PARTIAL REPLACEMENT OF CEMENT WITH RICE HUSK ASH AND GROUND GRANULATED BLAST FURNACE SLAG IN SCC

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by

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DECLARATION

I, Nemeyabahizi Jean Bosco (Regd. No.11110201), thusly proclaim that this thesis report entitled " **Partial Replacement of Cement with Rice Husk Ash and Ground Granulated Blast Furnace Slag in SCC** " submitted in satisfaction of the prerequisites for the honor of level of Master of Civil Engineering, in the School of Civil Engineering, Lovely Professional University, Phagwara, is my own work. This matter typified in this report has not been submitted to some extent or full to some other college or establishment for the honor of any degree.

Date **Nemeyabahizi Jean Bosco**

Place

CERTIFICATE

Certified that this project report entitled "**Partial Replacement of Cement with Rice Husk Ash and Ground Granulated Blast Furnace Slag in SCC**" submitted individually by student of School of Civil Engineering, Lovely Professional University, Phagwara , carried out the work under my supervision for the Award of Degree. This report has not been submitted to any other university or institution for the award of any degree.

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ABSTRACT

Self-compacting concrete (SCC) is concrete which has a very low yield stress, great deformability, and average viscosity (which is able to ensure uniform suspension of solid particles in transportation, placement time without using external compaction). SCC is the most High Performance Concrete with very good strength and durability properties. But, the mix proportioning and testing methods for flow properties are very different from those of the normal concrete. SCC is a type of concrete which has ability to flow under its own weight and completely fill the form work, without vibration effect, and at the same time cohesive enough to be handled without bleeding. It ensures proper filling and good structural performances of restricted areas and heavily reinforced structural members. SCC usually requires a large content of binder and chemical admixtures

In beginning 21st century, the construction industries have gain momentum. The big international and national project has increased significantly around the globe. The self compacting Concrete due to its high strength, workability, durability and less number of labors. SCC has gain momentum in that project and high demand of cement is increasing every day.

Searching alternative materials with similar properties as cement are very important aspect for engineers. RHA and GGBS are one those material and they are used as admixture. The usage of mineral admixtures in the production of SCC not only provides economical benefits but also reduces heat of hydrationIn this work, the primary factors are the extent of rice husk powder (15%, 20%) and bond content. Parameters kept steady are the measure of fine aggregate , coarse aggregate , water, SP content, w/b proportion. I will the extent of GGBS(5%,10%,15%,20%).

The essential point of this review is to investigate the achievability of utilizing rice husk cinder as supplementary cementitious material alongside GGBS as expansion material in SCC by inspecting its fresh properties, hardened properties.

The test results revealed that the fresh properties of SCC were significantly influenced by the incorporation of RHA and GGBS. All the results were well within the range Specified by the code. Using of RHA and GGBS as replacement of cement does not affect the strength properties negatively as the strength remains within limits up to 30% of binder material but start decrease when replacement goes up 40% of binder . Overall the hardened properties has seen as enhanced when cement replaced by combination of 15%RHA and 15%GGBS

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LIST OF ABBRIVIATIONS AND SYMBOLS

RHA- Rice Husk Ash

GGBS – Ground Granulated Blast Furnace Slag

SCC- Self compacting concrete

OPC - Ordinary Portland cement

mm - Millimetre

SP - Superplasticizer

N/mm2 - Newton per millimetre square

KN - Kilo Newton

min - Minute

sec / s - second

MPa - Mega Pascal

w /b - Water /binder

Kg/m3 - Kilogram per metre cube

% - Percentage

SCC0% - Mix with 0% RHA and 0% GGBS as replacement of cement

SCC(20+5)% - Mix with 20% RHA along with 5%GGBS as replacement of cement

SCC(20+10)% - Mix with 20% RHA along with 10% GGBS as replacement of cement

SCC(20+20)% - Mix with 20% RHA along with10% GGBS as replacement of cement

SCC(15+15)%- Mix with 15% RHA along with 15% GGBS as replacement of cemen

CHAPTER 1

INTRODUCTION

1.1 General

The improvement of SCC moreover implied as "Self-Consolidating Concrete" has starting late been a standout amongst the most basic progressions in building industry. Self-compacting concrete (SCC) is a novel concrete that can subside into the seriously fortified, significant and contract zones by its own particular weight, and can join itself without requiring inward of course outside vibration, and meanwhile keeping up its solidness without inciting to segregation and depleting. SCC asks for a significant measure of powder substance diverged from routine vibrated bond to convey a homogeneous and durable blend.

The basic practice to get self-similarity in SCC is to restrict the coarse total substance and the most extreme size and to use bring down water–powder extents together with new period super plasticizers. In the midst of the transportation and situation of SCC the extended flowability may achieve separation and depleting which can be overcome by giving the fundamental consistency, which is for the most part gave by growing the fine total substance; by obliging the greatest total size; by growing the powder content; or by utilizing consistency changing admixtures

One of the obstructions of SCC is its cost, related with the usage of creation admixtures and use of high volumes of Portland bond. One other choice to diminish the cost of SCC is the usage of mineral included substances, for instance, limestone powder, ordinary pozzolans, fly fiery remains and slag, which are finely confined materials added to concrete as discrete fixings either before or amid blending .

1.2 History behind Development of SCC

In Beginning 1983, the construction industries was more interested around the world, the money, big number of labors and time was spend for important structure, tall building as well as all big project for nation like Nuclear power plant, Tunnel, Dam, Bridge etc.

Japan was one of those countries having the capacity to construct the essential structure and the question of the quality of solid for building was a remarkable focus of passion for Japan. To make strong solid structures, adequate compaction by gifted laborers is required. In any case, the slow reduction in the quantity of the people with knowledge in this country development industry has prompted to a comparable diminish in the temperament of expansion work. The Answer for all this problems was to create the concrete which can be used on site with less numbers of labors and saving time, cost and as well as concrete with good quality in terms of durability and compressive strength.

After Japan start using this concrete, a lot of country across the world has starts using SCC and in this day it is most useful in every important structure because its properties, easily to constructed.

1.3 Motive behind Development of SCC

The intention being developed of Self-Compacting Concrete was the social issue on durability of solid structure that emerged around 1983 in Japan. Because of a continuous decrease in the quantity of gifted laborers in the Japan development industry, a comparative diminishment in the nature of development work occurred.

As a delayed consequence of this reality, one response for the achievement of solid structures free of the way of advancement work was the use of concrete, which could be compacted into every edge of a reinforced bars , essentially by technique for its own weight. As for its union, "Self-Compacting Concrete involve a vague fragments from generally vibrated customary solid, which are bond, totals, water, included substances and admixtures. In any case, the high measure of Superplasticiser for abatement of beyond what many would consider possible and for better workability", the high powder content as Lubricant for the coarse total, and additionally the utilization of consistency operators to expand the thickness of the concrete.

1.4 Global present development of SCC

After Japan in 1983, SCC has started used in construction industries, people across the world have increasing doing research on this type of concrete, scientist, Engineers have performed several tests on SCC, from USA to EUROPE, country like FRANCE,ENGLAND, GERMAN, SWEDEN many paper have been published on SCC, up 2002 it was clear that this type concrete it more important in construction because it have more advantage compare to other type of concrete in terms of durability and workability.

In India ,amid the most recent couple of years ,endeavors were made in the labs and in the field to create and utilize SCC. Some spearheading endeavors have been made in Delhi Metro extends in relationship with L&T and MBT .Nuclear Power Corporation , Gammon India, Hindustan

Construction Company have made substantial scale research facility trials .Laboratory examines directed at SERC(Structural designing exploration focus) Chennai, Indian Institute of Innovation at Madras, Roorkee and different spots have sufficiently given information sources and certainty to receive SCC in India. Of the considerable number of spots Delhi Metro extend have utilized SCC as a part of huge scale for vault development, burrow lining, segment throwing.(Sood et al. 2009)In India, the advancement of cement having self compacting properties is still especially in its infancy.During the last couple of years, few endeavors were made utilizing European Guidelines for testing SCC in the research centers and in the field. SCC was utilized by Nuclear Power Partnership of India Ltd. at Tarapur, Kaiga and Rajasthan Atomic Power Project (RAPP).

1.5 Advantages and Disadvantage :

Advantage:

Self Compacting Concrete (SCC) can be named a progressed development material. The SCC as the name recommend does not require to be vibrated to accomplish full compaction. This offers taking after advantages and advantage over customary cement.

- Improved nature of cement and lessening of on location repairs.
- Faster development times.
- Lower general expenses.
- Facilitation of presentation of computerization into solid development.
- Improvement of wellbeing and security is additionally accomplished through disposal of treatment of vibrators.
- Substantial diminishment of natural commotion stacking close by a site.
- Possibilities for usage of "cleans", which are presently squander items and which are expensive to discard.
- Better surface completions.
- Easier putting.
- Thinner solid segments.

Disadvantage

- Increased material costs, especially for admixtures and cementitious materials.
- Increased formwork costs due to possibly higher formwork pressures and to prevent leakage.
- Increased technical expertise required to develop and control mixtures.
- Increased variability in properties, especially workability.
- Increased quality control requirements.
- Reduced quality of hardened properties in some cases possibly including modulus of.
- Elasticity and dimensional stability—due to factors such as high paste volumes or finer combined aggregate grading.
- Delayed setting time in some cases due to the use of admixtures.
- Requires more trial batches at laboratory as well as at plants.

Increased risk and uncertainty associated with the use of a new product.

1.6 SRM's – Secondary Raw Materials

Secondary Raw Materials are finely material divided materials that replace or supplement the use of Portland cement. Their use reduces the cost and improves one or more technical properties of concrete. SCMs also called mineral admixture, contribute to the properties of hardened concrete through hydraulic or pozzolanic activity. In my research, I'm using Rice Husk Ash (RHA) and Ground Granulated Blast Furnace Slag (GBBGS) as Secondary cement materials.

1.7 Use of Rice Husk Ash as Filler Material

In this work, Rice Husk Ash was used as a mineral admixture. Rice husk is an agricultural residue obtained from the outer covering of rice grains during milling process. It constitutes 20% of the 500 million tons of paddy produced in the world. Initially rice husk was converted into ash by open heap village burning method at a temperature, ranging from 300℃ to 450℃. When the husk was converted to ash by uncontrolled burning below 500℃ the ignition was not completed and considerable amount of unburned carbon was found in the resulting ash. Carbon content in excess of 30% was expected to have an adverse effect upon the pozzolanic activity of RHA. The ash produced by controlled burning of the rice husk between 550℃ and 700℃ incinerating temperature for 1 hr, transforms the silica content of the ash into amorphous phase. The reactivity of amorphous silica is directly proportional to the specific surface area of ash.

The ash so produced is pulverized or ground to required fineness and mixed with cement to produce blended cement. About 600 million tons per year of rice paddy was produced all over the world out of which an estimated 120 million tons in year 2010-2011 was grown in INDIA. Rice husk is the outer covering of the rice grain that is removed as a result of milling process on rice kernel. Huge amounts of RHA obtained after burning of rice husk, probably has no use at all and getting rid of it is also a problem.

India is an agriculture based economy, every year produces a considerable amount of by-products such as rice husk. In this world fighting with the enemies like global warming and shortage of natural construction materials, Scientist, Engineer everyone is looking something alternatives which minimize the environment degradation as well as provide comparable output to the traditional materials. The Rice Husk Ash is one these material boost our believe we can reduce amount of cement used and save a lot money we use to pay on cement as well as saving environment.

1.8 Application of Rice Husk Ash

RHA is a carbon neutral green product. Lots of ways are being thought of for disposing them by making commercial use of this RHA. RHA is a good super-pozzolan . This super-pozzolan can be used in a big way to make special concrete mixes. There is a growing demand for fine amorphous silica in the production of special cement and concrete mixes.

This product can be used in a variety of applications like:

.Green concrete

.Self compacting concrete

• High performance concrete

• Refractory

• Ceramic glaze

• Insulator

• roofing shingles

• waterproofing chemicals

- Oil spill absorbent
- Specialty paints
- Flame retardants
- Carrier for pesticides
- Insecticides and bio fertilizers etc etc.

9.9 Use of Ground Granulated Blast Furnace Slag (GGBS) as filler Material

Impact heater slag is a by-item which got in the fabricate of pig-iron. It is an item delivered by the mix of the gritty constituents of iron-mineral with the limestone flux at high temperature in the impact heater (around 150000c). The liquid slag is quickly extinguished by a hose of water to yield a lustrous granular item called granulated impact heater slag. Hydrated slag's, granulated or palletized, give an indistinguishable hydrates from Portland bond i.e., C-S-H and AF1 stages. As they respond more gradually with water than Portland concrete, they can be enacted by various courses: synthetically in nearness of lime and sulfate activators, physically by pounding or thermally. Slag, which is acquired by pounding the granulated impact heater slag, is exceedingly pozzolanic in nature. Concrete substitution levels of slag can be much higher than that of other pozzolanic materials, for example, Fly fiery debris and silica smolder. By and large, GGBS has higher "CaO" content than different pozzolanas.

In INDIA Ground-granulated impact heater slag (GGBS) is gotten by extinguishing liquid iron slag (a by-result of iron and steel-production) from an impact heater in water or steam, to create a shiny, granular item that is then dried and ground into a fine powder.

1.10 Applications of GGBS

- ❖ GGBS make durable concrete structures in combination with ordinary portland cement and/or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years.

- Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blast furnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70%; and in the production of ready-mixed or site-batched durable concrete.

Use of GGBS significantly reduces the risk of damages caused by alkali silica reaction (ASR), provides higher resistance to chloride ingress reducing the risk of reinforcement corrosion and provides higher resistance to attacks by sulfate and other chemicals.

CHAPTER 2

TERMINOLOGY

2.1 Self-Compacting Concrete

Is a special concrete that can settle into the heavily reinforced, deep and narrow sections
By its own weight, and can consolidate itself without necessitating internal or external vibration, and at the same time maintaining its stability without leading to segregation and bleeding.

2.2 Cement

It material which is in powder form with very small size in micron unit, and it used as binder material. Cement made by calcining lime and clay,

2.3 Superplasticizer

These are the chemical admixtures which act as high range water reducers.

2.4 Secondary Raw Materials

Material which are used as replacement of primary material, here primary material is cement.

2.5 Porosity

Porosity is the measure of void fraction in a material.

2.6 Bleeding

When water are comes out to the surface.

2.7 Segregation

Segregation in concrete is a case of particle segregation in concrete applications, in which particulate solids tend to segregate by virtue of differences in the size, density, shape and other properties of particles of which they are composed.

2.8 Workability

Workability is a property of freshly mixed concrete. A concrete is said to be workable if it is Easily transported, placed, compacted and finished without any segregation.

CHAPTER 3

REVIEW OF LITERATURE

3.1 Physical and Chemical Properties of Cement, RHA and GGBS

Different researchers have concentrated on the physical and chemical properties of both the materials i.e. normal Portland bond, rice husk cinder and Ground granulated impact heater slag. Physical and compound properties of OPC are shown in *Table 3.1* and *Table 3.2*

Table 3.1 Chemical Composition of OPC

Chemical Composition	%Content		
	Ahmadi *et al*. (2007)	**Memon *et al*. (2011)**	**Sua-iam *et al*. (2013)**
Silicon Dioxide (SiO_2)	18.1	17.454	16.39
Titanium Oxide (TiO_2)	-	0.348	-
Aluminium Oxide (Al_2O_3)	5.58	4.422	3.85
Ferric Oxide (Fe_2O_3)	2.43	3.93	3.48
Manganese Oxide (MnO)	-	0.064	-
Magnesium Oxide (MgO)	2.43	2.346	0.65
Calcium oxide (CaO)	62	65.844	68.48
Sodium Oxide (Na_2O)	-	0.252	0.06
Potassium Oxide (K_2O)	-	1.117	0.52
Phosphorous Pent oxide (P_2O_5)	-	0.068	-
Sulphur Trioxide (SO_3)	3.1	3.979	4.00
LOI	4.4	-	1.70

Table 3.2 Physical Properties of OPC

Property	Value		
	Ahmadi *et al*. (2007)	**Memon *et al*. (2011)**	**Sua-iam *et al*. (2013)**
Specific Gravity	3.15 g/cm^3	3.14 g/cm^3	3.2 g/cm^3
Specific Surface	3415 cm^2/g	-	610 m^2/kg

Physical and chemical Properties of RHA

Table 3.3 Chemical composition limits of RHA

Composition	Percentage		
	Khani *et al*. (2009)	**Habeeb *et al*. (2010)**	**Givi *et al*. (2010)**
(SiO_2)	88.61	87.32	86.86
(Al_2O_3)	0.04	0.46	0.68
(Fe_2O_3)	0.22	0.67	0.93
(CaO)	0.91	0.67	1.31
(MgO)	0.42	0.44	0.35
(Na_2O_3)	0.07	0.12	0.12
(K_2O)	1.57	2.90	2.32
LOI	5.92	5.80	-

Table 3.4 Physical Properties of RHA

Property	**Value**		
	Khani *et al*. (2009)	**Habeeb *et al*. (2010)**	**Kishore *et al*. (2011)**
Specific Gravity	2.15	2.11	2.27
Colour	Grey	Black	Black

Physical and Chemical properties of GGBS is shown in *Table* 2.5 and 2.6.

Table 3.5 Chemical composition limits of GGBS

Constituents	**Percentage**		
	Nanet al.(2001)	**Hassan et al.(2013)**	**Givi et al.(210)**
(SiO_2)	33.81	29.35	34.01
(Al_2O_3)	13.63	11.72	14.02
(Fe_2O_3)	.32	.52	4.03
CaO)	40.51	49.76	32
(MgO)	6.96	4.20	7.2
(K2O)	-	.46	-
(LOI)	.40	1.32	-

Table 3.6 Physical Properties of GGBS

Property	Value		
	Adam et al. (2015)	**Nan et al. (2001)**	***Pai et al. (2014)***
Gravity Specific	2.58	2.92	2.83
Color	white	white	Dull white
Fineness	202.7 g/m2	-	-
Density	2067.06 Kg/m^3	-	-

3.2 Properties of Study

3.2.1 Fresh concrete properties with RHA

Studied the fresh concrete properties. Nine different mixes were prepared. These were subdivided into three groups: Control concrete, 5% RHA and 10% RHA. Dosage of super plasticizer was varied from 3.5% to 4.5% with an increment of 0.5%.

Slump Flow Test- Slump flow for all mixes except 10R3.5 (10% RHA and 3.5% super plasticizer) was within the EFNARC range of SCC. Flow increased with increase in quantity of super plasticizer. Proportionally, there was decrease in the flow with increase in the quantity of RHA. The experimental readings achieved in slump flow test were from 595 to 795 mm.

L Box Test – While testing the concrete for passing ability, majority of the mixes passed through the bars very easily and without blockage. Ratio of L BOX increased with the increase in the quantity of super plasticizer. Proportionally, the ratio decreased with the increased quantity of RHA. Experimental readings achieved in L box test were from 0 to 1.

V-Funnel Test- Most of the results of V funnel test remained more towards minimum range or even lesser. This shows more filling ability but less viscous mix. With the increase in quantity of RHA, viscosity of mix started increasing.

Safiuddin *et al*. (2012) studied the fresh concrete properties of self –consolidating concrete (SCC) incorporating rice husk ash (RHA). Air entrained SCC mixtures were produced based on w/b ratios of 0.30-0.40. RHA was used substituting 0-30% of cement by weight.

Filling ability of concrete - The filling ability results of all SCC mixes were obtained with respect to slump, slump flow, inverted slump cone flow and orimet flow.

1. Slump

The slump varied in the range of 265-280 mm *(Table 3.5).* The slump only increased by 5mm although the deformability of concrete was significantly improved in the presence of 30% RHA. It was then suggested that the slump is not a suitable criterion to assess the filling ability of SCC.

Table 3.7 Slump of different SCC mixture (Safiuddin *et al*., 2012)

Concrete Type	**Slump (mm)**
C30RHA0	275
C30RHA15	280
C30RHA20	275
C35RHA0	270
C35RHA5	270
C35RHA10	270
C35RHA15	280
C35RHA20	275
C35RHA25	275
C35RHA30	275
C40RHA0	265
C40RHA15	270
C40RHA20	265

2. *Slump Flow*

The droop stream of SCC blends shifted from 665 mm to 770 mm (Table 2.6). The scope of droop stream demonstrates a brilliant filling capacity of SCC. The droop stream was fundamentally expanded by 60 mm within the sight of 30.0% RHA.

Table 3.8 Slump Flow for various SCC mix (Safiuddin *et al*., 2012)

Concrete Type	Slump Flow (mm)
C30RHA0	710
C30RHA15	735
C30RHA20	770
C35RHA0	690
C35RHA5	700
C35RHA10	710
C35RHA15	720
C35RHA20	710
C35RHA25	740
C35RHA30	750
C40RHA0	665
C40RHA15	680
C40RHA20	675

3. *Orimet Test*

The orimet stream time of SCC blend differed from 4.8 sec to 11.5 sec (Table 3.9). The greatest worthy farthest point for orimet stream time is 9 sec (EFNARC, 2002). The blends having more esteem are more thick than other cement.

Table 3.9 Orimet flow of various mixes (Safiuddin *et al*., 2012)

Concrete Type	Orimet Flow	
	Flow Time (sec)	**Flow Spread (sec)**
C30RHA0	6.6	750
C30RHA15	9.2	770
C30RHA20	11.5	780
C35RHA0	5.7	720
C35RHA5	6.4	730
C35RHA10	7.2	740
C35RHA15	7.6	760
C35RHA20	8.8	750
C35RHA25	9.6	775
C35RHA30	10.4	795
C40RHA0	4.8	690
C40RHA15	6.8	715
C40RHA20	7.1	720

Sua-iam *et al*. (2013) Arranged a few blends were readied containing different fine total substitution sums. RHA were utilized to supplant the stream sand at levels of 0.0%, 10.0%, 20.0%, 40.0%, 60.0%, 80.0% or 100.0% by volume. The SCC blends were distinguished utilizing the structures RHAx as a part of which x is the volume rates of stream sand supplanted by RHA.

SlumpFlow test - All of the blends showed agreeable normal droop streams of 70 ± 2.5 cm measurement which means that great workability. The droop stream time expanded with expanding RHA content. The droop stream time expanded shifted in the scope of 6-15 sec, 8-20 sec and 6-16 sec for SCC blends containing RHA.

V-Funnel test- Acceptable flow times were obtained for mixtures RHA10 and RHA20. The RHA particles absorbed water, resulting in a highly viscous mix and reducing bleeding.

J-Ring test- There was either no blocking or minimal apparent blocking in samples containing RHA. A small degree of blocking was evident in the control and in mixtures containing 10%, 20%, or 40% RHA. Extreme blocking was observed in samples containing more than 60% RHA.

3.2.2 Fresh concrete properties with GBBS

Pratik et al. (2013) studied the fresh concrete properties. Four different mixes were prepared, with every mixes there is % of GGBBS, and admixtures combination of (SP+VMA). The results for Slump flow test and L box test are showing in following table.

SlumpFlow-The slump stream of SCC blends shifted from 690 mm to 720 mm (Table 2.10). The scope of droop stream shows not astounding filling capacity of SCC. The droop stream was fundamentally expanded by 20 mm within the sight of 20% GGBBS..

Table 3.10 slump flow Test (Pratik et al.,2013)

Percentage of GGBS	**Slump flow (mm)**	**Time in sec T_{50}**
0	690	4.7
20	710	4.6
30	730	4.67
40	720	4.62

Table 3.11 L box test

Percentage of GGBS	Height H1	Height H2	H2/H1	Time taken to reach 200mm	Time taken to reach 400mm
0	85	75	0.88	9.24	15.8
20	75	62	0.83	6.80	10.2
30	80	77	0.96	3.8	6.5
40	70	63	0.60	4.6	8.8

3.2.3 Hardened concrete properties

3.2.3.1 Compressive strength with RHA

Ahmadi *et al.* (2007) studied the compressive strengthof SSC mix containing RHA in comparison to normal mix.Six arrangement of self compacting concrete with normal cement Two diverse substitution rates of bond by RHA, 10%, and 20% with blend have no RHA and two distinctive water/cementicious material proportions (0.40 and 0.35), were utilized for both of self compacting and normal solid examples. The blend extents as indicated by w/b proportion received and are accounted for in Table 3.13 and 3.14.

Table 3.13 Mix Design of various SCC mixes (Ahmadi *et al.,* 2007)

Mix	Gravel	Sand	Water	Cement	RHA	W/B
SCC(0%RHA)	770	970	184	460	0	0.4
SCC(10%RHA)	770	970	184	414	46	0.4
SCC(20%RHA)	770	970	184	368	92	0.4
OC(0%RHA)	1043	700	184	460	0	0.4
OC(10%RHA)	1043	700	184	414	46	0.4
OC(20%RHA)	1043	700	184	368	92	0.4

Table 3.14 Mix Design of various SCC mixes (Ahmadi *et al.*, 2007)

Mix	Gravel	Sand	Water	Cement	RHA	W/B
SCC(0%RHA)	770	970	184	460	0	0.35
SCC(10%RHA)	770	970	184	414	46	0.35
SCC(20%RHA)	770	970	184	368	92	0.35
OC(0%RHA)	1043	700	184	460	0	0.35
OC(10%RHA)	1043	700	184	414	46	0.35
OC(20%RHA)	1043	700	184	368	92	0.35

Table 3.15 Specimen's Dimensions (Ahmadi *et al.*, 2007)

Type Of Test	Dimensions		
	Length (cm)	Width (cm)	Height (cm)
Compressive Strength	10	10	10

For compressive quality the examples were test at various ages from 7 to 180 days. The outcomes are appeared in Figure 2.1 and Figure 2.2. As indicated by results SCC blends demonstrate higher compressive quality than typical cement. This distinction is around 31% to 41% of ordinary cement compressive quality. However blends containing rice husk fiery debris show bring down compressive quality until 60 days as opposed to tests with no substitution, yet by expanding the rate of pozzolanic responses of rice husk slag in the grid, quality of composite blends goes up

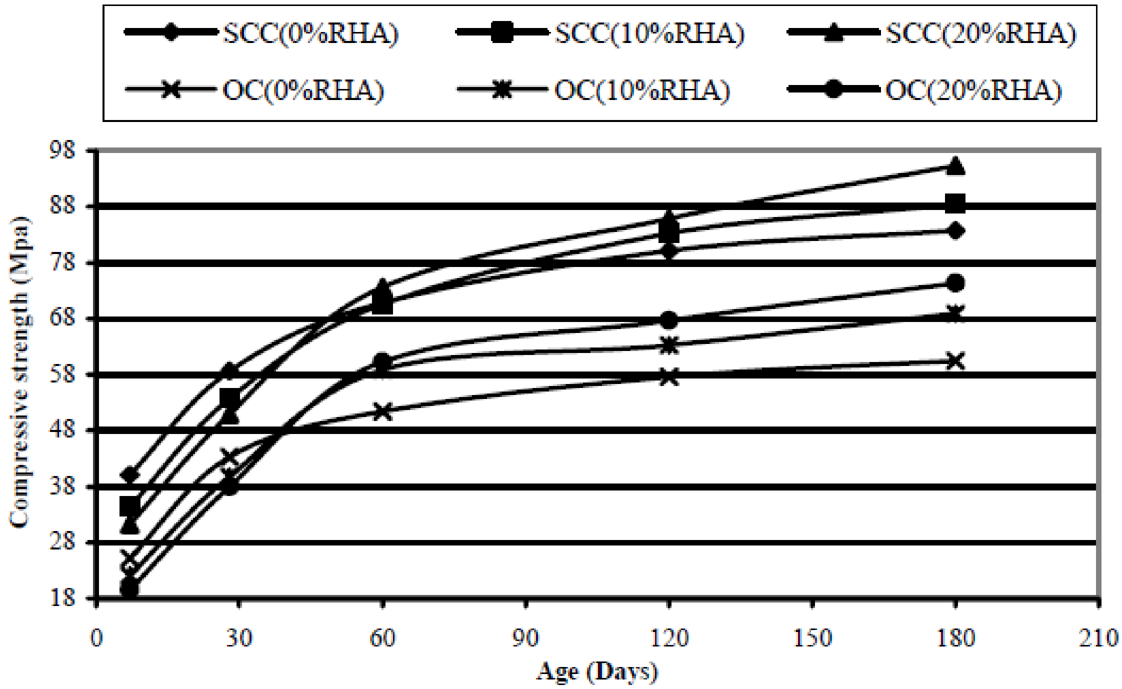

Figure 3.1 Compressive strength with w/b ratio 0.40 (Ahmadi *et al.*, 2007)

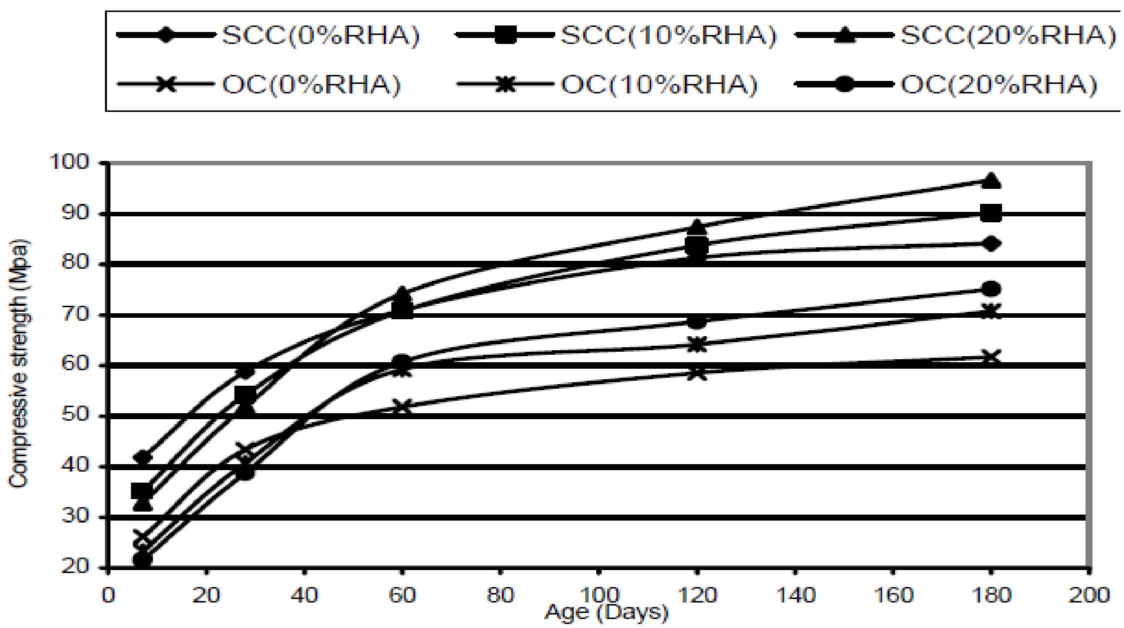

Figure 3.2 Compressive strength with- W/b ratio 0.35 (Ahmadi *et al.*, 2007)

The blends with 20%RHA slag have the most noteworthy compression quality than the others. Moreover water to fastener proportion has more effect on ordinary cement as opposed to self-minimized cement. Additionally, by expanding the measure of substitution, water to fastener proportion ascends**.**

Nor atan *et al*. (2011) -researches the compressive quality of self compacting concrete consolidating crude rice husk slag, exclusively and in blend with different sorts of mineral added substances, as incomplete bond substitution-.

Table 3.16 Mixture Proportions for the Control Mix, Binary Mix, Ternary Mixes and Quaternary Mixes (Nor atan *et al*., 2011)

Mix	Label	OPC	LP	FA	SF (kg/m^3)	RRHA	S	G
NM	CM	475	-	-	-	-	1047	712
BM	C/RHA	403.75	-	-	-	71.25	1027	698
TM1	C1/LP/RRHA	332.5	71.25	-	-	71.25	1023	695
TM2	C1/FA/RRHA	332.5	-	71.25	-	71.25	1007	686
TM3	C1/SF/RRHA	332.5	-	-	71.25	71.25	1012	688
QM1	C2/LP/FA/RRHA	261.25	71.25	71.25	-	71.25	1004	681
QM2	C2/LP/SF/RRHA	261.25	71.25	-	71.25	71.25	1006	683
QM3	C2/FA/SF/RRHA	261.25	-	71.25	71.25	71.25	994	676

Table 3.17 The Hardened Properties of the Control Mix (NM), Binary Mix (BM), Ternary Mixes (TM) and Quaternary Mixes (QM) (Nor atan *et al*., 2011)

Mix	Label	Age (Days)	Compressive Strength
NM	CM	7	36.5
		14	37.6
		28	37.8
		60	45.4
		90	44.7
BM	C/RRHA	7	22.7
		14	29.6
		28	39.8
		60	41.9
		90	42.5
TM1	C1/LP/RRHA	7	20.7
		14	29.4
		28	30.9
		60	38.5
		90	42.4
TM2	C1/FA/RRHA	7	24.3
		14	32.3
		28	38.9
		60	42.7
		90	43.4
TM3	C1/SF/RRHA	7	9.45
		14	38.3
		28	21.2
		60	23.6
		90	22.7
QM1	C2/LP/FA/RRHA	7	10.7
		14	13.6
		28	20.7
		60	21.4
		90	23.8
QM3	C2/FA/SF/RRHA	7	19.8
		14	25.4
		28	32.3
		60	38.3
		90	36.3

Tests did following 90 days uncover that the control blend (CM) got compressive quality estimations of 44.78MPa , while the parallel blend BM acquired 42.76MPa . This demonstrates supplanting 15% of OPC with RRHA creates marginally bring down compressive quality when contrasted with the control blend. Comparable outcomes are additionally indicated when 31% of OPC was supplanted with LP/RRHA and FA/RRHA mixes. Be that as it may, 30% supplanting with SF/RRHA mix delivered considerably brings down compressive. quaternary blends and are appeared to create equivalent outcomes with the control blend. Be that as it may, quaternary blend QM1 is appeared to display considerably bring down quality as contrasted and the control blend.

Saifuddin *et al.* (2010) concentrated the compressive quality of self solidifying superior cement (SCHPC). The solid blends were outlined in view of w/b proportions of .30, .35, .40, and .50, utilizing RHA % to 31% of bond by weight. An aggregate air substance of 6% was received for air entrained SCHPC's and 2 % for non air entrained SCHPC'S. Blends were named according to C (w/b proportion), R (substitution rate), An (air entrained).

Most elevated amount of later age quality was accomplished for C35RR30A6. Then again, the most minimal level of compressive quality al all was gotten for C50.RR0A6.The compressive quality of the solid with and no RHA expanded with a les w/b proportion. The expansion is straightforwardly relative to the decrease in solid porosity. In this review add up to porosity of cement diminished with lower w/b proportion. With diminished porosity, microstructure of cement is enhanced both in mass glue grid and interfacial move zone.

The RHA expanded the compressive quality of cement at age of 7, 28 and 56 days. It is essentially because of small scale filling capacity and pozzolanic movement of RHA.The expanded air content diminished the compressive quality of cement. The decrease in compressive quality was around 4 MPa per 1% expansion in air content. This is because of entrained air voids that expansion the aggregate vocontent. The expanded void substance diminished the heap conveying limit of cement, creating low compressive quality.

3.2.3.2 Compressive, Split tensile and flexural strength with GGBS

Pai et al. (2014) The concrete is tested for the hardened properties like compressive strength, split tensile and flexural strengths each for 7 days, 14 days and 28days. All tests were performed in accordance with the provisions of IS: 516-
1959 (Methods of tests for strength of concrete) and IS: 5816-1970
(Splitting tensile strength of concrete – Method of test). The test results are
listed in *Table 3.18*

Table 3.18 Test results on Hardened SCC (in MPa)

Property	**Curing Period**	**GGBS based SCC**	**SF based SCC**
Compressive Strength	**7 days**	21.44	9.20
	14 days	23.81	11.77
	28 days	26.23	18.32
Split Tensile Strength	**7 days**	1.35	0.97
	14 days	1.81	1.02
	28 days	2.03	1.63
Flexural Strength	**7 days**	4.41	3.66
	14 days	4.71	3.81
	28 days	4.82	3.86

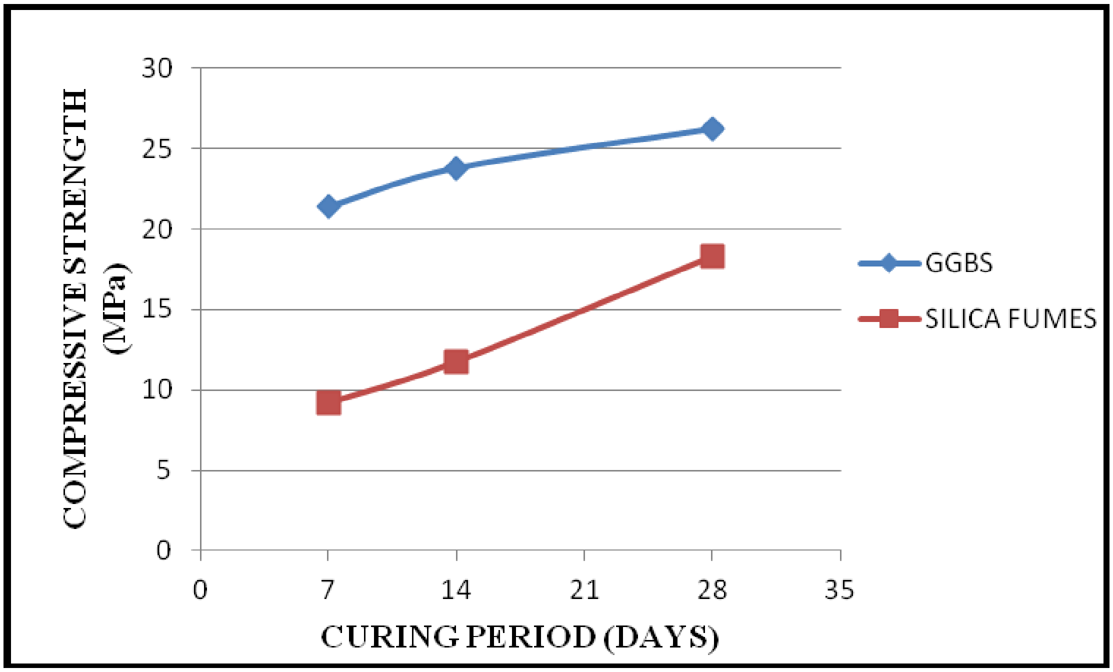

Figure 3.3 Variation of Compressive Strength with Curing period

Compressive Strength It may be noted from *Table 3.18* and also Fig 3.3 that the 28-days Compressive strength for GGBS based SCC of M25 grade is 26.23 MPa, Which is about 4.92% more than the design strength. From the test results for 7 days, 14 days and 28 days compressive strength of the SF based SCC, it may be noted that the results are not very satisfactory. This could be due to increase in the SF content which is about 50.19% of total powder content, whereas the maximum content of SF in the conventional concrete is restricted to 8% (Assem A.A.H et al. 2012). The Compressive strength of SF based SCC after 7 days, 14 days and 28 days are 9.20 MPa, 11.77 MPa and 18.32 MPa respectively. Whereas the Compressive strength of GGBS based SCC after 7 days, 14 days and 28 days are 21.44 MPa, 23.81 MPa and 26.23 MPa, which clearly indicates that the GGBS based SCC gives better strength than SF based SCC.

CHAPTER 4

RATIONALE AND SCOPE OF THE STUDY

In this experimental work, Ordinary Portland cement (OPC) grade 43. Superplasticizer Auramix 400 is used for SCC. The cement is to be replaced by combination of RHA and GGBS with a fixed proportion of RHA 20% and variation proportion of 5%, 10%, and 20% 0f GGBS there is also one mix of 15% RHA and 15%GGBS combine. All the fresh properties are tested in order to make sure that all material RHA and GGBS can be used and all design and desirable limit values are for self compacting concrete. The test on hardened SCC for various mixes is examined for the different proportions for specimens when there is replacement of cement. Normal specimens that are without replacement of cement are tested also. The results are compared for the normal/standard specimen and the experimented specimen (with replaced proportions) and the mix giving the best result is suggested to be used further for practical applications.

CHAPTER 5

OBJECTIVE OF THE STUDY

The construction project are increasing significantly around the globe, the solutions for Workability, durability and high tensile strength are needed in order to fill the dreams every engineer to build concrete structure of high strength, resistance to chemical attack, resistance to earthquake etc. One solution of type of concrete is SCC which need more amount of binder compare to normal concrete. In big project where millions tons of concrete are needed (e.g the Burj Khalifa), the cost of cement can be higher, when RHA and GGBS are used, the cost of binder material will decrease, enhancement of fresh properties and hardened properties. Of course there is benefit for environment as we know $CO_2$is released during the production of cement. So the main objective of the research is:

- To partially replacement of cement by RHA and GGBS
- To get better physical and mechanical properties by making use of these alternate materials.
- To make SCC economical by using RHA and GGBS.
- To find out the most suitable % for the replacement of cement
- To use RHA and GGBS in Construction in big project
- To reduce the content of cement by making use RHA and GGBS

CHAPTER 6

MATERIALS AND RESEARCH METHODOLOGY

6.1 General

The aim of this experiments work conducted is to study and compare the properties of SCC made when cement is replaced by combination of RHA and GGBS. In this work, research base on experiments conduct in labor, the paper which has already published and reading material from books. The experiments has been be held in my School labor (Lovely Professional University, School of Civil Engineering) and outside, several experiments has been conducted by myself with help of knowledge of my Supervisor .

6.2 Material Used

6.2.1 Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together The most important types of **cement** are used as a component in the production of mortar in masonry, and of concrete, which is a combination of **cement** and an aggregate to form a strong building material.

Test on Cement:

Fineness Test

Weight of cement=300g

Weight of passing cement=292g

Weight retained =4.5g<10% of 300

Hence accepted

Consistency test

Weight of cement=300g

Table 6.1 Reading for consistency

% of water	Wt .of water	Initial reading	Final reading
25	75 g	38 mm	35 mm
28.5	85 g	38 mm	17 mm
29	87 g	38 mm	10 mm
29.5	89 g	38 mm	8 mm

Cement consistency =30%

Initial and Final setting time

Weight of Cement=300g

Weight of water=0.85×0.3×300=76.5g

Initial setting Time=38min

Final setting Time=2h 47min=167min

Soundness of Cement

Initial distance=1 cm

Weight of cement=100g

Weight of added=0.78×0.3×100=23.4g

After 24hrs d_1=1.6 and d_2=1.4

After 3hrs boiling D_1=1.8 and D_2=1.7

Soundness= ((D_1-d_1) + (D_2-D_2))/2=0.25cm=2.5 mm<10mm

.Hence accepted

Specific Gravity Test

Weight of cement=50g

W_1= Wt of empty flask =108

W_2=Wt of flask + cement =159

W_3= Wt of flask +cement +diesel=395g

W_4=Wt of flask + diesel =358g

$S.G = (W_2-W_1)/((W_2-W_1)-(W_3-W_4))\times 0.92=3.1$

6.2.2 Test on coarse aggregate

Sieve analysis of course aggregate

Weight of sample tested=3.454Kg

Table 6.2 Observation for coarse aggregate test

Is sieve size in(mm)	WT of CA retained in(gm)	% WT retained	Cumulative percentage of total weight retained	% Passing	Desirable value as per Is 383
20	61	1.73	1.73	98.27	85-100
16	1438	42.63	43.36	55.64	0
12.5	1405	40.64	85	15	0
10	467	12.54	97.54	2.46	0-20
4.75	84	2.46	100	0	0-5
Pan	0	0	0	0	0

Water absorption of CA

The WA of CA used is 0.48%

Specific gravity of coarse aggregate

The specific gravity of coarse aggregate used is 2.56

6.2.3 Testing of fine aggregate

Water absorption of fine aggregate

The water absorption of fine aggregate being used is 1.2%

Specific gravity of fine aggregate

The specific gravity of fine aggregate being used is 2.74

Sieve analysis of fine aggregate

Table 6.3 Observation for Fine aggregate sieve analysis

Sieve sieze	**Weight of fine aggregate retained(gm)**	**Percentage retained**	**Cumulative percentage retained**	**Percentage Passing**	**Permissible percentage as per Is 383**
10mm	0.0	0.0	0.0	100	100
4.75mm	0.0	0.0	0.0	100	90-100
2.36mm	0.0	0.0	0.0	100	75-100
1.18mm	764	76.4	76.4	23.6	55-90
600Mm	160	16	92.4	7.6	35-59
300Mm	24	2.4	94.8	5.2	8-30
150Mm	50	5	99.8	0.2	0-10
Pan	2	0.2	100	0	

The fine aggregate being used is of Zone 2.

6.2.4 Water

Potable water was used for mixing and curing

6.2.5 Alternate materials

6.2.5.1 Rice Husk Ash (RHA)

RHA is produced by incinerating the husk of rice paddy.RHA used, was from Rudhiana cement plant and its physical properties are shown in Table 6

Table 6.4: Physical properties of RHA

Property	Result
Specific gravity	2.74
Consistency	28%
Colour	Black

Plate 6.1: RHA

6.2.5.2 Ground Granulated Blast Furnace Slag (GGBS)

GGBS is a non-metallic powder consisting of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form glassy sand like material. In this paper GGBS is from ASTRAA CHEMICALS-Chennai and its physical properties are shown in table 6.

Table 6.5: Physical properties of GGBS

property	Result
colour	Dull white
Specific gravity	3.02
consistency	32.5%

Plate 6.2: GGBS

6.2.6 Superplasticizer

Is a chemical compound used to increase the workability, without using anyadditional water. The SP used in this paper is Auramix 400 and is from Fosroc Chemicals (India) Pvt.ltd.

6.3 Mix Design/proportioning

A concrete mix can only be classified as Self-compacting if it has the following characteristics

- Filling ability
- Passing ability
- Segregation resistance

To achieve that, one the most aspect which should be done careful is mix design. EFNARC provide the guidelines for development of SCC.

But Okamura and Ozawa have proposed a simple mix-proportioning system assuming general supply from ready-mixed concrete plants. The coarse and fine aggregate contents are fixed so that self-compactability can be achieved easily by adjusting the water powder ratio and super plasticizer dosage only.

In this work try and error mix was used to find desirable value for fresh properties and hardened properties. The purpose was to design SCC-mix of high strength M45 grade. The design start with 450kg/m^3 for cement, 0.4 for water cement ration and 1% SP of binder. The good result values which have been used are shown in Table 6.6 and the values for fresh properties are in acceptable limited from EFNARC and are discussed in next point.

Table 6.6 : Mix Design

Mix	Cement(kg/m^3)	CA(kg/m^3)	FA(kg/m^3)	W/B	SP	RHA	GGBS
SSC 0%	530	750	916	0.41	1%	0	0
SCC(20%RHA+5%GGBS)	397.5	750	916	0.41	1%	106	26.5
SCC(20%RHA+10%GGBS)	371	750	916	0.41	1%	106	53
SCC(20%RHA+20%GGBS)	318	750	916	0.41	1%	106	106
SCC(15%RHA+15%GGBS)	371	750	916	0.41	1%	79.5	79.5

The Cubes, Beams and Cylinder were casted from every mix proportion Table 4, for testing (Hardened) Compressive strength, Flexure strength and Split tensile respectively, result are shown and discussed in next point.

6.4 Research Methodology

The main characteristics of SCC are the properties in the fresh state. The mix design is focused on the ability to flow under its own weight without vibration, the ability to flow through heavily congested reinforcement under its own weight, and the ability to retain homogeneity without segregation. The workability of SCC is higher than degree of workability mentioned in IS 456:2000. Those main characteristics in the fresh state are the following

- Passing ability
- Filling ability
- Segregation resistance

To accomplish these, several test must be done. In this work 4 tests has done to make sure the design mix can be used to make specimens for testing hardened properties.

❖ Testing fresh properties the following tests have been used

- Slump test
- V-Funnel test
- L-Box test
- U-Box test

After completing fresh properties tests, same mix design values have been bused for casting, cubes, beams and cylinders used as specimens for testing hardened properties.

6.5 Casting and Curing

For casting, cubes, cylinder and beams as test specimen they were cleaned, oiled properly, and securely tightened to correct dimensions before casting. Care was taken that there is no gaps left from where there is any possibility of leakage of slurry. Batching, mixing and casting was done carful. The concrete mixture was prepared by mechanical mixing. The coarse and fine aggregates were mixed thoroughly. Then water was added carefully so that no water was lost during mixing. To this mixture, the cement was added and the alternate materials were also added. These were mixed to uniform colour. Superplasticizer mixed with water

was also used as per the calculations made.

6.6 Test methods

6.6.1 Primary tests

All primary tests for material have done, as it was discussed in chap 6.2. Test like Specific gravity, sieve analysis is examined in this work and all values they are in desirable limit. Test for material help us to decide which material will use.

6.6.2 Fresh concrete tests

Testing concrete in fresh state to make sure concrete will remain with those three characteristics is most aspect when you are using SSC, this making more focusing on testing concrete for every trial mix before casting, to unsure that concrete will remain constant and have all requirement for good SCC.

Filling ability: The ability to flow under its own weight without vibration.

Passing ability: The ability to flow through heavily congested reinforcement under its own weight.

Segregation resistance: The ability to retain homogeneity without segregation

6.6.2.1 SlumpTest

The slump flow test is done to assess the horizontal flow of concrete in the absence of obstructions. It is a most commonly used test and give good assessment of filling ability. It can be used at site. The test also indicates the resistance to segregation.

Plate 6.3: Slumpflowtest

The usual slump cone having base diameter of 200mm, top diameter 100mm and height 300mm is used. A stiff base plate square in shape having at least 700mm side.

Concentric circles are marked around the centre point where the slump cone is to be place. A firm circle is drawn at 500mm diameter.

Interpretation: The high the flow value, the greater its ability to fill formwork under its own weight. A value at least 650mm is required for SCC. In case of severe segregation most aggregate will remain in centre of pool of concrete and mortar and paste at the periphery of concrete.

6.6.2.2 V-funnel test

The V-funnel test is used to determine the filling ability (flowability) of concrete with maximum size of aggregate 20mm size. The funnel is filled about 12 litres of concrete. Find time taken for it to flow down.

Plate 6.4: V-funnel test

Interpretation: Open within 10 seconds the trap door and record the time taken for the concrete to flow down. Record the time for emptying. For good result should come in range of 8-12 seconds. This can be judged when the light is seen when viewed from top. The whore test is to be performed within 5 min.

6.6.2.3 L-box test

The test assesses the flow of concrete and also the extent to which the concrete is subjected to blocking by reinforcement (passing ability).

Plate 6.4: L-box test process

Interpretation: If the concrete flows as freely as water, at rest it will be horizontal. There for H_2/H_1 will be equal to 1. Therefore nearest the values, the blocking ration is unity, the better the flow of concrete. The European Union research team suggested a minimum acceptable value of 0.8.

6.6.2.4 U-Box test

The test is used to measure the filling ability of SCC. The apparatus consist of a vessel that is divided by middle wall into two compartments.

Plate 6.6: U-box test

Interpretation: If concrete flows as freely as water, at rest it will be horizontal so H_1-H_2 will be equal to zero. Therefore nearest the test value, the filling height, is to be zero, the better the flow and passing ability of concrete. The acceptable value of filling height is 30mm maximum.

6.7 Hardened Concrete Properties

6.7.1 Compressive strength

After doing all fresh properties test, casting and curing done as it has discussed in 6.5. In this work compressive strength is tested on basis of 7days, 28 days and 56 days of curing. The cube which is used for specimens is 150 mm x 150 mm x 150 mm size. The test was done by using digital recording CTM, the rate of load is 5.1 KN/Sec and maximum load before specimen got failure was recorded and by knowing load we can calculate corresponding compressive strength.

Plate 6.7: Setup for Compressive strength showing concrete failure

<u>**Calculation of strength**</u>

Formula: **strength=**P/A

Where **p** is applied load and **A** cross sectional area of specimen Cube

Note: strength in PMa, P in KN and A mm^2

6.7.2 Split tensile strength

After doing all fresh properties test, casting and curing done as it has discussed in 6.5. In this work split tensile strength is tested on basis of 7days, 28 days and 56 days of curing. The cylinder which is used for specimens is 10 cm diameter and 20 cm height size. The test was done by using digital recording CTM, the rate of load is 2.1 KN/Sec and maximum load before specimen got failure was recorded and by knowing load we can calculate corresponding tensile strength.

Plate 6.8: Setup for Split tensile strent showing concrete failure

<u>Calculation of tensile strength</u>

Formula: **T=** 2P/πLD where

T = Split Tensile Strength in MPa
P = Applied load,
L= Length of Concrete cylinder sample in mm.
D= Diameter of Concrete cylinder sample in mm.

6.7.3 Flexural strength

After doing all fresh properties test, casting and curing done as it has discussed in 6.5. In this work flexural strength is tested on basis of 7days, 28 days and 56 days of curing. The beam which is used for specimens is 100 mm x100 mm x 500mm size. The test was done by using digital recording CTM, the rate of load is 0.9 KN/Sec and maximum load before specimen got failure was recorded and by knowing load we can calculate corresponding flexural strength

Plate 6.9: Setup for flexural before failure

Plate 6:10: Setup for flexural after failure

Calculation of flexural strength

Formula: **fb**$=PL/bd^2$

Where

fb =flexural strength in MPa

L = Effective span of the specimen in mm

b = Width of the specimen in mm

d = Depth of the specimen in mm

CHAPTER-7

RESULTS AND DISCUSSIONS

7.1 General

In this chapter the parameters studied on control and concrete made with replacement of Cement with combination of RHA and GGBS in SCC are discussed. The parameters such as Workability, Compressive strength, Tensile strength and flexural strength are discussed and Comparison between various mixes is being done.

7.2 results and Discussions on Fresh concrete properties

SCC is type of concrete which need large paste volume in order to achieve both high strength and self compacting properties. From all round performance points of view, the use of a large aabinder paste volume is undesirable as it would lead to high heat of hydration, greater shrinkage and creep. In order to get good workability and avoid this heat of hydration different trial mix were tested and value which is used was discussed in Chap 6.3, SP is used to enhance workability without increasing water. The results are showing in *table 7.1*

Table 7.1: Result for different fresh cocrete properties test

Mix	Slump Flow (mm)	V-Funnel Time (sec)	L-Box (H2/H1)	U-Box (H2-H1)
SCC0%	718	11	0.96	25
SCC(20%RAH+5%GGBS)	692	10	0.92	24
SCC(20%RHA+10%GGBS)	690	10	0.93	24
SCC(20%RHA+20%GGBS)	681	10	0.89	23
SCC(15%RHA+15%GGBS)	661	9	0.875	23

7.3 Compressive strength

When it comes to talk about concrete structure, first things comes in mind is compressive strength. Concrete are very strong in compression, to design concrete which will used in construction that can resist compressive stresses. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal. SCC is one of type concrete which most efficiency and has high strength compare to normal concrete, in this work M45 grade concrete is designed. Admixture RHA and GGBS are used as replacement to enhance fresh and hardened properties, in this work 20%RHA is fixed and added along with 5%, 10%, 20% of GGBS for three different mix and for more investigation 15%RHA and 15%GGBS was used as another mix to check the range strength will be maximum. The result are showing in *Table 7.2*

Table 7.2: Compressive strength test results for various SCC mixes

`Property	Mix	Curing period		
		7days (MPa)	28days (MPa)	56days (MPa)
Compressive strength	SCC0%	35.13	50.5	56.1
	SCC(20%RAH+5%GGBS)	36.2	51.6	57
	SCC(20%RHA+10%GGBS)	36.8	52.7	57.5
	SCC(20%RHA+20%GGBS)	35.6	52.1	54.8
	SCC(15%RHA+15%GGBS)	37.8	53.60	59.1

It may be noted from *Table 7.2* and also Fig 7.1 and 7.2 that the 28-days compressive strength when cement replaced by 15%RHA and 15%GGBS is 53.6 MPa, which is about 16.04% more than the design strength. For 28-days when there is no replacement of cement strength is 50.5, which is about 10.89% more than the design strength. From 10.89% to 16.04%, Compressive Strength increased 5.15%

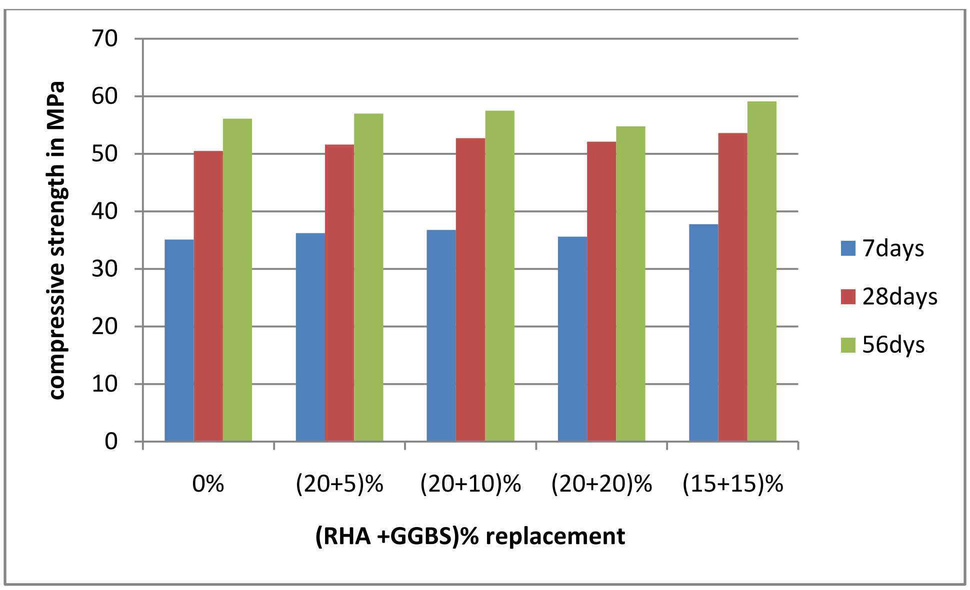

Figure 7.1: Compressive strength of SCC mixes at various ages

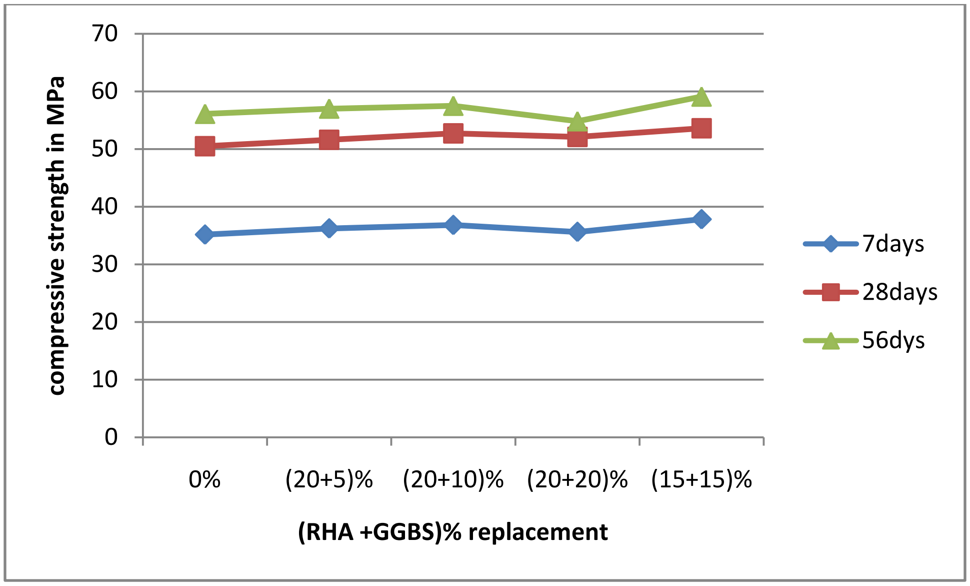

Figure 7.2: Compressive strength of SCC mixes at various ages

7.4 Split tensile strength

The split tensile strength of all the mixes was determined at the ages 7 days, 28 days and 56 days when additional percentages of RHA along with GGBS in concrete mix. The split tensile strength results of individual concrete mix are also shown graphically. The maximum values of split tensile strength of concrete is when combination of 15%RHA and 15%GGBS are used as replacement while minimum values is when combination of 20%RHA and 20%GGBS are used as replacement of cement.

Table 7.3: Split tensile strength test results for various SCC mixes

`Property	Mix	Curing period		
		7days (MPa)	28days (MPa)	56days (MPa)
Split tensile strength	SCC0%	3.29	3.45	3.97
	SCC(20%RAH+5%GGBS)	3.5	3.67	4.2
	SCC(20%RHA+10%GGBS)	3.61	3.7	4.4
	SCC(20%RHA+20%GGBS)	3.49	3.5	4.17
	SCC(15%RHA+15%GGBS)	3.72	3.85	4.8

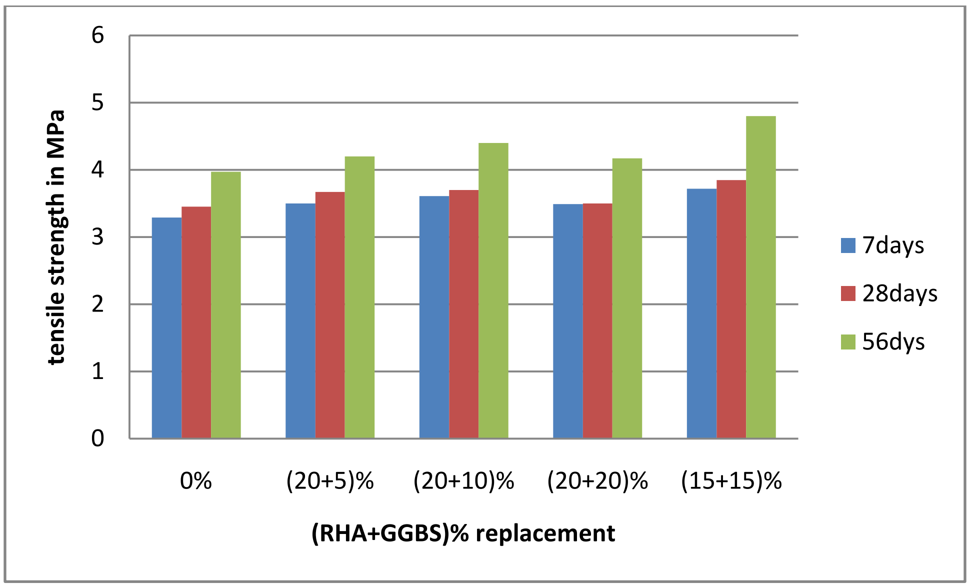

Figure 7.3: Split tensile strength of SCC mixes at various ages

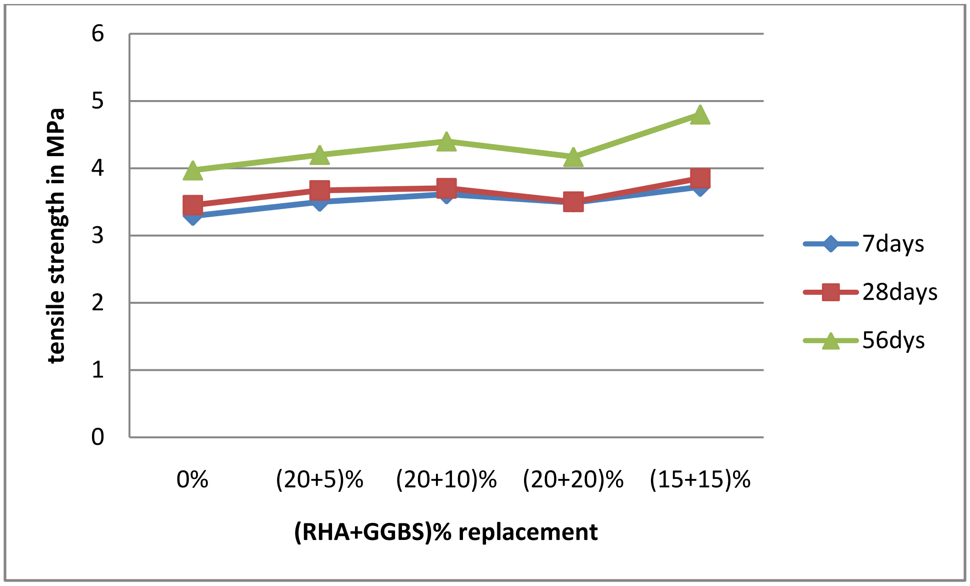

Figure 7.4: Split tensile strength of SCC mixes at various ages

It may be noted from *Table 7.3* and also Fig. 2 that the 28-days Split Tensile strength when cement replaced by 15%RHA and 15%GGBS is 3.85 MPa, while up 15%RHA and 15%GGBS the split tensile strength was increasing significantly.

7.5 Flexure strength

The flexural strength of all the mixes was determined at the ages 7 days, 28 days and 56 days when additional percentages of RHA along with GGBS in concrete mix. Flexural strength results of individual concrete mix are also shown graphically. The maximum values of flexural strength of concrete is when combination of 15%RHA and 15%GGBS are used as replacement while minimum values is when combination of 20%RHA and 20%GGBS are used as replacement of cement.

Table 7.4: flexural strength test results for various SCC mixes

Property	Mix	Curing period		
		7days (MPa)	28days (MPa)	56days (MPa)
Flexural strength	SCC0%	9.34	9.47	11
	SCC(20%RAH+5%GGBS)	9.5	9.61	11.8
	SCC(20%RHA+10%GGBS)	9.58	9.65	12.3
	SCC(20%RHA+20%GGBS)	9.48	9.5	10.87
	SCC(15%RHA+15%GGBS)	9.68	9.83	12.93

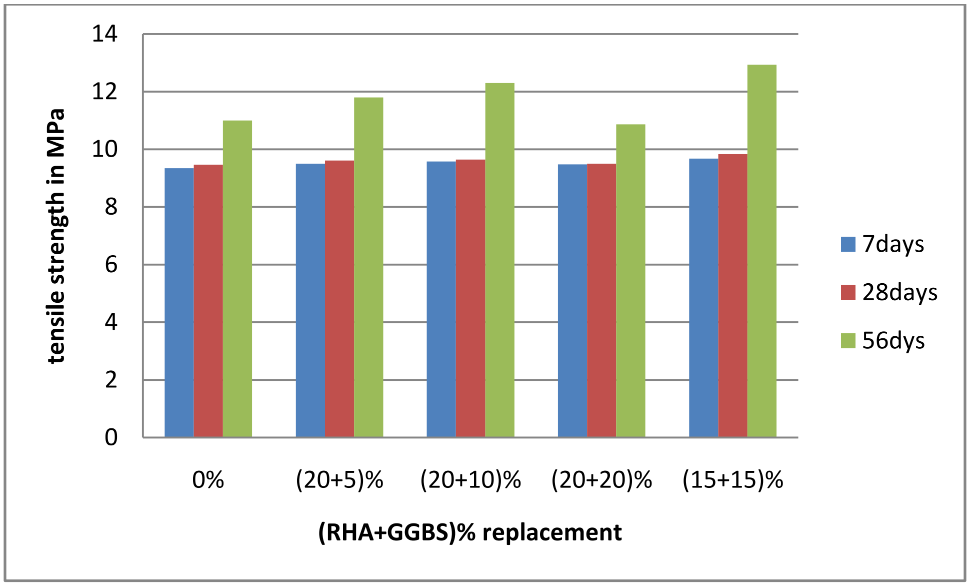

Figure 7.5: Flexural strength of SCC mixes at various ages

It may be noted from *Table 7.4* and also Fig 7.5 and 7.6 that the 28-days Flexural strength when cement replaced by 15%RHA and 15%GGBS is 9.83 MPa, and it is increasing significantly, while when cement replaced by 20%RHA and 20%GGBS, Flexural strength start decrease.

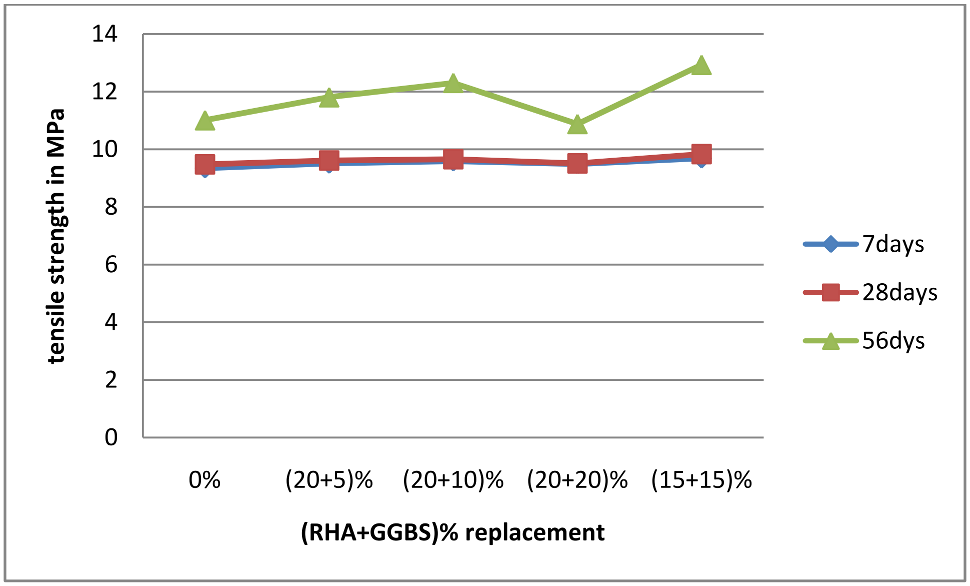

Figure 7.6: Flexural strength of SCC mixes at various ages

CHAPTER 8

CONCLUSION AND FUTURE SCOPE

8.1 General

This work was based on experimental analysis to investigate the compressive strength, split tensile strength and flexural strength of concrete with different level of replacement of cement wit combination of RHA along with GGBS. Cement was partially replaced by RHA and GGBS at four different levels of replacement .Tests were performed after 7 days, 28 days and 56 days of curing of concrete. Results were compared when there is no replacement of cement and as we discussed in chap 7, its showing the admixture which is used in this work can be trusted and used in construction.

8.2 Conclusions

The construction project are increasing significantly around the globe, the solutions for workability, durability and high tensile strength are needed in order to fill the dreams every engineer to build concrete structure of high strength, resistance to chemical attack, resistance to earthquake etc. One solution of type of concrete is SCC which need more amount of binder compare to normal concrete. In big project where millions tons of concrete are needed (e.g the Burj Khalifa), the cost of cement can be higher, when RHA and GGBS are used, the cost of binder material will decrease, enhancement of fresh properties and hardened properties. Of course there are benefit for environment as we know CO_2 is released during the production of cement. From the experimental investigations, the following conclusions may be drawn:

- The SCC mixes containing RHA and GGBS as powder mat their fresh properties as per EFNARC guidelines, have satisfied the norms laid down by EFNARC.
- The combination of RHA and GGBS based SCC has good Compressive strength, Split tensile strength and flexural Strength when compared to SCC without replacement or when cement is replaced by those admixtures separately.
- The good results for all hardened properties tested in this work comes when cement replaced by 15%RHA and 15%GGBS, and when replacement goes up 20%RHA and 20%GGBS of binder, all results for hardened properties start decrease.

8.3 FUTURE SCOPE

Mechanical properties for both the materials have shown positive results up to 15% RHA combine with 15%GGBS, more investigation should be done in future for checking at which percentage range of replacement can be used on site, because in this work we have seen that more than 20% from both material means 40% of binder material all properties start having negative effect. But we didn't check weather if decrease RHA and increase GGBS what will happen, so mean in future those investigation be done.

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Appendix

1 Self Compacting Concrete

SCC is type of concrete which need large paste volume in order to achieve both high strength and self compacting properties. From all round performance points of view, the use of a large binder paste volume is undesirable as it would lead to high heat of hydration, greater shrinkage and creep. However using admixture can reduce heat hydration and use SP it is read get full workability without increasing water.

2 Superplasticizer

Is a chemical compound used to increase the workability, without using anyadditional water. The SP used in this paper is Auramix 400 and is from Fosroc Chemicals (India) Pvt.ltd.

3 Ground Granulated Blast furnace Slag

GGGBS which is both cementitious and pozzolanic material may be added to improve rheological properties.