A STUDY ON SELF-CURING AND SELF-COMPACTING CONCRETE USING POLYETHYLENE GLYCOL

[1]Dadaji B. Jadhav , [2]Ranjana Ghate
[1]Dadaji B Jadhav Is Currently Pursuing Master Degree Program In Structural Engineering And Construction, BIT Ballarpur, Maharashtra
[2]Ranjana Ghate Is An Astt. Prof. In Dept. Of Civil Engineering, BIT Ballarpur, Maharashtra, India

***Abstract*— Self-curing is done in order to fulfill the water requirements of concrete whereas self-compacting concrete is prepared so that it can be placed in difficult positions and congested reinforcements. This investigation is aimed to utilize the benefits of both self-curing as well as self-compacting. The present investigation involves the use of self-curing agent viz., polyethylene glycol (PEG) of molecular weight 4000 (PEG 4000) for dosages ranging between 0.1 to 1% by weight of cement added to mixing water. Two mixes with different w/c ratio were considered in the investigation.**

Workability tests i.e. slump flow, T50, V-funnel, J-ring, L-box were conducted on the fresh concrete whereas water retention and compressive strength were evaluated to determine the properties of hardened concrete.

Comparative studies were carried out for water retention and compressive strength for conventional SCC and self-cured SCC.

The compressive strength of self-cured SCC are comparable with traditional cured specimens at lower w/c ratio whereas does not provide satisfactory results at higher w/c ratio.

Keywords- self-curing, polyethylene glycol (PEG), water retention, compressive strength

***Index Terms*—Introduction, Scope and Objective of Investigation, Experimental programmer, Results and discussion, Conclusions, Comparative study of test results, References.**

I. INTRODUCTION

1. Need for self–curing

When the mineral admixtures react completely in a blended cement system, their demand for curing water (external or internal) can be much greater than that in a conventional ordinary Portland cement concrete. When this water is not readily available, due to depercolation of the capillary porosity, for example, significant autogenous deformation and (early-age) cracking may result. Due to the chemical shrinkage occurring during cement hydration, empty pores are created within the cement paste, leading to a reduction in its internal relative humidity and also to shrinkage which may cause early-age cracking. This situation is intensified in HPC (compared to conventional concrete) due to its generally higher cement content, reduced water/cement (w/ c) ratio and the pozzolanic mineral admixtures (fly ash, silica fume). The empty pores created during self-desiccation induce shrinkage stresses and also influence the kinetics of cement hydration process, limiting the final degree of hydration. The strength achieved by IC could be more than that possible under saturated curing conditions. Often specially in HPC, it is not easily possible to provide curing water from the top surface at the rate required to satisfy the ongoing chemical shrinkage, due to the extremely low permeabilities often achieved.

2. Mechanism of internal curing

Continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials (free energy) between the vapour and liquid phases. The polymers added in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules which in turn reduces the vapour pressure, thus reducing the rate of evaporation from the surface.

3. Potential materials for self-curing

The following materials can provide internal water reservoirs:

[1] Lightweight Aggregate (natural and synthetic, expanded shale),
[2] LWS Sand (Water absorption =17 %)
[3] LWA 19mm Coarse (Water absorption = 20%)
[4] Super-absorbent Polymers (SAP) (60-300 mm size)
[5] SRA (Shrinkage Reducing Admixture) (propylene glycol type i.e. polyethylene-glycol)
[6] Wood powder

4. Concrete deficiencies that self-curing can address

The benefit from self-curing can be expected when

1. Cracking of concrete provides passageways resulting in deterioration of reinforcing steel,
2. low early-age strength is a problem,
3. permeability or durability must be improved,
4. Need for: reduced construction time, quicker turnaround time in precast plants, lower maintenance cost, greater performance and predictability.

5. Self-compacting concrete

Self-compacting concrete is basically a concrete which is capable of flowing in to the formwork, without segregation, to fill uniformly and completely every corner of it by its own weight without any application of vibration or other energy during placing.There is no standard self-compacting concrete. Therefore each self-compacting concrete has to be designed for the particular structure to be constructed. However working on the parameter which affects the basic properties of self-compacting concrete such as plastic viscosity, deformability, flowing ability and resistance to segregation, self-compacting concrete may be proportioned for almost any type of concrete structure. To establish an appropriate mixture proportion for a self-compacting concrete the performance requirements must be defined taking into account the structural conditions such as shape, dimensions, reinforcement density and construction conditions. The construction conditions include methods of transporting, placing, finishing and curing. The specific requirement of self-compacting concrete is its capacity for self-compaction, without vibration, in the fresh state. Other performances such as strength and durability should be established as for normal concrete. The highly fluid nature of SCC makes it suitable for placing in difficult conditions and in sections with congested reinforcement. Use of SCC can also help minimize hearing-related damages on the worksite that are induced by vibration of concrete. Another advantage of SCC is that the time required to place large sections is considerably reduced.

- **Principles of SCC mixture design**

Small sized and limited coarse aggregate reduce internal stresses causing blockage. HRWRs increase the paste flow, VMAs increase paste viscosity to reduce segregation and mineral admixtures lower the heat of hydration and enhance the stability.

- **Need of Study**

A very limited work is reported from this area having the benefits of both self-curing as well as self-compaction. The future for this type of concrete is very bright due to scarcity of skilled man power, non-mechanization of construction industry, abundant availability of construction materials available at very low cost. The properties of this type of concrete, if found satisfactory would be a great step in concrete technology compiling the advantages of both internal curing as well as self-consolidation.

II. LITERATURE REVIEW

This chapter includes the literature review that has been carried out in order to understand the concept behind the topic and accordingly plan the experimental programmer for further research in the same field.

1. Self-Curing Concrete

Dhir et al. [1] focused on achieving optimum cure of concrete without the need for applying external curing methods. The chemical ability to reduce evaporation from solution and to improve water retention in OPC was measured by weight loss. Initial surface absorption and compressive strength tests were made to determine surface permeability and strength development. The scanning electron microscope was used to determine the influence of admixtures on cement paste microstructure.

Conclusion

- It is possible to improve water retention in cement paste by means of a chemical addition to the mix.
- Improved water retention does not always lead to a proportionate increase in degree of cement hydration and hence better concrete properties, although in many cases it does.
- A number of chemicals improved concrete surface characteristics. It appears that the presence of the chemical is enhancing hydration beyond that achieved by water retention.

Liang et al. [2] observed that a combination of wax preferably paraffin wax and glycol preferably polyethylene glycol(PEG),when added to concrete enables internal curing which in many respects is equal to or superior to traditional forms of curing concrete. The internal curing compound used has 10%PEG, 57%paraffin wax, 33% water (comp. 2).

The curing compound was tested for the following parameters

- Evaporation rate
- Porosity
- Shrinkage
- Weight loss
- Compressive strength

The test results were compared with two other curing compounds, membrane curing and no curing condition.

The curing compounds used were

Compound 1- Water, wax emulsion & high MW polyethylene oxide

Compound 2- Water, paraffin wax, PEG (current invention)

Compound 3- Water based polyethers

The following conclusion has been reached

- Internal curing composition 2 exhibits moisture retention characteristics similar to those of the solvent borne resin membrane and performs better than 3 day water curing.
- Internal curing composition 1 & 2 give compressive strength similar to those of the solvent borne resin membrane, however composition 3 shows a significantly lower strength at higher dosages.
- Porosity and absorption values of internal curing compound are comparable with solvent borne resin membrane and 3 day water curing.

2. Self-Compacting Concrete

Nan-su et al. [3] proposed a new mix design method for self-compacting concrete (SCC). First, the amount of aggregates required is determined, and the paste of binders is then filled into the voids of aggregates to ensure that the concrete thus obtained has flowability, self-compacting ability and other desired SCC properties. The amount of aggregates, binders and mixing water, as well as type and dosage of superplasticizer (SP) 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 indicate that the proposed method could produce successfully SCC of high quality.

Conclusions

- The aggregate PF determines the aggregate content and influences the strength, flowability and self-compacting ability.

- SCC designed and produced with the proposed mix design method contains more sand but less coarse aggregates, thus the passing ability through gaps of reinforcement can be enhanced.

Bingol et al. [4] studied the effect of air curing, water curing and steam curing on the compressive strength of Self Compacting Concrete (SCC). For the study, SCC is produced with using silica fume (SF) instead of cement by weight, by the ratios of 5%, 10% and 15%, and fly ash (FA) with the ratios of 25%, 40% and 55%.

Conclusions derived from the experiment were:

- The increase in the replacement percentage of SF resulted in increases in compressive strength; while the increase of FA content affected the compressive strength inversely. SCC mixes with 15% SF replacement of cement content provided the highest compressive strength.
- The highest compressive strength values were obtained from standard cured specimens (cured in water for 28 days). The increase in the water curing duration resulted in increases in compressive strength. Air curing caused compressive strength decreases and the lowest strength values are obtained from air cured specimens for all groups.
- Both SF and FA replacement groups gained more strength according to control group without any mineral admixture, at steam curing applications.

III. CONCLUSIONS

- Use of PEG as a self-curing agent resulted in better hydration of concrete.
- It can give strength on par with concrete with conventional curing methods.
- Good workability can be achieved with the use of PEG.
- Lower water loss and increased relative humidity can be expected.
- Lower water permeability and sorptivity achieved.
- Reduces self dessication, autogenous shrinkage and chemical shrinkage to a maximum extent.
- Overall better performance of concrete.
- Lower workability observed in case of Polyacrylamide (PAM) due to the formation of gelatinous structure.
- Lower dosage of PEG more efficient than higher dosage.
- Lower molecular weight PEG more effective than higher molecular weight PEG.
- SCC with silica fume performs satisfactory than SCC with Fly Ash from strength point of view.
- SCC requires initial water curing to achieve desirable properties.

Research Significance

- from the literature review carried out on different materials i.e. Light weight aggregate (LWA) and Super absorbent polymers (SAP) it Can be concluded that use of these potential materials tend to decrease the mechanical properties of concrete.
- Thus in the current program use of shrinkage reducing admixture i.e. PEG has been made in order to get the maximum efficiency in relation to mechanical properties.
- Also from the earlier investigation carried out in the institution the dosage has been reduced to 0 to 1% to make the concrete more efficient.

IV. SCOPE AND OBJECTIVE OF INVESTIGATION

- The objective of the investigation is to use the water soluble polymeric glycol, selected from a group consisting of polyethylene glycol (PEG) of average molecular weight (M.W) from 200 to 10000 as self-curing agent and to decide the optimum dosage for different curing conditions under arid atmospheric conditions.
- The objective is to study the compressive strength and water retention by varying the percentage of PEG from 0% to 1% by weight of cement for self-compacting concrete and compare it with conventional SCC. Concrete weight loss with time was evaluated to determine the water retention capacity. Slump flow test, J ring test, L box test and V-Funnel test were carried out on the fresh concrete to evaluate the workability of concrete.
- Two mixes of self-compacting concrete were considered for the study. Polyethylene glycol (PEG) of molecular weight 4000 was used as a self-curing agent in concrete. The concrete mix with and without Self curing agent were subjected to different types of curing i.e. conventional and indoor curing to study the above mention parameters.
- Other objectives were to compare the effect Polyethylene glycol (PEG) on other grades of SCC and to find out the optimum dosage for each grade.

Experimental programme

The experimental program is designed to investigate the strength of self-curing self-compacting concrete by adding poly ethylene glycol PEG4000 @ 0.1%, 0.5% and 1% by weight of cement to the concrete. The experimental program is aimed to study the workability, compressive strength and water retention capacity. The slump flow test, J ring test, U box test, L box and V-Funnel test were conducted for all mixes to kNow the fresh property of concrete. Compressive strength test was conducted at 7 and 28 days. The cubes were weighed for 3, 7,14,21,28 and 56 days from the date of demoulding to investigate the water retention capacity. In this investigation the maximum dosage of self-curing agent was restricted to 1% and minimum dosage to 0.1%. Two different mixes with 28 days cube compressive strengths of concrete were aimed i.e. 70MPa & 50MPa. A total of 90 cubes were cast for the experimental programme.

Nomenclature for specimen

MIX A - 28 days cube compressive strength of about 70 MPa
MIX C - 28 days cube compressive strength of about 50 MPa
O - Ordinary Portland cement (OPC)
PEG - Polyethylene Glycol
H - PEG 4000(Higher Molecular Weight)
I - Indoor Curing

W - Wet/Conventional Curing
SP - Superplasticizer
S.C.A - Self-Curing Agent
SCC - Self-Compacting Concrete

i. For example sample with name AOW represents SCC Mix A with PEG 4000 and dosage of 0% by weight of cement subjected to wet curing.

ii. Sample AOI represents SCC Mix A with PEG 4000 and dosage of 0% by weight of cement subjected to indoor curing. Sample AH1 represents SCC Mix A with PEG 4000 and dosage of 1% by weight of cement subjected to indoor curing.

Materials used

The different materials used in this investigation are:

1. Cement
2. Fine aggregate
3. Coarse aggregate.
4. Polyethylene Glycol(PEG-4000)
5. Polycarboxylate Ether (superplasticizer)
6. Fly Ash
7. Silica Fume
8. Water

Mix design by Nan-Su Method

The principal consideration of the proposed method is to fill the paste of binders into voids of the aggregate framework piled loosely. The loose unit weight of the aggregate is according to the shoveling procedure of ASTM C29, except discharging the aggregate at a height of 30 cm above to the top of the measure. Usually, the volume ratio of aggregate is about 52–58%, in other words, the void in the loose aggregate is about 42–48% according to ASTM C29. The strength of SCC is provided by the aggregate binding by the paste at hardened state, while the workability of SCC is provided by the binding paste at fresh state. Therefore, the contents of coarse and fine aggregates, binders, mixing water and SP will be the main factors influencing the properties of SCC. With the proposed method, all we need to do is to select the qualified materials, do the calculations, conduct mixing tests and make some adjustments, and SCC with good flowability and segregation resistance can be obtained with self-compacting ability as specified by the JSCE. The procedures of the proposed mix design method can be summarized in the following steps.

Conclusions

After analyzing the results obtained from the experimental programme, the following conclusions could be made regarding the use of PEG-4000 in case of self-compacting concrete with low as well as high w/c ratios

1. For Water Retention

- Increasing the percentage dosage of PEG-4000 increases the weight loss for lower w/c ratio. Thus lower dosage showing better water retention for lower w/c ratio.
- Increasing the percentage dosage of PEG-4000 decreases the weight loss for higher w/c ratio. Thus for higher w/c ratio higher dosage shows better water retention.
- Weight loss is more in initial ages compared to later ages for both the grades of concrete. However the loss is more in initial ages for lower grade compared to higher grade. This may be attributed to better sealing of lower w/c ratio in higher grade of concrete.
- With increase in age of curing, there is general increase in the weight loss. However the loss is more at lower grade as compared to high grade.
- Water retention of SCC with low w/c ratio improves with the addition of PEG-4000 and the optimum dosage is found to be 0.1%
- Water retention of SCC with high w/c ratio improves only at high dosage of PEG-4000. Thus the optimum dosage for high w/c ratio is found to be 1%

2. For Compressive Strength

- Compressive strength of SCC with lower w/c ratio improves with the addition of PEG-4000 and is almost equivalent to wet curing. Thus PEG-4000 inclusion proves to be beneficial. The optimum PEG dosage at lower w/c ratio was found to be 0.1%.
- Compressive strength of SCC with high w/c ratio does not show favourable results and were observed to be less than indoor curing for all the dosages. Thus addition of PEG-4000 for high w/c ratio is insignificant

V. COMPARATIVE STUDY OF TEST RESULTS

In this chapter with reference to the similar work carried on PEG-4000 for 28 days cube compressive strength of about 60MPa i.e. Mix B, the comparison has been made for water retention and compressive strength so that addition of PEG-4000 can be analyzed.

1. Water retention

The average weight loss for all the mixes i.e. Mix A, Mix B, Mix C are given in Tables 7.1, 7.2, 7.3 respectively at the ages of 3, 7, 14, 21, 28, 56 days. The w/c ratios used for Mix A, Mix B, Mix C are 0.38, 0.45 and 0.52 respectively.

The conclusions that can be drawn in terms of water retention are:

- Increasing the percentage dosage of PEG-4000 increases the weight loss for lower w/c ratio i.e. Mix A. whereas increasing the percentage dosage of PEG-4000 decreases the weight loss for higher w/c ratio i.e. Mix B and Mix C.
- For lower w/c ratio lower dosage of PEG-4000 gives better water retention whereas for higher w/c ratios higher dosage shows better water retention.
- Weight loss is more in initial ages compared to later ages for all the grades of concrete. However the loss is more in initial ages for lower grades compared to higher grade. This may be attributed to better sealing of lower w/c ratio in higher grade of concrete.

2. Compressive Strength

The compressive strength values at the age of 7 and 28 days for all the mixes i.e. Mix A, Mix B, Mix C are shown in Table 7.4 and the results are plotted in figure 7.4, 7.5, 7.6

The conclusions arrived are:

- Compressive strength of SCC with lower w/c ratio (Mix A) improves with the addition of PEG-4000 and is almost equivalent to wet curing. Thus PEG-4000 inclusion proves to be beneficial. The optimum PEG dosage at lower w/c ratio was found to be 0.1% for Mix A.
- Compressive strength of SCC with high w/c ratio (Mix B) improves with the addition of PEG-4000 and is higher than indoor curing at all dosages of PEG-4000. The optimum dosage was found to be 1%.
- Compressive strength of SCC with high w/c ratio (Mix C) does not show favourable results and were observed to be less than indoor curing for all the dosages. Thus addition of PEG-4000 for high w/c ratio is insignificant.

VI. ACKNOWLEDGMENT

With immense pleasure and great respect I take this opportunity to express my deep sense of gratitude toward my guide **Miss. R. M. Ghate,** Assistant professor and M-tech co-ordinator, **Mr. M.K. Ghumde,** Assistant Professor, Civil Engineering Department, BIT, Ballarpur for invaluable guidance, inspiration, constant encouragement and motivation throughout the project work.

I am grateful to **Prof. S. B. Sohoni**, Head of Department, Civil Engineering, B.I.T, Ballarpur for providing the amicable environment and allowing me to useful available facilities in this department during the course of this study.

We thankfull to **Dr. M. Basavaraj** our beloved principal, for his encouragement and providing all facilities needed in our project.

I am thankful to **Prof. R. M. Ghate** and all the respected Professor from the department of Civil Engineering, BIT, Ballarpur, who helped me to understand basic methodologies of my project.

I am very thankful to my friend and well-wisher who directly or indirectly helped me at every stage to complete this work.

Last but not least, I would like to thanks my family and almighty without their good wishes and blessing this dissertation work could not have been completed.

DADAJI BHAGWAT JADHAV

REFERENCES:

[1] **R.K. Dhir, P.C. Hewlett and T.D. Dyer**, “An investigation into the feasibility of formulating ' self-cure' concrete”, Materials and Structures Vol.27(1994), 606-615.

[2] **R.K. Dhir, P.C. Hewlett and T.D. Dyer**,” Durability of „Self-Cure“ Concrete”, Cement and Concrete Research, Vol. 25. No. 6, 1153-1158, 1995.

[3] **Roland Tak Yong Liang, Robert Keith Sun**, “Compositions and Methods for CuringConcrete”, Patent No.: US 6,468,344 B1, Date of Patent Oct. 22, 2002.

[4] **Mario Collepardi, Antonio Borsoi, Silvia Collepardi, Jean Jacob Ogoumah Olagot, Roberto Troli**, “Effects of shrinkage reducing admixture in shrinkage compensating concrete under non-wet curing conditions”, Cement & Concrete Composites vol. 27 (2005) 704–708.

[5] **M. Collepardi, A. Borsoi, S. Collepardi, R. Troli and M. Valente**, “Self-Curing, Shrinkage-Free Concrete”, ACI Material Journal SP 234-47 (2006) 755-764.

[6] **A.S.El-Dieb**, “Self-curing Concrete: Water Retention, hydration and moisture transport”, Construction and Building Materials Vol.21 (2007) 1282-1287.

[7] **Wen-Chen Jau**, “Self-curing Concrete”, United States Patent Application Publication, Pub. No: U.S. 2008/0072799 A1, Pub.date: Mar. 27, 2008.

[8] **Bart Craeye , Matthew Geirnaert , Geert De Schutter**,“Super absorbing polymers as an internal curing agent for mitigation of early-age cracking of high-performance concrete bridge decks”, Construction and Building Materials vol. 25 (2011) 1–13.

[9] **Garje Rajesh Kumar**, “Self Curing Concrete”, International RILEM conference on advances in construction materials through science and engineering, Hong Kong, China 5-7 september 2011, pp.116-123.

[10] **Marianne Tange Hasholt , Ole Mejlhede Jensen , Konstantin Kovler , Semion Zhutovsky**,“Can superabsorent polymers mitigate autogenous shrinkage of internally cured concrete without compromising the strength?”, Construction and Building Materials vol. 31 (2012) 226–230.

[11] **Raghavendra Y.B and Aswath M.U**,” Experimental investigation on concrete cured with various curing Methods-A Comparative Study”, International Journal of Advanced Scientific Research and Technology, Issue: 2, Vol.3 (2012) 577-584.

[12] **Jagannadha Kumar M.V, Srikanth M, Rao K.Jagannadha**,”Strength Characteristics of Self-curing Concrete”, International Journal of Research in Engineering & Technology,Issue:1,Vol.1(2012) 51 -57.

[13] **A.S. El-Dieb, T.A. El-Maaddawy and A.A.M. Mahmoud**, “Water-Soluble Polymers as Self-Curing Agent in Silica Fume Portland Cement Mixes”, ACI Material Journal Vol.278 (2011) 1-18.

[14] **Ozawa K, Maekawa K, Kunishima M & Okamura H,** “Development of high performance concrete based on the durability design of concrete structures”, EASEC-2, Vol. 1, 1989, pp.445-450.

[15] **Okamura H & Ozawa K**, “Mix-design for self-compacting concrete”, Concrete Library of JSCE, No. 25, June 1995, pp.107-120.

[16] **Nan Su, Kung-Chung Hsu, His-Wen Chai,** “A simple mix design method for self-compacting concrete”, Cement and Concrete Research, 6 June 2001, pp1799-1807.

[17] **A.M.M. Sheinn, C.T. Tam, F.L. Rodrigo**, “Comparative study on hardened properties of self-compacting concrete (SCC) with normal slump concrete (NSC)”, 29th conference Our World in Concrete and Structures (OWICs) ,2004

[18] **Salih Yazicioglu, Sinan Caliskan, Kazim Turk**, “Effect of curing conditions on the engineering properties of self-compacting concrete”, Indian Journal of Engineering & Materials Sciences, Vol. 13, February 2006

[19] **Hui Zhao , Wei Sun , Xiaoming Wu, Bo Gao**, “Effect of initial water-curing period and curing condition on the properties of self-compacting concrete”, Materials and Design 35 (2012) 194–200

[20] **A. Ferhat Bingol , Ilhan Tohumcu**, “Effects of different curing regimes on the compressive strength properties of self-compacting concrete incorporating fly ash and silica fume”, Materials and Design 51 (2013) 12–18

[21] **Pamnani Nanak J., Verma A.K., Bhatt Darshana R**., "Comparison Of Compressive Strength Of Medium Strength Self Compacted Concrete By Different Curing Techniques", International Journal of Engineering Trends and Technology (IJETT) - Volume4Issue5- May 2013, ISSN: 2231-5381
[22] Text book on " Concrete Technology- "Theory and Practice" by M.S.SHETTY
[23] **EFNARC**, "Specification and Guidelines for Self-Compacting Concrete", EFNARC, Association House, UK, February 2005.
[24] **IS-383-1970**, "Specification for coarse and fine aggregates from natural sources for concrete".
[25] **IS: 516–1956 (Reaffirmed 1999),** "Indian Standard Methods of Tests for Strength of Concrete".
[26] **IS: 12269:1987**, "Specifications for 53 grade ordinary Portland cement".
[27] **IS: 2386**, "Method of test for aggregate for concrete", reprinted 1997.
[28] **IS: 456-2000**, Code of practice for plain and reinforced concrete. Bureau of Indian Standards, 2000.