Development of High Strength Self Curing Concrete Using Super Absorbing Polymer

K. Bala Subramanian, A. Siva, S. Swaminathan, Arul. M. G. Ajin

***Abstract*—**Concrete is an essential building material which is widely used in construction industry all over the world due to its compressible strength. Curing of concrete plays a vital role in durability and other performance necessities. Improper curing can affect the concrete performance and durability easily. When areas like scarcity of water, structures is not accessible by humans external curing cannot be performed, so we opt for internal curing**.** Internal curing (or) self curing plays a major role in developing the concrete pore structure and microstructure. The concept of internal curing is to enhance the hydration process to maintain the temperature uniformly. The evaporation of water in the concrete is reduced by self curing agent (Super Absorbing Polymer – SAP) there by increasing the water retention capacity of the concrete. The research work was carried out to reduce water, which is prime material used for concrete in the construction industry. Concrete curing plays a major role in developing hydration process. Concept of self curing will reduce the evaporation of water from concrete. Self curing will increase water retention capacity as compared to the conventional concrete. Proper self curing (or) internal curing increases the strength, durability and performance of concrete. Super absorbing Polymer (SAP) used as internal curing agent. In this study 0.2% to 0.4% of SAP was varied in different grade of high strength concrete. In the experiment replacement of cement by silica fumes with 5%, 10% and 15% are studied. It is found that replacement of silica fumes by 10 % gives more strength and durability when compared to others.

***Keywords*—**Compressive Strength, High strength Concrete Rapid chloride permeability, Super Absorbing Polymer.

I. Introduction

Curing the concrete lessen the chances of concrete scaling, surface dusting, concrete cracking and helps to improve the strength and abrasion resistance. Now a day, many researches are going on about the different types of curing and other methods to improve the concrete durability and other strength parameters.

A. High Strength Concrete

In the construction industry high strength concrete has been very common in designing tall structures and other advantages of concrete is its increased strength, higher stiffness, higher durability, economical cost, reduced creep, drying shrinkage, good impact resistance and resistance to abrasion. High strength concrete is achieved by adding different materials like fly ash, silica fumes and super plasticizers, fibers etc. By following the empirical deign of the conventional concrete procedures changes in variation of fracture of fracture models, microstructures the higher strength can be achieved. The main reason we opt for the higher strength concrete is the lack of the conventional concrete standards.

B. Self Curing (Internal Curing) Concrete

Internal curing (or) self curing plays a major role in developing the concrete pore structure and microstructure. The concept of internal curing is to enhance the hydration process to maintain the temperature uniformly. The evaporation of water in the concrete is reduced by self curing agent (Super Absorbing Polymer – SAP) thereby increasing the water retention capacity of the concrete. Self curing concrete can be done in one of the difficult terrains where human access is not possible and the structures are inaccessible, presence of high chemical content such as chlorides, fluorides and other salts. Self curing enables the concrete to reduce the shrinkage and rupture. Any laxity in curing can lead to the less performance and durability of the concrete structure. If proper curing is done we can meet the requirements of the performance and the durability.

II. Literature Review

H. Abdul Razak et al. [1] investigated the metakaolin and silica fume used as cement replacement materials at 5, 10, and 15% by mass. Water-cementitious materials ratios varied from 0.27 to 0.33, and strength testing was conducted up to an age of 180 days. The author concluded that the accuracy of the model increases with concrete age. At ages 28 days and above, 97% of the estimated strengths are within ± 5% of the actual value.

A. S. El-Dieb et al. [2] investigated Water retention for the concrete mixes incorporating self-curing agent is higher compared to conventional concrete mixes, as found by the weight loss with time. Self-curing concrete suffered less self-desiccation under sealed conditions compared to conventional concrete. Self-curing concrete resulted in better hydration with time under drying condition compared to conventional concrete. Water transport through self-curing concrete is lower than air-cured conventional concrete. Water sorptivity and water permeability values for self-curing concrete decreased with age indicating lower permeable pores % as a result of the continuation of the cement hydration.

K. Bala Subramanian. M.E, Assistant Professor, is with the Department of Civil Engineering, Vel Tech High Tech Dr. Rangarajan Dr. Sakunthala Engineering College, Chennai, Tamilnadu, India (e-mail: balasubramanianak@gmail.com).

A. Siva Ph.D Research Scholar is with the Department of Civil Engineering,, Anna University, CEG Campus, Tamil Nadu, India-600025 (e-mail: shiva86aaa@gmail.com).

S. Swaminathan and Arul M. G. Ajin, Under Graduate Student, are with the Department of Civil Engineering, Prince Shri Venkateshwara Padmavathy Engineering College, Tamil Nadu, India-600127 e-mail: swami.charan23@gmail.com, arul.ajin13@gmail.com).

Mohammad Abdur Rashid et al. [3] experimented regarding the requirements of ingredient-materials for producing high strength concrete (HSC) along with the results of an experimental study on achieving HSC has been reported in this paper. Use of quality materials, smaller water-binder ratio, larger ratio of coarse aggregate (CA) to fine aggregate (FA), smaller size of coarse aggregate, and suitable admixtures with their optimum dosages are found necessary to produce HSC. In the experimental study, the targeted strengths of concretes were from 60 MPa to 130 MPa. The strength of concrete depends upon the strength of these components, their deformation properties, and the adhesion between the paste and aggregate surface. The Basic considerations for the mix design of high strength concrete are:

i. Reduced water-cement ratio.
ii. Extensive use of plasticizers.
iii. Application of cement with a high strength potential.
iv. Application of pozzolans and in particular SF.

This paper concludes as the production of HSC may or may not require the special materials, but it definitely requires materials of highest quality and their optimum proportions. In the production of HSC, use of strong, sound, and clean aggregates is essential. Use of lower water-cement ratio along with super plasticizer is the most vital factor to be considered in HSC productions

Arnon Bentur et al. [4] concluded that, autogenous shrinkage did not occur in the lightweight concrete with SSD lightweight aggregate. However, it should be noted that expansion was observed in the concrete, as additional hydration reaction of cement took place due to the supply of internal water from the lightweight aggregate into the dense cement matrix. A partial replacement of normal-weight aggregate by SSD lightweight aggregate was effective in eliminating all the autogenous shrinkage in high-strength concrete. The water retained in AD lightweight aggregate was not sufficient to prevent autogenous shrinkage, although it did reduce its magnitude significantly.

Roberto Troli et al. [5] stated about combined use of SRA and a CaO-based expansive agent in terms of more effective expansion in the absence of wet curing. These effects are significantly reduced when a self-compacting concrete is used because of the prolonged fluid and plastic state of this mixture. This is also due to the higher dosage of super plasticizer in the self-compacting concrete with respect to that used in ordinary super plasticized concrete. Use a super plasticizer with a reduced retarding effect or to use an expansive agent based on CaO produced at higher temperature (>1100°C) so that the restrained expansion occurs later and then in a hardened Concrete.

Michael Golias et al. [6] evaluated the use of lightweight aggregate (LWA) with different moisture contents for use in the internal curing of cementitious mixtures. Oven-dry 24 h pre-wetted and vacuum saturated LWA were tested to determine their influence on the internal curing performance of cementitious systems. When used in oven-dry state, the LWA in a mixture is able to absorb water from the paste prior to setting. The majority of the water absorbed by the LWA is then returned as internal curing water to the paste after set. The oven-dry LWA was able to absorb approximately 55% of the 24 h absorption value (S = 0.55). By adjusting the mixture proportions to account for this LWA absorption, it was possible to achieve internal curing benefits (increase in strength and degree of hydration and decrease in autogenous shrinkage and water sorption). While the majority of internally cured applications will still benefit from pre-wetting the aggregate before use, this paper validates potential applications for dry bag products or other systems where this may be more difficult to achieve. When vacuum saturated, the LWA appears to retain more of the extra water in smaller pores. When being held in these smaller pores, it is more difficult for the IC water to migrate into the cement paste; however, these mixtures still showed relatively good internal curing performance.

Ole Mejlhede Jensen et al. [7] have suggested that internal curing is mainly based on the saturated lightweight aggregate particles and superabsorbent polymers. Internal curing ensures the surrounding source to water for the cement paste during the cementitious reactions in the concrete. In which cells and gels are the major water containers found in nature. A cell membrane provides a boundary to water, whereas a polymer network incorporates water in its intermolecular space. Normal aggregate, Bentonite clay, super absorbent polymers, pumice, perlite, Liapor and Leca, Stalite, Diatomaceous earth, and Emulifised water may be used for internal curing. These materials cost based on availability and transportation. The realistic possibilities for internal water curing of concrete are found within superabsorbent polymers and substances with physically held water, i.e. mainly lightweight aggregates. The concrete may need up to 50 kg/m^3 of internal curing water to offset self-desiccation and self-desiccation shrinkage.

M. Yaqub et al. [8] have concluded that smaller size aggregate, fineness modulus of fine aggregate and increase of cement content play major role to develop high strength concrete which can give high compressive strength.

III. Experimental Investigation

The experimental investigation has been performed to investigate about the strength of the self curing concrete by adding poly ethylene glycol (PEG 400) at 0.2%, 0.3%, 0.4% by weight of cement. Concrete was obtained high strength by adding mineral admixture (Silica fume –SF) as a replacement of cement with varying percentages as 5%, 10%, and 15% and by increase the workability by mixing of chemical admixture (Super Plasticizer-Glenium B233). The optimum dosage of Super Plasticizer has been found by Marsh Cone test.

In this experiment, one set of conventional cured high strength concrete and another set of self cured high strength concrete were experimented. The following sets of tests were done to study the compressive, tensile, and flexural strength. The grade of concrete investigated is M 60, M 70, M 80.The subsequent tests such as compressive strength, split Tensile strength, Flexural strength, Rapid Chloride Permeability Test and Water sorpitivity Test are carried out for conventionally cured High Strength Concrete and with High Strength Self Cured Concrete. The tests results were analyzed and compared.

IV. Materials Used

The different types of materials used in this investigation are given below:

A. Cement

According to the Indian Standards 12269:1987 Ordinary Portland cement (OPC) of grade 53 was used.

B. Fine Aggregate

Usually sand or stone dust and its size is limited to 4.75mm gauge, i.e., passing through 4.75mm IS sieve but retained on 75 micron sieve according to the IS: 383–1970 code recommendations.

C. Course Aggregate

Broken stone/gravel and its size is 4.75mm gauge plus i.e., retained on 4.75mm IS sieve.

D. Super Plasticizers

In this project, GLENIUM B233, a High Range Water Reducer is chosen as a super plasticizer. This complies with IS 9103:1999 and ASTM C494 Type F. GLENIUM B233 is an admixture of a new generation based on modified polycarboxylic ether. The product has been primarily developed for applications in HPC where the high durability and performance is required. GLENIUM B233 is free of chloride and low alkali. It is compatible with all types of cements.

E. Super Absorbent Polymer (SAP)

The common SAPs are added at rate of 0–0.6 wt % of cement. The SAPs are covalently cross-linked. They are Acryl amide/acrylic acid copolymers. One type of SAPs are suspension polymerized, spherical particles with an average particle size of approximately 200 mm; another type of SAP is solution polymerized and then crushed and sieved to particle sizes in the range of 125–250 mm. The size of the swollen SAP particles in the cement pastes and mortars is about three times larger due to pore fluid absorption. The swelling time depends especially on the particle size distribution of the SAP. It is seen that more than 50% swelling occurs within the first 5 min after water addition.

V. Marsh Cone Test (Optimum Dosage of Super Plasticizer)

Marsh cone testing method is used for finding the saturation dosage (or) optimum dosage for mix design. When flow time is measured with different super plasticizer dosages expressed as a percentage of the solids contained in the super plasticizer to the cement mass at a given time, a curve is composed of two lines having different slopes. Figs. 1-4 show the procedure and the test results of the marsh cone stability test.

Fig. 1 Marsh cone Apparatus

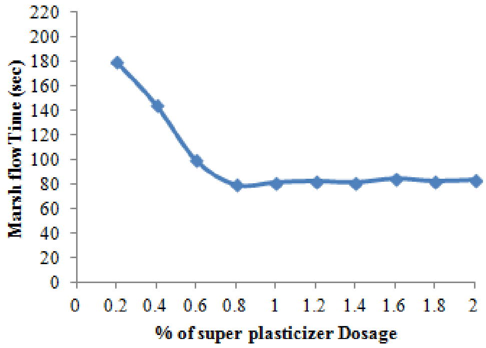

Fig. 2 Optimum Dosage of Super plasticizer for M60

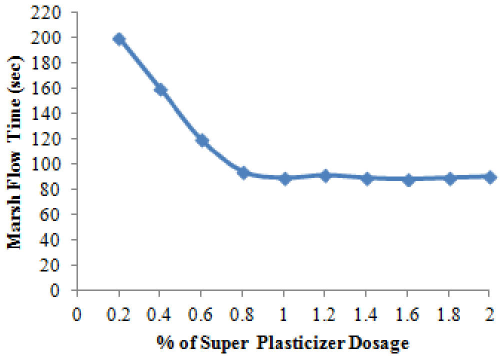

Fig. 3 Optimum Dosage of Super plasticizer for M70

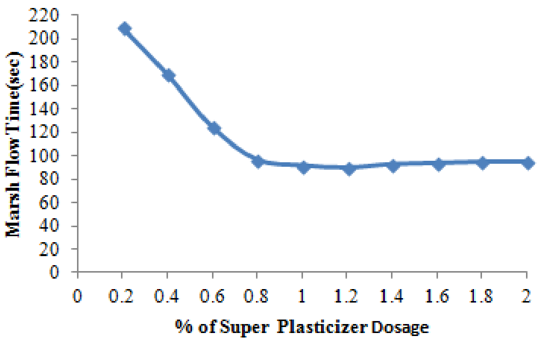

Fig. 4 Optimum Dosage of Super plasticizer for M80

VI. Compressive Strength of Cube

The cube specimens were tested on compression machine of capacity of 3000 kN. The machine was cleaned and the specimen was placed in such a manner it was given load on opposite sides equally. The centre of the frame was aligned to the centre of the loading frame. The load was applied constantly in an increasing manner till the ultimate load. The maximum load was applied to the specimen. Figs. 5-9 show the procedures and the test results of the compression test.

Fig. 5 Casting of Cubes

Fig. 6 Compressive strength Test

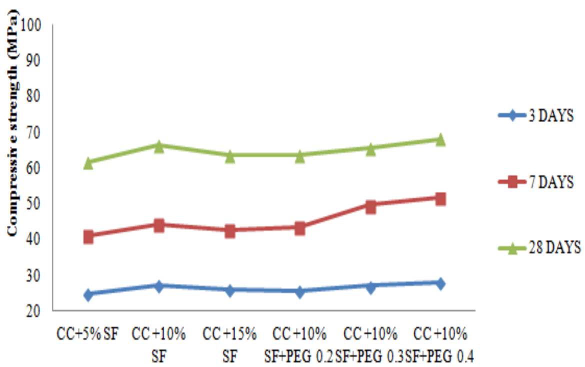

Fig. 7 Compressive Strength Result for M60

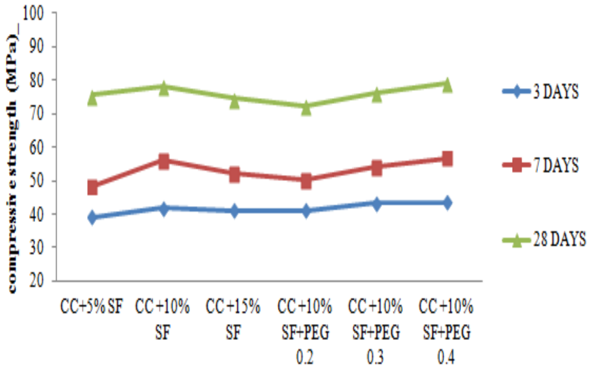

Fig. 8 Compressive Strength Result for M70

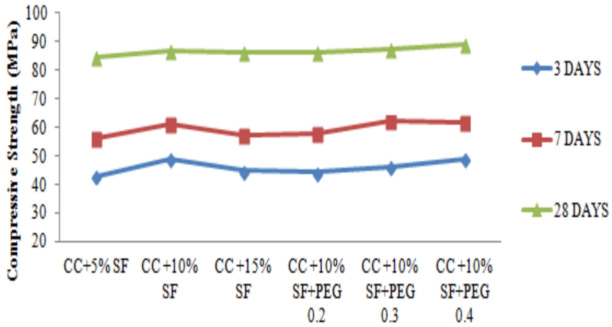

Fig. 9 Compressive Strength Result for M80

VII. Split Tensile Strength of Cylinder

The split tensile tests were carried to find the tensile strength of the cylinder. The test results of the M60, M70, and M80 grade of concrete were plotted in Figs. 10-13.

Fig. 10 Split Tensile strength Test

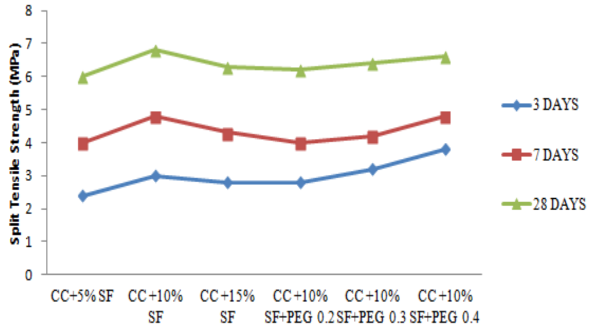

Fig. 11 Split Tensile Strength Result for M60

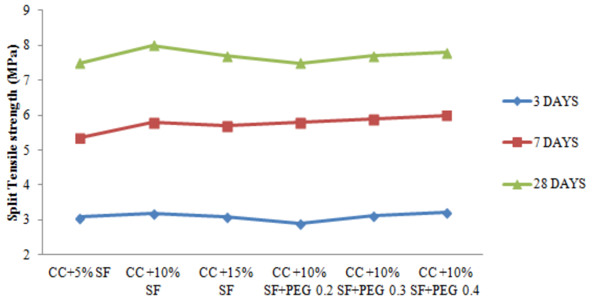

Fig. 12 Split Tensile Strength Result for M70

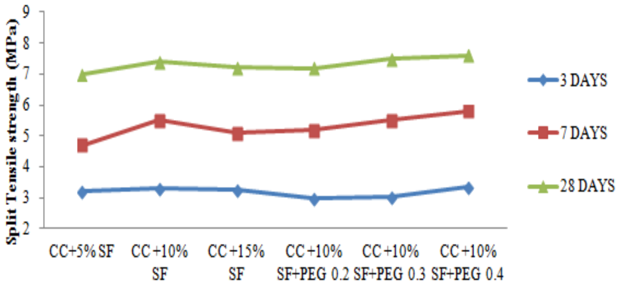

Fig. 13 Split Tensile Strength Result for M80

VIII. Flexural Strength of Prism

The flexural strength test was carried for the prisms of grade M60, M70, M80 cured for 28 days. Fig. 14 shows the testing apparatus of the flexural strength apparatus. Fig. 15 shows the graph of the tested results which are plotted in the graph.

IX. Rapid Chloride Permeability Test

The rapid chloride permeability test for cylinder was carried to find out the permeability of chloride in the concrete. Fig. 16 shows the testing apparatus of the rapid chloride permeability test apparatus. Fig. 17 shows the graph of the tested results which are plotted in the graph.

Fig. 14 Flexural strength Test

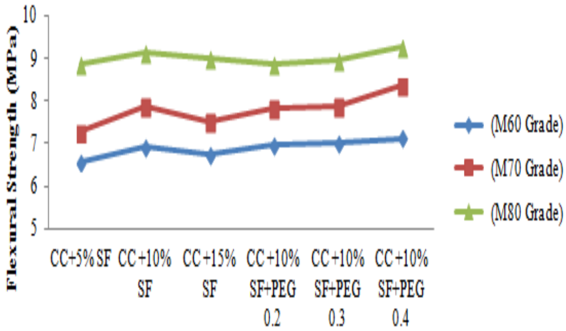

Fig. 15 Flexural Strength Result

Fig. 16 Rapid chloride Permeability Test

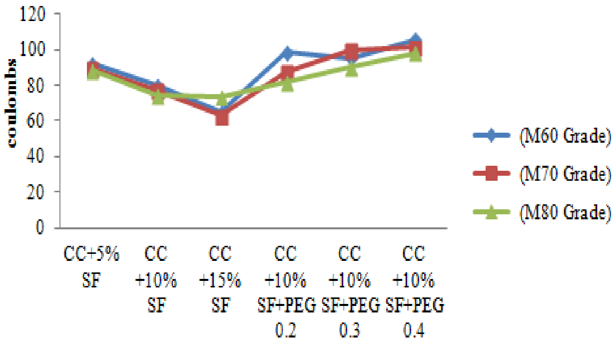

Fig. 17 Rapid Chloride permeability Result

X. Water Sorpitivity Test

The water sorpitivity tests are carried out on cylinders (diameter 50 mm, height 100 mm) are poured and stored immediately after mixing in a room temperature and tested at the age of 28 days (according to the IS Code). The Water sorpitivity test for cylinder was carried to find out the porosity in the concrete**.** The cylinder surface expect bottom surface coated by air tight resin with three layer. The bottom surface is immersed in water 2mm-5mm depth and water absorption measured with periodic time interval. Fig. 18 shows the testing apparatus of the test water sorptivity apparatus. Figs. 19-21 show the graph of the tested results of M60, M70 and M80 grade of concrete which are plotted in the graph respectively.

Fig. 18 Water Sorpitivity Test

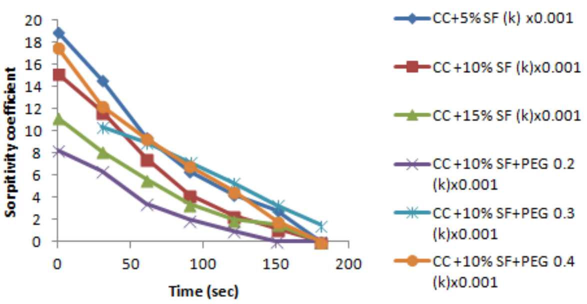

Fig. 19 Water permeability Result for M60

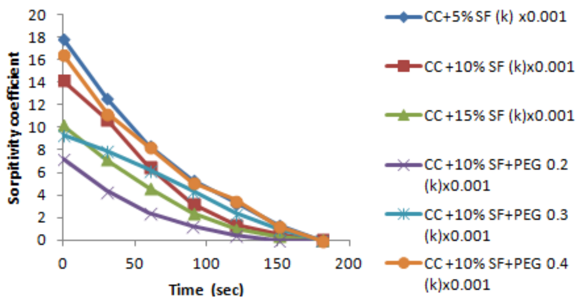

Fig. 20 Water permeability Result for M70

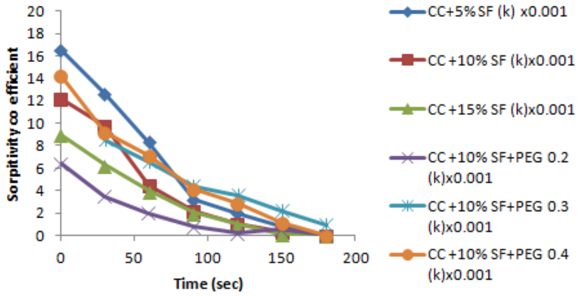

Fig. 21 Water permeability Result for M80

XI. Conclusions

From this investigation of the authors, the following could be concluded.

1. Desired strength characteristics and Rapid chloride permeability properties results were obtained by using Polyethylene Glycol as Self-curing agent.
2. From the workability test results, it was found that the self-curing agent improved Workability.
3. For High Strength Concrete, the strength development of concrete is more if the replacement percentage of silica fume by weight of cement is 10% but Rapid chloride permeability of the concrete decreases if the replacement percentage of silica fume by weight of cement is 15%.
4. The Strength of the concrete increases significantly with the increase of self-curing agent. i.e., concrete with 0.4% of PEG gives more strength than that with 0.2%, and 0.3%

References

[1] H. Abdul Razak and H.S. Wong, "Strength estimation model for high-strength concrete incorporating metakaolin and silica fume", Cement and Concrete Research journal, 2005, Vol. 35, pp 688– 695
[2] Dieb A.S, "Self-curing concrete: Water retention, hydration and moisture transport, Construction and Building Materials journal, 2007, Vol 21, pp 1282-1287.
[3] Mohammad Abdur Rashid and Mohammad Abul Mansur, "Considerations in producing High Strength Concrete", Journal of Civil Engineering, 2009, Vol. 37(1), pp 53-63
[4] Arnon Bentur, Shin-ichi-Lgarashi, and Konstantin Kovler, "Preventation of autogenous shrinkage in high-strength concrete by internal curing using wet lightweight aggregates" Cement and Concrete Research, 2001, Vol. 31,pp 1587-1591.
[5] Roberto Troli, Antonio Borsoi, Silvia Collepardi, Glenda Fazio, Mario Collepardi, and Saveria Monosi, "Self compacting/curing/Compressing Concrete" 6th International Congress, Global Construction, Ultimate Concrete opportunities, Dundee, U.K ,2005.
[6] Michael Golias, Javier Castro, Jason Weiss , "The influence of the initial moisture content of lightweight aggregate on internal curing", Construction and Building Materials , 2012, Vol. 35 ,pp 52–62.
[7] Ole Mejlhede Jensen. Pietro Lura, "Techniques and materials for internal water curing of concrete" Materials and Structures, 2006, Vol.39, pp 817–825.
[8] M. Yaqub, Imran Bukhari, "Development of mix design for high strength Concrete," 31st Conference on our world in concrete & structures, Singapore, 2006.