Mechanical Properties of Self Compacting Concrete with Partial Replacement of Rice Husk Ash

D Sathya Narayana
Department of Civil Engineering,
Chirala Engineering College,
Chirala, Andhra Pradesh, India

A Pavani
Department of Civil Engineering,
Chirala Engineering College,
Chirala, Andhra Pradesh, India

N Venkata Hussain Reddy
Department of Civil Engineering,
SVR Engineering College, Nandyal,
Andhra Pradesh, India

ABSTRACT

Self-compacting concrete (SCC) is relatively a recent development in the construction world. SCC is defined basically by two properties: Deformability and segregation resistance. It flows under its own weight while remaining homogeneous in composition. This research is aimed at examining the feasibility of using Rice Husk Ash as supplementary cementations material. In this research, the main variables are the proportion of rice husk ash (0%, 10%, 15%, 20%) and cement content.

All the results were in range as per code specified. Mix 20RHA showed minimum workability. The increase of about 25% strength at 7 days, 33% strength at 28days and 36% strength at 56 days were observed with increase of RHA content from control mix (0RHA) to 15RHA. Maximum splitting tensile strength was also obtained by the mix 15RHA. Greatest increase in mechanical properties was observed for the mix containing 15% rice husk ash. The inclusion of rice husk ash as replacement of cement does not affect the strength properties negatively as the strength remains within limits up to 20%replacement. Inclusion of RHA showed great improvement in durability Properties of concrete.

KEYWORDS: RHA, SCC, Split Tensile strength, Compressive strength, Porosity

1. INTRODUCTION

1.1 GENERAL

Cement-based materials are the most abundant of all man-made materials and are among the most important construction materials, and it is most likely that they will continue to have the same importance in the future. However, these construction and engineering materials must meet new and higher demands. When facing issues of productivity, economy, quality and environment, they have to compete with other construction materials such as plastic, steel and wood. One direction in this evolutionism towards self-compacting concrete (SCC), a modified product that, without additional compaction energy, flows and consolidates under the influence of its own weight.

Self – compacting concrete (SCC) is a fluid mixture, which is suitable for placing in difficult conditions and also in congested reinforcement, without vibration. Development of self-compacting concrete (SCC) is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. In principle, a self – compacting or self – consolidating concrete must:

- Have a fluidity that allows self – compaction without external energy
- Remain homogeneous in a form during and after the placing process and
- Flow easily through reinforcement

Self-compacting concrete is not affected by the skills of workers, the shape and amount of reinforcing bars or the arrangement of a structure and, due to its high-fluidity and resistance to segregation it can be pumped longer distances, (Bartos, 2000).

1.2 HISTORY BEHIND DEVELOPMENT OF SELF-COMPACTING CONCRETE

Modern application of self-compacting concrete (SCC) is focused on high-performance, better and more reliable and uniform quality. Self-compacting concrete, in principle, is not new. Special applications such as underwater concreting have always required concrete, which could be placed without the need for compaction; in such circumstances vibration was simply impossible. Early self compacting concretes relied on very high contents of cement paste and, once super plasticizers became available, they were added in the concrete mixes. The mixes required specialized and well-controlled placing methods in order to avoid segregation, and the high contents of cement paste made them prone to shrinkage. The overall costs were very high and applications remained very limited. The introduction of “modern” self-leveling concrete or self-compacting concrete(SCC) is associated with the drive towards better quality concrete pursued in Japan around 1983, where the lack of uniform and complete compaction had been identified as the primary factor responsible for poor performance of concrete structures. Due to the fact that there were no practical means by which full compaction of concrete on a site was ever to be fully guaranteed, the focus therefore turned onto the elimination of the need to compact, by vibration or any other means.

1.3 BENEFITS AND ADVANTAGES

Self compacting concrete (SCC) can be classified as an advanced construction material. The SCC as the name suggests, does not require to be vibrated to achieve full compaction. This offers following benefits and advantages over conventional concrete.

- Improved quality of concrete and reduction of onsite repairs.
- Faster construction times.
- Lower overall costs.
- Facilitation of introduction of automation into concrete construction.
- Improvement of health and safety is also achieved through elimination of handling of vibrators.
- Substantial reduction of environmental noise loading on and around a site.
- Possibilities for utilization of “dusts”, which are currently waste products and which are costly to dispose of.
- Better surface finishes.
- Easier placing.
- Thinner concrete sections.
- Greater Freedom in Design.
- Improved durability, and reliability of concrete structures.

Ease of placement results in cost savings through reduced equipment and labor requirement.

SCC makes the level of durability and reliability of the structure independent from the existing on site conditions relate to the quality of labor, casting and compacting systems available.

The high resistance to external segregation and the mixture self – compacting ability allow the elimination of macro – defects, air bubbles, and honey combs responsible for penalizing mechanical performance and structure durability.

1.4 SECONDARY RAW MATERIALS (SRM)

Raw materials are basically supplementary cementations materials, fillers, powders depending upon their role in fresh and hardened state. They are less energy intensive materials, industrial byproduct that requires less or no processing. They themselves posses little or no cementations value but will in finally divided form and in presence of moisture reacts with cement at ordinary temperature to form compounds possessing cementations properties. SRM’s helps in advancement of hydration and especially in improving the hydration product. They usually replace part of cement. These basically include limestone powder (LSP), fly ash (FA), ground granulated blast furnace slag (GGBS), silica fumes (SF) and rice hush ash (RHA). SRM’s are also called mineral admixtures, contributing towards properties of hardened concrete through physical and chemical properties including hydraulic or pozzolanic activity. These materials react chemically with calcium hydroxide released from hydration of Portland cement to form cement compounds.

These materials often added to concrete to make concrete mixtures more economical, reduce permeability, increase strength or influence other concrete properties.

1.5 TESTS AND PROPERTIES

1.5.1 PROPERTIES

Fresh Self Compaction of Concrete must possess the following properties:

- Filling ability: This is the ability of the SCC to flow into all spaces within the formwork under its own weight.
- Passing ability: This is the ability of the SCC to flow through tight openings such as spaces

between steel reinforcing bars, under its own weight.

- Resistance to segregation: The SCC must meet the required levels of properties A & B

whilst its composition remains uniform throughout the process of transport and placing.

1.5.2 TESTS

Some of the important tests conducted on fresh SCC to evaluate its workability are summarized in

Table 1.1 and are briefly explained later.

Table 1.1: Test methods to evaluate the workability properties of SCC

Property	**Test Methods**	
	Field (Quality Control)	
Filling Ability	Slump Flow Test T50cm Flow Test	Slump Flow Test
Passing Ability	L-Box Test	J Ring Test
Segregation Resistance	V-Funnel At T5 Mints	V-Funnel At T5

2. LITERATURE REVEIW

2.1 INTRODUCTION

Present-day self-compacting concrete can be classified as an advanced construction material. As the name suggests, it does not require to be vibrated to achieve full compaction. This offers many benefits and advantages over conventional concrete. These include an improved quality of concrete and reduction of on-site repairs, faster construction times, lower overall costs, facilitation of introduction of automation into concrete construction. The composition of SCC mixes includes substantial proportions of fine-grained inorganic materials and this gives possibilities for utilization of mineral admixtures.

Bertil Person (2001) carried out an experimental and numerical study on mechanical properties, such as strength, elastic modulus, creep and shrinkage of self-compacting concrete and the corresponding properties of normal compacting concrete. The study included eight mix proportions of sealed or air-cured specimens with water binder ratio (w/b) varying between 0.24 and 0.80. Fifty percent of the mixes were SCC and rests were NCC. The age at loading of the concretes in the creep studies varied between 2 and 90 days. Strength and relative humidity were also found. The results indicated that elastic modulus, creep and shrinkage of SCC did not differ significantly from the corresponding properties of NCC.

Nan Su et al (2001) proposed a new mix design method for self-compacting concrete. First, the amount of aggregates required was determined, and the paste of binders was then filled into the voids of aggregates to ensure that the concrete thus obtained has flow ability, self-compacting ability and other desired SCC properties. The amount of aggregates, binders and mixing water, as well as type and dosage of super plasticizer to be used are the major factors influencing the properties of SCC. Slump flow, V-funnel, L-flow, U-box and compressive strength tests were carried out to examine the performance of SCC, and the results indicated that the proposed method could be used to produce successfully SCC of high quality. Compared to the method developed by the Japanese Ready-Mixed Concrete Association (JRMCA), this method is simpler, easier for implementation and less time-consuming, requires a smaller amount of binders and saves cost.

Safiuddin et al. (2008) observed that drying shrinkage occurs when concrete hardens and dries out at the early age. It induces potential flow channels in the form of micro cracks. These cracks provide the access to deleterious agents, and thus affect the durability of concrete. The drying shrinkage of SCC does not differ very much from that of normal concrete. Several studies reported that it could be even lower in SCC. In general, the reduced coarse aggregate content and the increased amount of cementing material are expected to cause more drying shrinkage in SCC. But the porosity also affects the drying shrinkage of concrete. As the porosity is reduced in SCC, it compensates the negative effects of aggregate and binder on drying shrinkage. In addition, the drying shrinkage tends to decrease in SCC since a very small amount of free water is available in the system. Also, SCC has minimum empty voids on concrete surface that are largely responsible for drying shrinkage.

Felekoglu et al. (2005) has done research on effect of w/c ratio on the fresh and hardened properties of SCC. According to the author adjustment of w/c ratio and super plasticizer dosage is one of the key properties in proportioning of SCC mixtures. In this research, fine mixtures with different combinations of w/c ratio and super plasticizer dosage levels were investigated. The results of this research show that the optimum w/c ratio for producing SCC is in the range of 0.84- 1.07 by volume. The ratio above and below this range may cause blocking or segregation of the mixture.

Bui et al. (2002) discussed a speedy method in order to test the resistance to segregation of Self-compacting concrete. Extensive test conduct of SCC with different water-binder ratios, paste volumes, combinations between coarse and fine aggregates and various types and contents of mineral admixtures was carried out. The test was helpful in concluding the method along with the apparatus used for examining the segregation resistance of SCC in both the directions (vertical and horizontal).

Cengiz (2005) used fly-ash with SCC in different proportional limit of 0%, 50% and 70% replacement of normal Portland cement (NPC). He investigated the strength properties of self compacted concrete prepared using HVFA (high volume fly ash). Concrete mixtures made with water cementations material ratios ranged from 0.28 to 0.43 were cured at moist and dry curing conditions. He investigated the strength properties of the mix and developed a relationship between compressive strength and flexural tensile strength. The study proved that it is possible to convert an RCC (zero slump) concrete to a workable concrete with the use of suitable super plasticizer.

3 MATERIAL USED

3.1 CEMENT

Cement is a binder, a substance used in construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used solely, but is used to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete.

Cements used in construction are usually inorganic often lime or calcium silicate based, and can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to set in the presence of water.

3.2 PORTLAND CEMENT:

Common type of powdery cementations building material made from finely pulverized alumina, iron oxide, lime, magnesia, and silica burnt together in a kiln. When mixed with water and sand (or gravel) it turns into masonry mortar (or concrete) and, after a series of complex internal reactions, sets like a stone. Invented in 1824 by the UK bricklayer Joseph Aspdin (1779-1855), it gets its name from its resemblance (upon hardening) to the famous Portland limestone (obtained from quarries on the Isle Of Portland), the traditionally preferred choice for building churches, mansions, and palaces.

Table 4.1: Basic tests conducted on Ordinary Portland cement

S.No.	Characteristics	Values Obtained
1	Normal Consistency (%)	**28.2**
2	Initial Setting Time(min)	**120**
3	Final Setting Time (min)	**425**
4	Fineness (m2/kg)	**281**
5	**Specific Gravity**	**3.50**

3.3 FINE AGGREGATES

Fine aggregates are granular material, such as sand, gravel, crushed stone. Fineness modulus of sand (fine aggregate) is an index number which represents the mean size of the particles in sand. It is calculated by performing sieve analysis with standard sieves. The cumulative percentage retained on each sieve is added and subtracted by 100 gives the value of fine aggregate.

3.4 COARSE AGGREGATES

The material which is retained on IS sieve no. 4.75 is termed as a coarse aggregate as per IS: 383 (1970).The crushed stone is generally used as coarse aggregates. The nature of work decides the maximum size of the coarse aggregates. Locally available coarse aggregates having the maximum size of 10 mm was used in our work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested as per IS: 2386 (1963) (Part 3). The results of various tests conducted on coarse aggregates

3.5 WATER

Generally, water that is suitable for drinking is satisfactory for use in concrete. Water from lakes and streams that contain marine life also usually is suitable. When water is obtained from sources mentioned above, no sampling is necessary. When it is suspected that water may contain sewage, mine water, or wastes from industrial plants or canneries, it should not be used in concrete unless tests indicate that it is satisfactory. Water from such sources should be avoided since the quality of the water could change due to low water or by intermittent tap water is used for casting.

3.6 SUPPLEMENTARY CEMENT MATERIALS

3.6.1. RICE HUSK ASH

The rice husk ash used in the present study.

Plate 4.1: Rice husk ash used in the study

3.7 ADMIXTURE

Conplast SP430 complies with IS: 9103 (1979), BS: 5075 (Part 3) and ASTM-C-494Type 'F' as a high range water reducing admixture. Conplast SP430 is based on Sulphonated Naphthalene Polymers and is supplied as brown liquid instantly dispersible in water and specially formulated to give high water reduction up to 25%without loss of workability, Specific gravity 1.22 to 1.225 at 30°C.

3.8 MIX PROPORTIONING

Proportioning characteristics Selectable water-powder ratios are limited to a narrow range. The unit absolute volume of powder should be not less than 0.l6 m3/m3. A wide variety of powders are available to select from. Characteristics of physical properties Powder-type self-compacting concrete can be made into high strength concrete, due to the low water-binder ratio. Certain types of powder can lead to high autogenously shrinkage.

3.9 CASTING AND CURING

For casting, the entire test specimen were cleaned and oiled properly. These were 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. Careful procedure was adopted in the batching, mixing and casting operations. The coarse aggregate sand fine aggregates were weighed first with an accuracy of 0.5 g. The concrete mixture was prepared by hand mixing on a non-absorbing platform.

On the non- Absorbing platform, 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. These were mixed to uniform color. Then water was added carefully so that no water was lost during mixing. For each mix 24 samples were prepared, which consists of 9 cubes (150x150x150 mm) for 7, 28 and 56 days compressive strength and 9 cylinders (300x150 mm) for split tensile strength at 7, 28and 56 days and 6 cylinders (200x100 mm) for RCPT at 7 and 28 days.

4. RESULTS AND DISCUSSIONS

4.1 GENERAL

In this chapter the parameters studied on control and concrete made with replacement of cement with rice husk ash in self compacting concrete are discussed. The parameters such as Compressive strength, Tensile strength, Rapid chloride permeability test, Porosity, X-Ray diffraction (XRD), Scanning electron microscope(SEM) are discussed and comparison between various mixes are discussed.

4.2 RICE HUSK ASH

Replacement of rice husk ash with cement on concrete is basically discussed in this article. Reactivity of rice husk ash is basically due to the high amorphous silica content and also due to large surface area governed by porous structure of particles. This makes rice husk ash a very reactive pozzolanic material. In chemical reaction of Portland cement in concrete, there is release of calcium hydroxide. Silica present in rice husk ash reacts with this calcium hydroxide to form additional binder material called as calcium silicate hydrate (C-S-H) similar to the C-S-H produced by Portland cement. It works as additional binder that gives RHA concrete its improved properties. Mechanism of rice husk ash in concrete can be studied basically under three roles:

Matrix Densification and Pore size Refinement: The presence of filler like rice husk ash in the Portland cement concrete mixes causes reduction in volume of large pores. RHA acts as filler due to its fineness. It fits into the spaces between grains in same way like cement grains fill the spaces between fine aggregates grains and sand fills the spaces between particles of coarse aggregates.

Reaction with free-lime (From hydration of cement): CH crystals present in Portland cement pastes are a source of weakness. Cracks can easily propagate through or within these crystals without any significant resistance.

This affects the strength, durability and other properties of concrete. Rice husk ash which is siliceous material reacts with CH results in reduction in CH content in addition to forming strength contributing cementations products which in other words can be termed as ‘‘Pozzolanic Reaction’’.

Cement paste–aggregate interfacial refinement: In concrete the transition zone between the aggregate particles and cement paste plays a significant role in the cement-aggregate bond. Rice husk ash addition influences the thickness of transition phase in mortars and the degree of the orientation of the Chrystal’s in it.

The thickness compared with mortar containing only ordinary Portland cement decreases.

Hence mechanical properties and durability is improved because of the enhancement in interfacial or bond strength.

Mechanism behind is not only connected to chemical formation of C–S–H(i.e. pozzolanic reaction) at interface, but also to the microstructure modification (i.e. CH) orientation, porosity and transition zone thickness) as well.

4.3 FRESH CONCRETE PROPERTIES

In order to study the effect on fresh concrete properties when rice husk ash is added to the concrete as cement replacement, the SCC containing different proportions of rice husk ash were tested for Slump flow, V-funnel, L-box and U-box. Various mixes have been designed and tested for fresh concrete properties. SP content varied from 0.8-1.5% and w/b ratio was varied from 0.35-0.45. Optimum results were obtained by the mix with 1% SP and 0.41 w/c ratio.

The results of fresh properties of all self compacting rice husk ash concrete are included in Table: 4.1. The table shows the properties such as Slump flow, V-funnel flow time, L-box, U-box. In terms of Slump flow, all SCC’s exhibited satisfactory slump flow in the range of 550-800 mm, which is an indication of good deformability.

Mixture ID	Slump Flow (mm)	U-Box (H1-H2)	L-Box (H2/H1)
0RHA	730	5	1
10RHA	700	18	0.9
15RHA	670	25	0.8
20RHA	600	30	BLOCKING

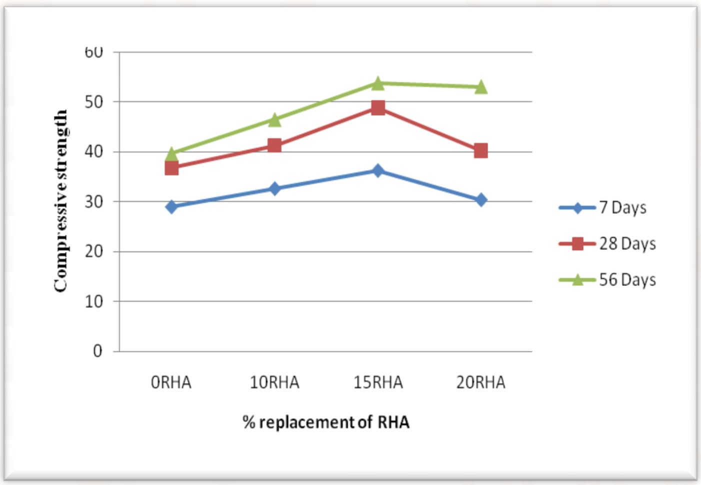
Table 5.1: Fresh concrete properties for mixes with and without Rice Husk Ash

The time ranging from 6-12 sec is considered adequate for a SCC. Test results of this investigation indicated that all SCC mixes meet the requirement of allowable flow time. Maximum size of aggregate was kept as 12 mm in order to avoid blocking effect in L-box. The gap between re- bars of L-box test is 35 mm. The L-box ratio H2/H1 for the mixes was above 0.8.

The U-box difference in height of concrete in two compartments was in range of 5-40 mm. All the fresh properties of concrete values were in good agreement to that of values given by European guidelines.

4.4 COMPRESSIVE STRENGTH

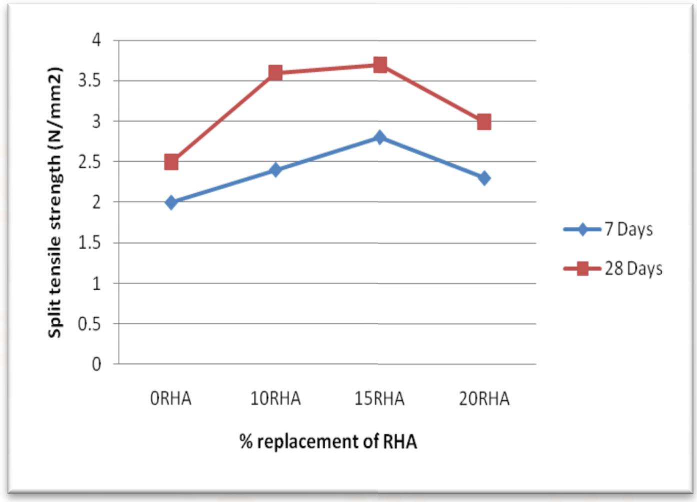
In order to study the effect on compressive strength when rice husk ash is added to the self compacting concrete, as cement replacement, the cube containing different proportions of rice husk ash was prepared and cured for 7 days, 28 days and 56 days. The test was conducted on ASTM capacity 3000 KN. From the results as mentioned in Table 4.2, it is concluded that 56 days strength is higher than 7d and 28d strength. This is basically due to continuous hydration of cement with concrete.



Graph 4.1: Compressive strength test results for various SCC mixes

4.5 SPLITTING TENSILE STRENGTH

Split tensile strength of the concrete was carried out at the age of 7 days, 28 days. Split tensile strength of SCC mixes at various percentages RHA



Graph 4.2: Split Tensile strength results of SCC mixes with and without Rice Husk Ash

The highest strength is obtained by the mix 15RHA at all ages. As per results shown in Graph 4.2 the split tensile strength increased with increase in percentage of RHA up to15% replacement by RHA. There is decrease in strength for mix 20RHA, but the values are still higher than control mix at all ages. With increase in RHA content from (10-20%) SCC mixes develop splitting tensile strength between 2.0 and 2.8 MPa for 7 days, 2.5 and 3.7 MPa for 28 days.

4.6 POROSITY

The porosity is the significant factor as it affects directly the durability of the SCC. The results of porosity of SCC concrete mixes are given in below Graph 4.3.The results indicate that the porosity decreased with increase in curing time. The main reason behind this is due to the additional or increased rate of hydration and/or pozzolanic reactions. There is more formation of C-S-H gel as a product of pozzolanic reaction between calcium hydroxide and silica. This gel fills the voids and increases the density of concrete. Lowest porosity is achieved by mix 15RHA. 20RHA mix shows increase in porosity, but it is still less than the CM.As shown in Graph 3, the porosity decreased with increase in age. This is basically due to large formation of C-S-H gel, dense structure is formed so porosity decreased. Results are comparable to as per standard values.

Graph 4.3: Porosity values for various SCC mixes

5. CONCLUSIONS

5.1 GENERAL

The strength and durability characteristics of Self compacting concrete (SCC) incorporating Rice Husk Ash (RHA) have been computed by replacing 10%, 15%, and 20% cement by rice husk ask. The inclusion of rice husk ash as replacement of cement does not affect the strength properties negatively as the strength remains within limits. The concrete was endowed with comparable mechanical properties and greater resistance to aggressive agents (chemical, physical and environmental).On the basis of present study following conclusions have been drawn.

5.2 FRESH CONCRETE PROPERTIES

The present results show that it is possible to design a SCC mix incorporating Rice Husk Ash (RHA) up to 15%. The SCC mixes have a slump flow in the range of 600-800 mm, V-funnel time in the range of 4-10 s, L-box ratio was greater than 0.8 for all mixes and difference in height of concrete in two compartments in U-box in the range of 5-40 mm. With increase in rice husk ash content the workability decreased.

5.3 COMPRESSIVE STRENGTH

For constant water cement ratio, compressive strength increased up to 15%replacement of cement by Rice husk ash. Above 15%, decrease in strength was observed due to reduced hydration reaction and lower cement content, but its value was still higher than controlled mix. SCC mixes develop compressive strength ranging from 29.0 to 32.6 MPa, from 36.7 to 41.2 MPa, from 39.6 to 46.4 MPa at 7, 28 and 56days.

The increase of about 25% strength at 7 days, 33% strength at 28 days and 36%strength at 56 days were observed with increase of RHA content from control mix (0RHA) to 15RHA.

5.4 SPLITTING TENSILE STRENGTH

Similar trend was shown as for compressive strength. The split tensile strength increased up to 15% replacement of cement by Rice husk ash. SCC mixes develop split tensile strength ranging from 2.0 to 2.8 MPa, form 2.5 to 3.7 MPa, from 2.8 to4.0 MPa at 7, 28 and 56 days.

5.5 POROSITY

With the inclusion of rice husk ash into the matrix, reduced the pores for all mixes. Porosity decreased with increase in curing time due to increased rate of hydration with time. Lowest porosity is obtained by the mix 15RHA. All the values obtained were less than the values obtained by controlled mix containing 0% replacement by rice husk ash. This concludes that inclusion of rice husk ash gives positive effect on the major durability property of SCC.

REFRENCES

1) Bertil Persson, “A comparison between mechanical properties of self-compacting concrete and the corresponding properties of normal concrete” Cement and Concrete Research, 31, 2001, pp 193-198.
2) Nan Su, Kung-Chung Hsu and His-Wen Chai, “A simple mix design method for self-compacting concrete” Cement and Concrete Research, 31, 2001, pp 1799– 1807.
3) N. Bouzoubaa and M. Lachemi, “Self-compacting concrete incorporating high volumes of class F fly ash Preliminary results” Cement and Concrete Research, 31, 2001, pp 413-420.
4) Dr. R. Sri Ravindrarajah, D. Siladyi and B. Adamopoulos, “Development of High-Strength SelfCompacting Concrete with reduced Segregation Potential” 1 Vol., 1048 pp., ISBN: 2-912143-42-X, soft covers.
5) Hajime okamura, Masahiro ouchi, “Self Compacting Concrete” Journal of Advanced Concrete Technology, volume 1, 2003, pp 5-15.

6) Paratibha Aggarwal, Aggarwal and Surinder M Gupta, “Self-Compacting Concrete - Procedure for Mix Design” Leonardo Electronic Journal of Practices and Technologies, Issue 12, 2008, pp 15-24.
7) S. Girish, R.V. Ranganath and Jagadish Vengala, “Influence of powder and paste on flow properties of SCC” Onstruction and Building Materials, 24, 2010, pp 2481–2488.
8) E. Todorova, G. Chernev, G. Chernev.” Influence of metakaolinite and stone flour on the properties of selfcompacting concrete” Journal of Chemical Technology and Metallurgy, 48, 2, 2013, 196-201.
9) Cristian Druta, “Tensile strength and bonding characteristics of self-compacting concrete” B.S. (Mechanical Eng.), Polytechnic University of Bucharest, 1995 August 2003.
10) S Subramanian, S. “Interfaces in concrete – Achieving performance” International Conference on Concretes, Dundee, Scotland (1999).
11) Surabhi.C.S, Mini Soman, Syam Prakash.V, “Influence of Limestone Powder on Properties of Self-Compacting Concrete” 10th National Conference on Technological Trends (NCTT09) 6-7 Nov 2009.
12) Mayur B. Vanjare, Shriram H. Mahure, “Experimental Investigation on Self Compacting Concrete Using Glass Powder”, International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 3, May-Jun 2012, pp.1488- 1492.
13) Suraj N. Shah., Shweta S. Sutar, Yogesh Bhagwat, “Application of industrial Waste- in the manufacturing of Self compacting concrete” Govrnment college of engineering, karad.