optimum temperature

Optimum temperature for burning is 600-700 C.

On above temperature structure is amorphous and carbon content is minimal. (Nick Zemke Emmet Woods June 2009)

2.4 Effect on Concrete Properties

Only 20% by weight of husk is recovered as ash when rice husk is burnt. Of which 75% is silica by weight.

Silica can improve properties of fresh concrete, reduce heat evolution, reduce permeability and may increase strength at longer ages. (Gansen, Rajgopal, Thangavel, 2008)

2.5 Emission of CO_2

CO_2 is emitted during the calcination of cement kiln dust (CKD) in the kiln. CKD is a by-product of the kiln process and a portion of the CKD is placed back in the kiln and incorporated into the clinker

CO_2 is emitted during clinker production (not cement production)

Carbon dioxide (CO_2) is a byproduct of a chemical conversion process used in the production of clinker, a component of cement, in which limestone ($CaCO_3$) is converted to lime (CaO).

CO_2 is also emitted during cement production by fossil fuel combustion. (Michael J. Gibbs, Peter Soyka and David Conneely ICF Incorporated).

2.6 Outcomes

RHA is suitable for Partial replacement of cement in concrete due to high silica content. Use of RHA reduces amount of cement used in construction industry. (Rahmat Madandoust, Malek Mohammad Rajbor, Hamed Ahmadi Mogahdem 2003)

CHAPTER 3

3 METHODOLOGY

3.1 Introduction

Rice husk ash is produced by burning the outer covering of rice. It contains enough amount of silica. Which can be used in concrete to modify its properties. Rice husk is very common waste material in Pakistan. Rice husk ash is chosen for this study because it is concluded from literature review that it will enhance the properties.

The most important property of cement is its binding nature which provides strength. The rice husk ash used in the research, was prepared in laboratory and it was rich with silica (the properties RHA will be discussed in next chapters). As the strength depends upon the amount of calcium hydroxide released from calcium silicate.

The research question concluded from literature review was about strength and shrinkage of cement paste. The research covers the effect of RHA on cement paste with special regards to strength and shrinkage. The reason behind choosing the strength for research is lack of research in the field of simple paste. Author found very few researches comprising the effect of RHA on strength of simple paste.

3.2 Research Hypothesis

Rice husk ash is a secondary cementitious material and it will affect the properties of cement. Current research is done to explore that to what extent the RHA is going to affect the strength and shrinkage of simple paste if its consistency remains constant.

As RHA requires more water for hydration than the control mix. Hypothetically speaking that RHA will increase the water percentage in the paste and this leads towards the reduction of strength and increase in linear shrinkage of system. There is need to find out the shrinkage in the form of linear early shrinkage because it is mostly concern of civil engineer.

The simple paste is chosen for the research because there is lot of concreting going on with the help of concrete pumps and in those pumps the amount of cement is more as compared to the regular mixes prepared. So that amount of cement may lead itself to cracking after going through shrinkage. As only cement is responsible for shrinkage of concrete.

Research is carried out to find that if that Shrinkage will be acceptable when we use RHA in the mix then RHA is going to increase water demand of system. As it is stated in literature review. The more the amount of water in the system the more it will shrink because the overall amount of solids is decreased from a given volume. Shrinkage is mostly measure of amount of volume lost due to hydration or vaporization from the system.

Now the strength is chosen for study too, because varying water cement ratio of concrete effect its strength. The strength of cement paste gives a fair idea of strength of concrete. So we selected the cement paste for study. Moreover there is very less research available on strength of simple paste.

3.3 Conceptual Design of Research Planning

THE scope of this research as defined earlier is limited to the strength and shrinkage of paste and the consistency of system is kept constant.

3.3.1 Materials Chosen

Three materials were chosen for study

- Rice husk ash (prepared in NICE lab)
- Rice husk ash (procured from field)
- Cement

3.3.2 Prepared Rice Husk Ash

Preparation of rice husk ash is a very delicate process and it require immense amount of intention and dedication. We prepared rice husk ash in lab with the help of a Master's student Mr. Abdul Mujeeb Khan Niazi. RHA we used was prepared in NICE laboratory.

The rice husk used for preparation of RHA was acquired from J.B Rice mil Gakkar and it was taken into account that no water came into contact with the rice husk during whole process. The acquired rice husk which was sealed into tight containers was opened and spread over treys and put into oven. It was heated at 120^o C for 2 weeks to make sure that no accumulated water was present within the rice husk.

Dried rice husk was burnt in carbonizer present in NICE. During the burning process rice husk was constantly stirred to make sure that no heat pockets were formed. The maximum recorded temperature was 633^o C. After three hours of incineration, Ash was collected and put into furnace. The temperature of finance was kept at 650^o C. this was done to minimize the carbon content from ash and also to make sure that all of rice husk is burnt. The reason for keeping the temperature range below 650^o C is the reactivity of different forms of silica. If the silica is in amorphous form then it is very reactive and pozolanic. While in case of crystalline silica content the reactivity and pozolanic activity is reduced. The melting point as mentioned in Mehta's research is 800^o C. At this temperature silica present in rice husk is melted and when slow cooling is done then it is converted into crystalline form, which in turn reduces the pozolanic activity the silica present in the powder is checked through XRD that if it is amorphous or not.

3.3.3 Procured Rice Husk Ash

This rice husk ash was procured from rice mill located in Gakkar. In that rice mill rice husk is burnt and heat evolved is used in boiling of water which produces steam and that steam is used in softening of paddy's outer covering.

The rice husk ash is produced as a byproduct during the whole process which is wasted or disposed of in the environment which causes pollution. We collected sample and checked the morphology as well as the quantity of silica content.

3.3.4 Cement

Cement we used was acquired from Askari cement factory and this was OPC grade 53 cement. It was packed into the sealed containers and no water came into contact during the whole process of transportation to minimize margin of error due to changing humidity.

3.4 Tests Performed

Following tests were performed on the cement paste.

3.4.1 Consistency Test

For consistency there are two approaches which we can follow which we can follow

1) ASTM C187
2) B.S 12 :1978

The ASTM C187 exhibits fairly good results so we decided to choose it.

The main reason for choosing it is that we tried both of above mentioned procedures but ASTM C187 Gave value of consistency of simple paste at 26 % and other One Exhibited the results at 27% water.

The main difference in both of those methods is of mixing regime.

For mixing of paste Hobart mixer was used.

Figure 2. Hobart Mixer

Figure 3. Hobart mixer two different angular velocities

This mixer has capacity of variable angular velocities. The powder is mixed with water at two different angular velocities.

First slow mixing is done then after fifteen seconds of wait fast mixing is done. It mixes the system fairly well. Many researchers have used this mixer to find out percentage of water required for consistency.

3.4.2 Strength Testing

The strength of specimen was measured by ASTM C348 and C349. The main reason for choosing this method was that, this method gives values of flexure strength of cement as well as compressive strength of cement. This can be done by breaking the prism in two for flexure strength and now both of these pieces give compressive strength. The machine used for this purpose is available in the NICE laboratory.

Figure 4. Flexure and Compression Testing Machine

The strength of samples was measured at 7 days, 14 days, and 28 days because with time the hydration of cement proceeds and there is need to find out the strength at different time intervals.

3.4.3 Shrinkage Testing

The shrinkage of four samples was measured in shrinkage apparatus present in NICE laboratory. The samples were prepared in Hobart mixer and placed in the channels containing neoprene sheet. This apparatus is self-recording and results are fairly reproducible.

Figure 5. Shrinkage Apparatus

Linear early shrinkage was measured for all the samples and graphs were plotted in Microsoft excel after collecting data from shrinkage apparatus.

The reason behind using this instrument is that it gives linear early shrinkage of system. This is total change in length of system in the given period. It includes autogenous shrinkage as well as drying shrinkage. In the field our main concern for shrinkage is due to the fear of cracking. Cracking is produced due to the total shrinkage. Therefore we used shrinkage apparatus to measure linear early shrinkage.

3.5 Samples Prepared

The following samples were chosen with respect to every test mentioned.

3.5.1 Consistency Test

4 samples were prepared for consistency. One was control sample and other three were containing RHA. The amount of RHA replaced in samples was 10%, 15% and 20% of the weight of cement powder.

Sr. No.	%RHA	%Cement
1	0	100
2	10	90
3	15	85
4	20	80

Table 1. RHA Replacement in Cement for Consistency.

3.5.2 Strength Testing

The details of sample formed for strength testing is as following. Sample was kept in curing tank for the desired period.

%RHA	No. of samples	days
0	3	7
		14
		28
10	3	7
		14
		28
15	3	7
		14
		28
20	3	7
		14
		28
Total		36 samples

Table 2. Samples Chosen for Strength Testing.

Compression as well as flexure testing is done at the same prism.

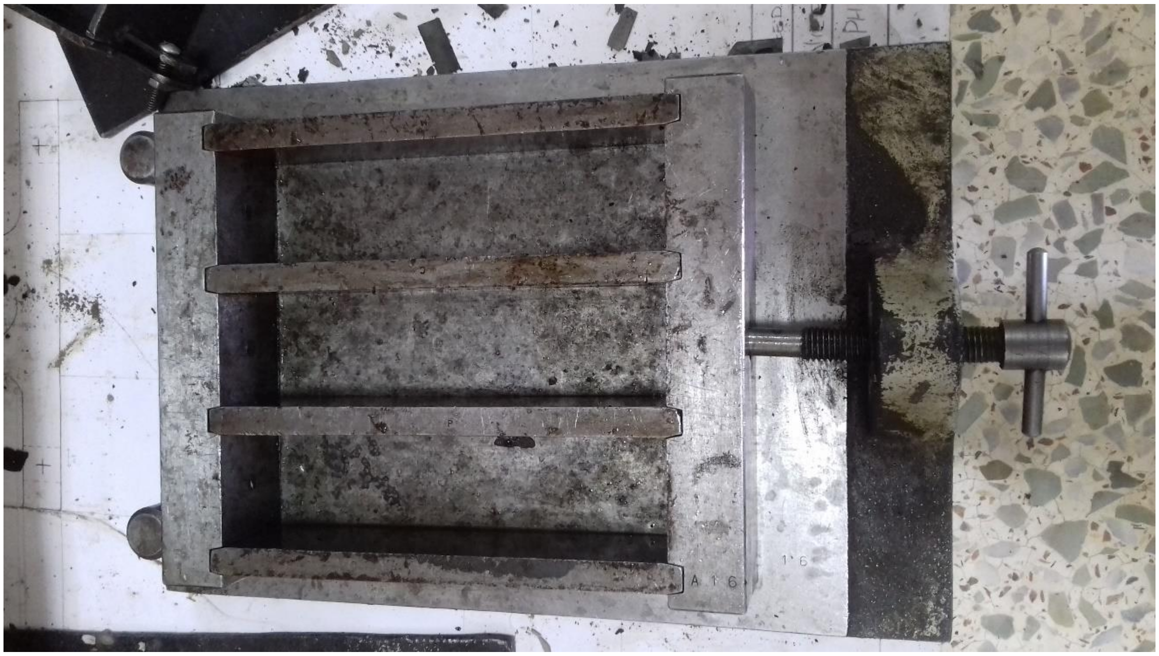


Figure 6. Prism Molds

3.5.3 Shrinkage Test

For measurement of linear early shrinkage only 4 samples were made.

Sr. No.	%RHA	%Cement
1	0	100
2	10	90
3	15	85
4	20	80

Table 3. RHA Replacement in Cement for Shrinkage Testing

The shrinkage of every sample was measured at least for 40 hours because after that time period the graph is nearly parallel to the x-axis.

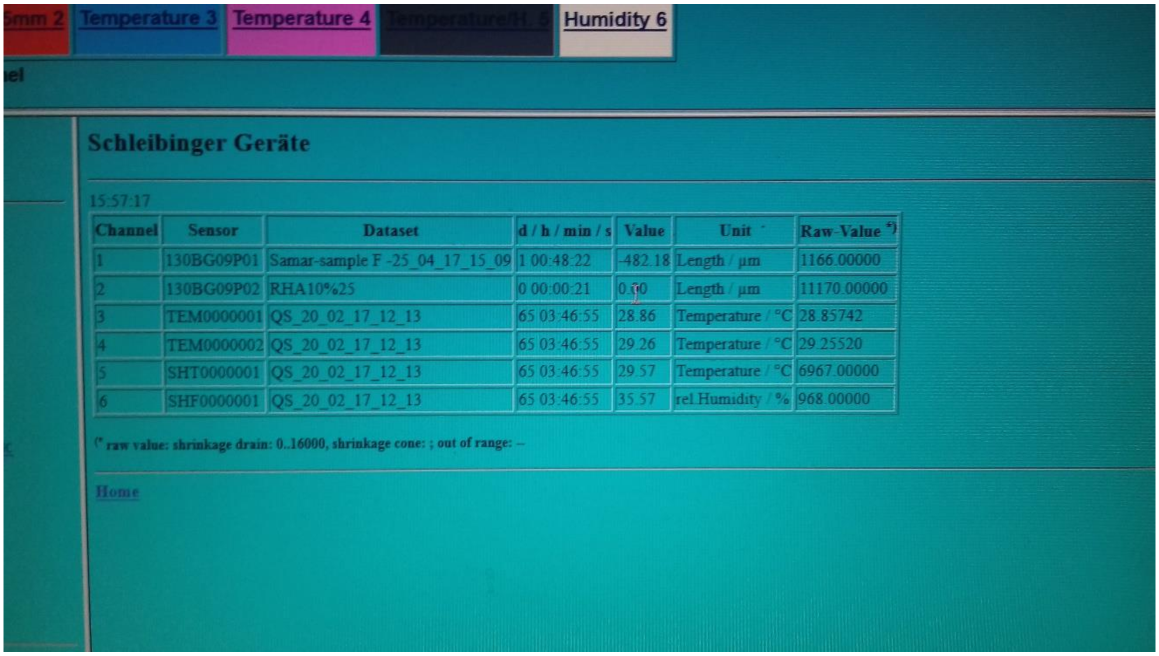


Figure 7. Auto Data Collector's Settings for 10% RHA Sample.

The actual graphs and calculations will be given in next chapters.

3.6 RHA Powder Analysis

For the analysis of RHA, XRD and XRF of powder were carried out.

XRD gives the morphology of powder. The powder should be amorphous in order to react with the cement. The amorphous silica produces calcium silicate. Crystalline silica is less reactive.

XRF is called x-ray fluorescence. It used to check the quantity elements present in the RHA powder.

3.6.1 Procured RHA from Field

To apply the research to field we firstly need to know the morphology and element analysis of RHA procured.

The RHA produced in the boilers of Lahore rice mills was collected. In the boilers, rice husk is burned and heat is transferred to water. The waste material is RHA which is deposited to the open environment and it causes air, water and soil pollution.

The XRD and XRF analysis of this RHA was carried out and results will be discussed later.

3.6.2 Particle Size Analysis

The particle size analysis was done and this gave idea about the reactivity of powder.

As the literature review concludes that finer the powder RHA, more reactive will it be.

Particle size analysis also helped in further interpretation of results.

3.7 Factors and Their Introduction

Temperature and humidity are two major factors playing role in the strength and shrinkage of paste. The apparatus for measuring these values is installed right next to the shrinkage apparatus and values were recorded.

The strength of paste is affected by the water demand of powder. The water demand of powder is increased with the increase of amount of RHA in the system. This increase of water demand means that strength of paste will be reduced.

The percentage of RHA replaced was also kept variable because we wanted to examine the effect of varying percentages of RHA for replacement in cement. As mentioned earlier RHA replaced was 10, 15 and 20 percent of cement weight.

3.8 Pilot study

The method of research we chose was described earlier and few alterations can be done without changing the scope of project.

First of all water demand can be kept constant and super plasticizer can be introduced in the system to achieve desired consistency. This led to the actual happening in the procedure and super plasticizer was introduced in sample which led to the random change in the system and when curing was done the sample got dissolved in the curing tank. That’s why we decided to stick our research to the simple paste and no SP was introduced. The consent of supervisor was also present in the decision.

The study could have been carried out on mortar instead of paste but as mentioned earlier we defined our scope to only paste also a lot of research is available on mortar but nearly no research is available on paste.

Literature review gives us the idea that most of researchers believe that 10-20 percent of RHA replacement is optimum for concrete. Therefore we chose these percentages.

The study could have been carried out with the varying particle sizes of RHA powder but due to the limited time and resources this was not feasible.

Data of strength was collected by compression testing machine. It gave load and strength of specimen, both in compression as well as flexure.in case of shrinkage auto data collector software was used which takes readings after every 60 seconds.

The consistency was measured through vicat apparatus and no digital method was used. This method also gave reproducible results.

XRF graph was collected from askari cement factory. XRD graph was collected from chemistry lab of QAU. PSA data was also in the form of graph.

The analysis of raw data was done by making graphs of data and comparing those graphs. Which gave fair idea about conclusions. The details are mentioned in next chapters.

CHAPTER 4

4 RESULTS AND DISCUSSION

4.1 Particle Size Analysis (PSA):

Particle Size Analysis is performed to obtain information about characteristics like Mean Size, Variance and standard deviation of a material. This gives us an insight about the reactivity and its effect on the microstructure of the formulation.

PSA was performed on both the cement sample and the Rice Husk Ash (RHA) sample to obtain the distribution graph and the mean size. The results are presented below.

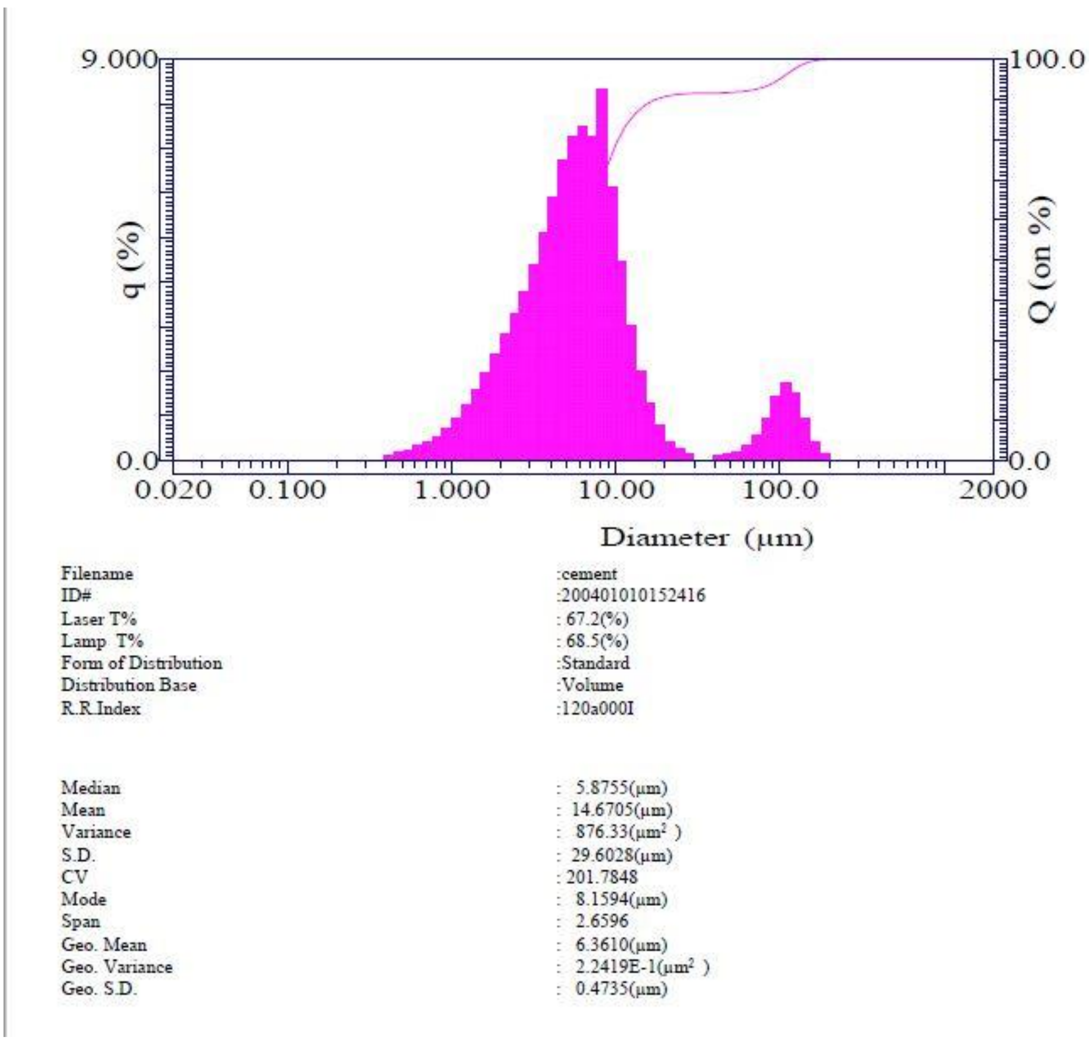
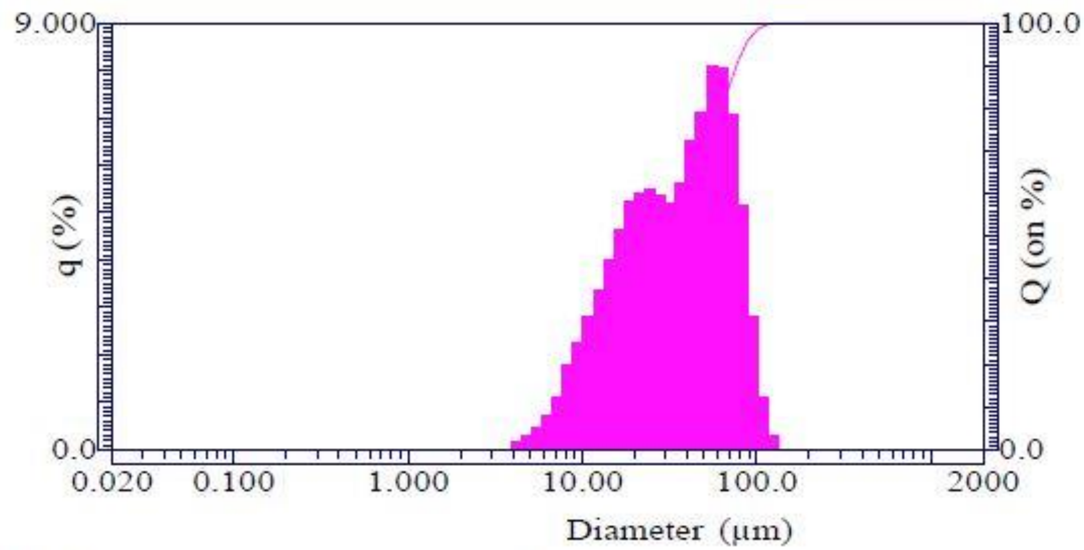


Figure 8. Particle Size Distribution of Cement



Filename	:RHA
ID#	:200401010159417
Laser T%	: 95.9(%)
Lamp T%	: 97.9(%)
Form of Distribution	:Standard
Distribution Base	:Volume
R.R.Index	:120a000I
Median	: 35.7373(µm)
Mean	: 40.4925(µm)
Variance	: 630.32(µm^2)
S.D.	: 25.1061(µm)
CV	: 62.0019
Mode	: 55.5338(µm)
Span	: 1.8073
Geo. Mean	: 32.3569(µm)
Geo. Variance	: 9.5942E-2(µm^2)
Geo. S.D.	: 0.3097(µm)

Figure 9. Particle Size Distribution of RHA

The results show us that the mean size of the cement used in our study is 14.7µm while that of the RHA used is 40.5µm. Generally it is preferred to have a fine pozolanic material to increase its reactivity and enhance the microstructure of the formulation but this has adverse effect on the water requirement and shrinkage of the formulation. Moreover the literature review showed that RHA may have a mean size ranging anywhere from 10µm to 50µm.

4.2 X-ray Fluorescence (XRF):

This test is used for the chemical analysis of a material. It gives us the percentage of certain compounds present in the specimen under consideration.

There were types of RHA initially available. The first one will be referred to as 'Field RHA' as it was procured from a rice mill where the husk was burnt as a fuel to heat water. The second one will be referred to as 'Prepared RHA' as it was prepared by a PG student in NICE under controlled conditions.

The compound of interest in RHA is SiO_2 as this compound in its amorphous form gives RHA its pozolanic properties. Ideally the amount of SiO_2 should be in the range of 80-98%.

But both samples of RHA do not fall in this range. Especially the Field RHA has only 59.65% SiO_2 which shows that there are other impurities, chiefly unburnt carbon, present in it due to its uncontrolled burning. The RHA prepared at NICE, although has a better proportion of SiO_2 but due to limitation of the equipment present, high amounts of SiO_2 could not be obtained.

Compound	Value	Unit
SiO_2	19.97	%
Al_2O_3	5.37	%
Fe_2O_3	2.91	%
CaO	64.9	%
MgO	1.54	%
K_2O	0.83	%
Na_2O	0.18	%
SO_3	2.25	%

Table 4. XRF of Askari Cement

Compound	Value	Unit
SiO_2	59.65	%
Al_2O_3	0.68	%
Fe_2O_3	0.04	%
CaO	1.38	%
MgO	0.21	%
K_2O	0.9	%
Na_2O	0.07	%
SO_3	0.17	%

Table 5. XRF of Field RHA

Compound	Value	Unit
SiO_2	71.23	%
Al_2O_3	1.29	%
Fe_2O_3	0.76	%
CaO	1.94	%
MgO	3.85	%
K_2O	2.82	%
Na_2O	1.43	%
SO_3	0.32	%

Table 6. XRF of Prepared RHA

4.3 X-Ray Diffraction (XRD):

XRD gives us information about the Morphology and phase detection of a material. The broader the peaks, the more amorphous the material. Below are the results of XRD of both RHA samples.

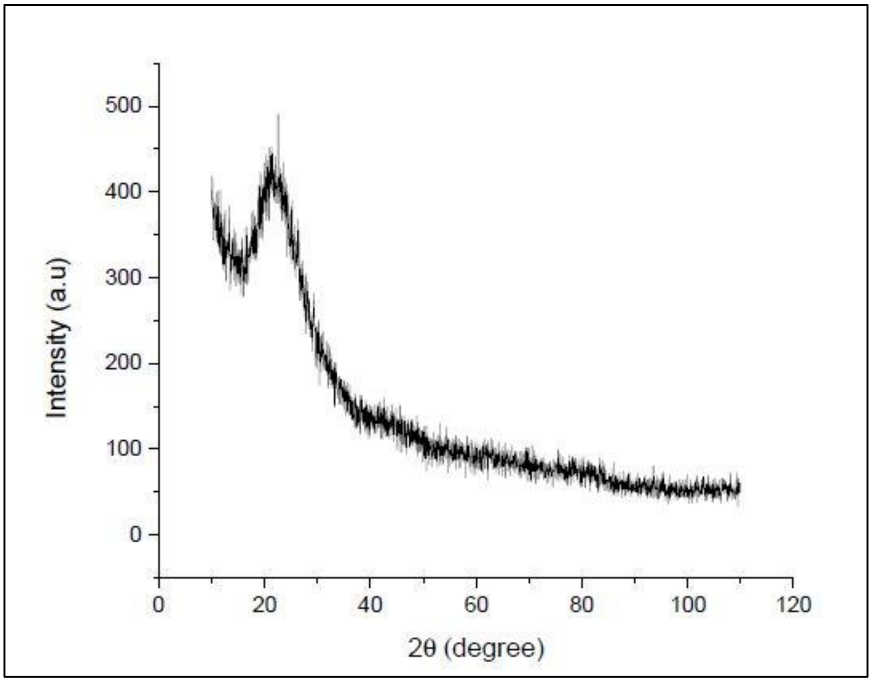


Figure 10. XRD of Field RHA

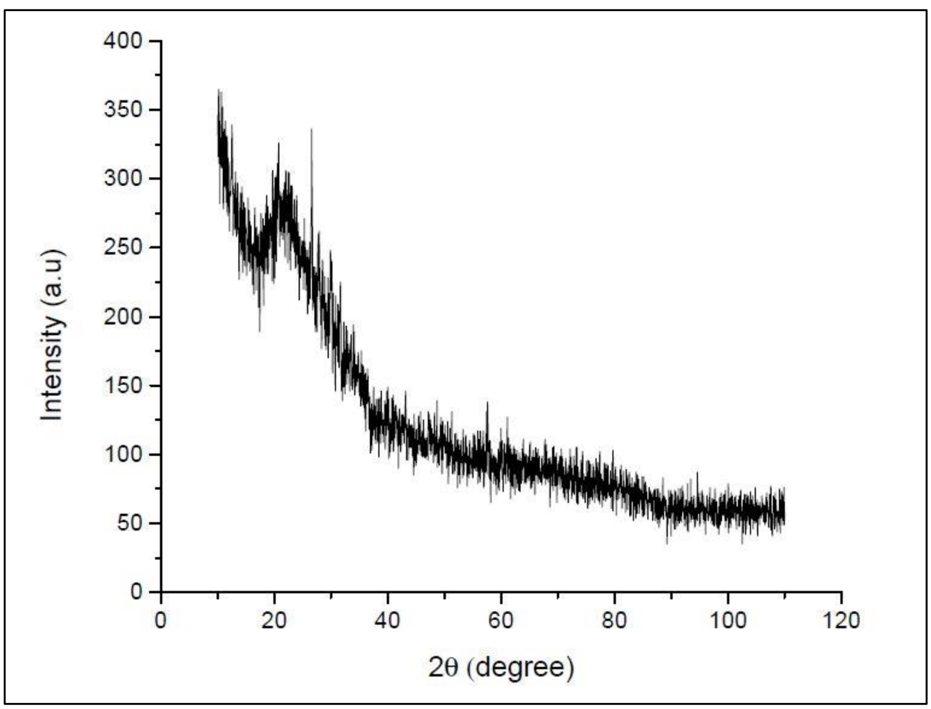


Figure 11. XRD of Prepared RHA

For proper pozolanic reactivity of RHA the SiO_2 present should be of the amorphous nature as crystalline SiO_2 does not react with the cement reactants and only acts as a filler material.

Both samples of RHA show similar broad characteristic peaks at 22° signifying their amorphous structure. Though it can be observed that the field RHA sample shows a more intense peak as compared to the prepared RHA signifying more crystalline SiO_2 present in the field RHA.

4.4 Consistency Test:

The consistency test conforming to ASTM C-187, gives us the amount of water to cement ratio to be used for further tests including flexure test and compression test. Moreover it gives us a measure of 'workability' of the formulation. Workability is broadly defined as the ease with which the cement paste can be applied or the 'flow ability' of the cement paste.

The table below shows the standard consistency of our four formulation.

% RHA	Standard Consistency
0	0.26
10	0.35
15	0.4
20	0.46

Table 7. Relationship between RHA replacement and Consistency

It can be clearly observed that the percentage replacement of RHA has an adverse effect on workability, i.e. more water is required to achieve the same amount of workability as more RHA is replaced with cement.

The Graph below show the relationship between amount of RHA replacement and the standard consistency.

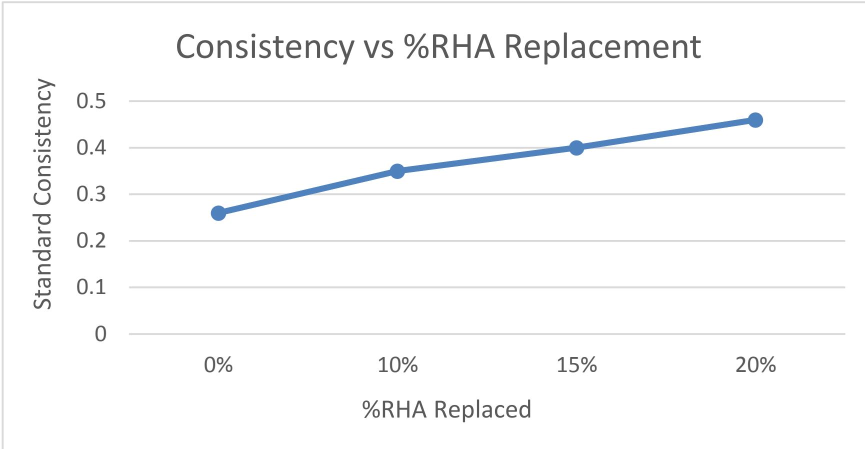


Figure 12. Relationship between Consistency and amount of RHA replacement.

The relationship between RHA replacement and the standard consistency is close to linear. This increase in water requirement is consistent with other studies conducted on RHA. This may be attributed to the higher surface area of RHA and its reactivity which consumes more water early in the hydration process.

4.5 Compressive Strength Test

The compressive strength test was conducted in accordance with ASTM C-349 on broken prism samples. Each formulation had 3 samples which were broken into 2 giving us a total of 6 samples for each formulation. The average compressive strength was calculated and is tabulated below.

% RHA	Days	Strength (Psi)
0	7	7769.58
	14	10133.33
	28	11550.48
10	7	4029.31
	14	6208.33
	28	6601.87
15	7	3724.08
	14	5258.18
	28	5892.61
20	7	2689.34
	14	3690.25
	28	4426.85

Table 8. Compressive Strength of Formulations

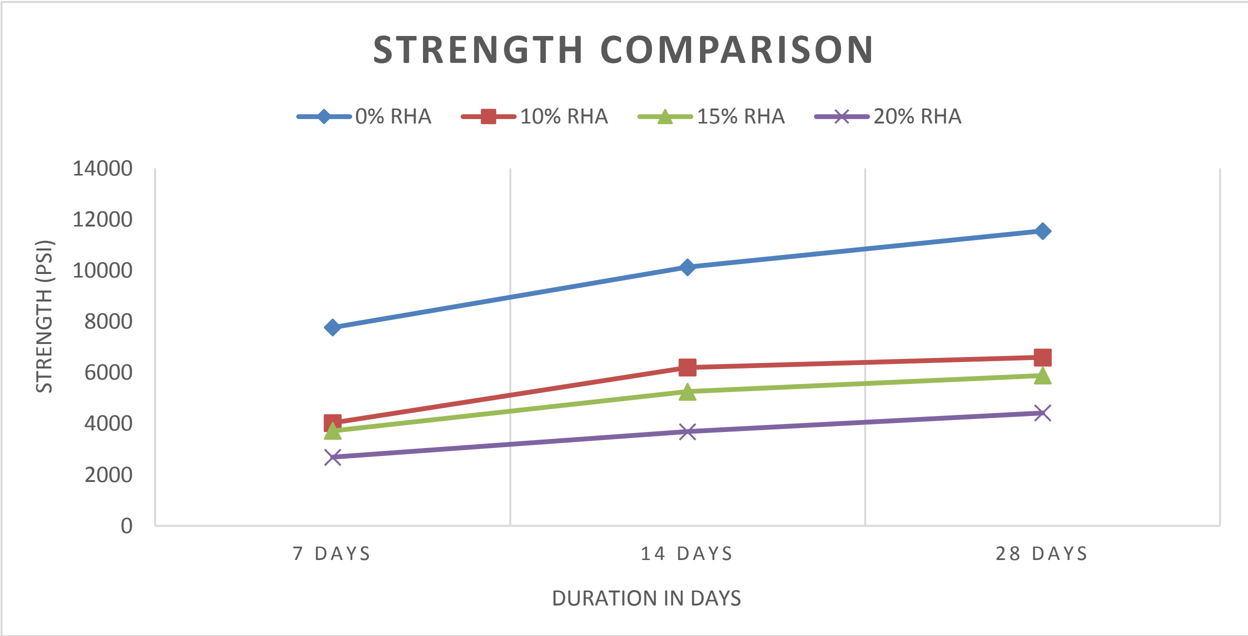


Figure 13. Strength Comparison of Formulations

It can be observed that the initial addition of 10% RHA drastically reduced the strength of the cement paste. This is mostly attributed to the higher amount of water present in the RHA formulations which is a consequence of the inherent increased water demand of the RHA formulations.

Moreover, another factor which may have reduced the strength further is the difference in size of RHA and cement particles. Smaller particles have been shown to enhance the strength of the formulation.

Our results are consistent with other results which show lower early strength development in RHA samples.

The difference in strength between 10% RHA and 15% RHA is relatively small when compared between other formulations. This seems to be the sweet spot between amount of RHA Replacement and strength.

4.7 Linear Shrinkage Test

Linear shrinkage gives us information about the volume changes in the specimens. The greater the volume changes, the more adverse effect it has on the formulations. Below is a comparative graph of the Shrinkage in the various formulations.

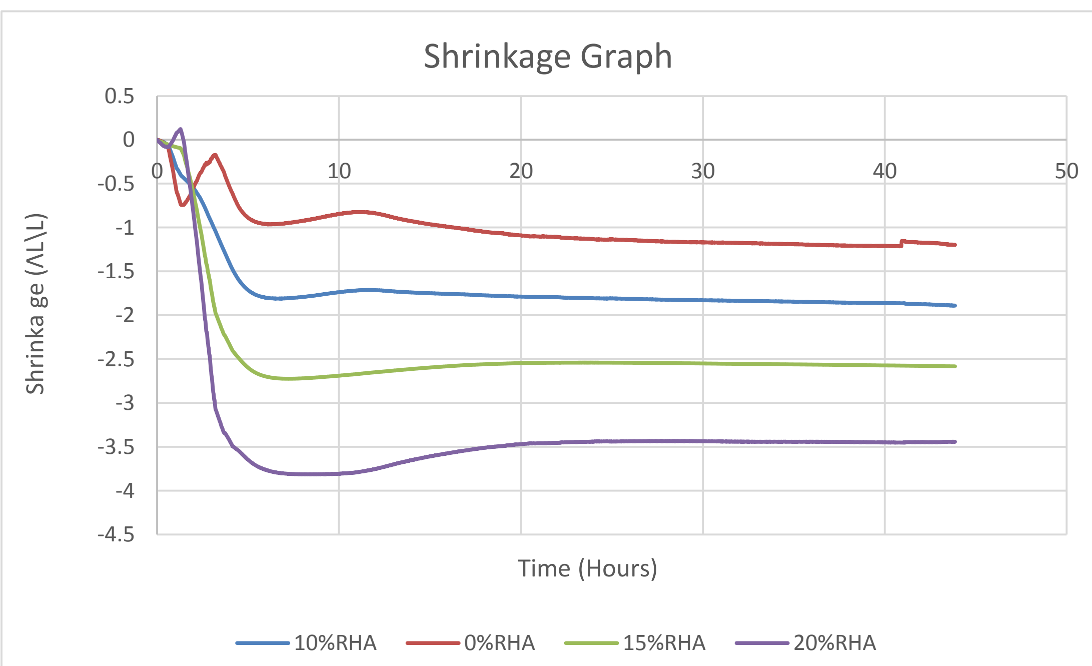


Figure 14. Shrinkage Comparison of Formulations

It is a known fact that shrinkage increases with increasing amount of water. It can be seen that with the increase in amount of replacement of RHA, the shrinkage of the formulation increases as well. This is due to the fact that the amount of water is greater in formulation with RHA present. It should be noted that there is no drastic increase in shrinkage in the 10% RHA formulation compared to the control sample with no RHA as opposed to the drastic decrease in strength observed with 10% RHA sample. This may hint towards better shrinkage performance of RHA if the amount of water is kept the same. But in its original form, RHA drastically increases the water requirement hence leading to greater amounts of shrinkage.

CHAPTER 5

5 CONCLUSION

The following conclusions can be drawn from the research undertaken:

- The preparation of RHA is a delicate process as it requires controlled temperature. Moreover the current infrastructure present in Rice mills is inadequate to produce amorphous as well as carbon free RHA.
- RHA drastically increases the water demand of formulations. There is an approximately linear relation between amount of RHA replaced and the water demand.
- Due to the inherent property of RHA to increase water demand, it significantly reduces the strength of cement formulation. This eliminates the use of RHA in high strength concrete.
- With increasing RHA replacement, the shrinkage of the formulations increases. Though this increase is rather linear and not abrupt or drastic as compared to the decreased strength in RHA samples.
- RHA slows the rate of strength gain i.e. RHA is unsuitable for applications requiring early strength.

RECOMMENDATIONS

We suggest the following recommendations to make RHA a viable cement replacer:

- As w/c in concrete is kept high (0.4-0.6) further Studies have to be conducted on concrete itself to test if RHA provides sufficient strength to be used as structural concrete.
- The major problem with RHA is its requirement of greater amounts of water compared to cement. If the water demand of RHA can be reduced its strength will increase significantly.
- Refinement in RHA production is required to increase its pozolanic activity and in turn make it a viable material to be used in cement.

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