International Journal of Civil Engineering and Technology (IJCIET)
Volume 8, Issue 8, August 2017, pp. 790–797, Article ID: IJCIET_08_08_081
Available online at http://http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=8&IType=8
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

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STUDY ON EFFECTS OF CURING TECHNIQUES ON DURABILITY PROPERTIES OF SELF-COMPACTING CONCRETE WITH METAKAOLIN

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ABSTRACT

The current trend in the construction industry is either using Self Compacting Concrete (SCC) or developing new mix proportions for the application of SCC to various structures. However, many research workers have observed that curing methods and conditions in the field affect the behavior of SCC constructions. Besides, limited knowledge about the impact of curing on the long-term durability of SCC. Consequently, it is necessary to know the behavior of SCC under several curing requirements and the influence of pozzolanic material such as metakaolin on acid and sulphate resistance test. This paper reports the outcomes of a research study accompanied to estimate the effect of curing methods on the durability properties of self-compacting concrete with metakaolin. Six types of curing compounds, namely Immersion, Hot water, Ice, Sea water, Polyethylene Film, Wet Covering and Curing compound is being applied on the concrete specimens. The results showed that Immersion curing has the least effect on acid and sulphate resistance of SCC made with metakaolin.

Key words: durability, Self Compacting Concrete, pozzolanic, Metakaolin, Polyethylene Film, resistance test.

Cite this Article: S. Dayanidhy and Dr. N. Balasundaram, Study on Effects of Curing Techniques on Durability Properties of Self-Compacting Concrete with Metakaolin. *International Journal of Civil Engineering and Technology*, 8(8), 2017, pp. 790–797.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=8&IType=8

1. INTRODUCTION

Development of Self-Compacting Concrete (SCC) is a pleasing fulfillment in the construction industry to surmount difficulties connected with cast-in-situ concrete. SCC has no influence on the skills of labors, the shape and amount of reinforcement or the design of a structure and due to its tremendous fluidity and resistance to segregation, it can be tapped longer distances. SCC is formed at the time to enhance the durability of concrete constructions. Since then, numerous researches have been conducted and SCC has been used in constructions in Japan, mainly by large construction firms. Studies for installing a rational mix design method and Self-Compacting examining methods have been carried out from the perspective of making it a standard concrete.

Curing is the means of regulating the rate and degree of moisture loss from concrete throughout cement hydration. It is noted that when we adopt a particular method of curing it drives to change in temperature and humidity and hence attacking the strength of concrete. The properties of hardened concrete, especially the strength and durability, are exceedingly influenced due to curing since it has a striking impact on the hydration of the cement. The progressions in the construction and chemical industry have paved the way for the advancement of the new curing procedures like self-curing agents, Accelerators, Membrane curing compounds, Water proofing compounds, Wrapped curing, etc. With the expanding scale of the project, traditional curing systems have declared to be a costly thing as there are several possible problems and they have been substituted by Self-curing agents and Membrane curing compounds up to some extent as they can be employed in difficult areas, Vertical structures, Water scarce areas, etc .

It is determined that the chemical reactions among cement & water give C-S-H gel which links the components of concrete, with coarse & fine aggregates, mineral admixtures, etc., and transforms these particles into a rock solid mass [Kulkarni S.B. August 2011]. It is recognized that blended cement needs prolonged curing to transform calcium hydroxide into C-S-H gel. Nevertheless, in the case of OPC as well, voids in the concrete gets packed up and separated by the formation of C-S-H gel after ten days of curing. To have a compact microstructure and impermeability, lengthy curing is a must which drives to magnified durability.

It is perceived from the literature review that few techniques of curing have been investigated for SCC. Nevertheless, a complete study of curing methods usefully suitable in the field and its impact on different durability properties of SCC may be understood. The variation in the microstructure of concretes due to various curing systems may also be examined for durability.

Three sample cubes were cured for each chosen techniques of curing namely normal water immersion, ice water, hot water, sea water, polyester film, wet covering and external curing compound.

Water immersion-W: The cube samples are stored in a shallow water pond directly after de-moulding. They continue in pond till the day of examination.

Hot Water Curing-H: In this examination, the cube samples are stored in the airtight oven in 30 min of adding water. The oven is set to temp 93^{o} C in an hour time and retained at this temperature for 5 hours. The cube samples are taken from the oven, peeled, cooled and tested within 30min.

Ice curing-B: The cube samples were stored in an ice making drum in an ice factory for the detailed period. The temperature within the drum is sustained at zero ^{o}C. The drums were brought out on the morning of the day of examination to thaw the ice before testing.

Sea water curing-S: The sea water is brought to the laboratory from the Bay of Bengal and stored in small drums with cube samples inside. This is alike to immersion curing.

Polyethylene film-P: The cube samples were wrapped with a transparent 0.01 mm thick polyethylene film after de-molding, treating exposed surfaces of concrete as soon as stored in a semi-open place in ambient temperature. Attention is taken that at least three wraps of a sheet are set without marring the finish of samples.

Wet Covering with Gunny Bags-W: Wet jute bags covers were stored as soon as the cube samples were de-molded to sustain water on the surface of the concrete. They were stored wet continuously for the period of tests.

External curing compounds-C: Wax based liquids with the brand name FAIRCURE is sprinkled over the freshly completed cube specimen once the free water on the surface has dried and there is no water seen on the surface apparent on the specimens. This liquid forms an impermeable layer that minimizes the deterioration of moisture from the concrete.

2. MATERIALS AND PROPERTIES

2.1. Cement

The physical characteristics of cement significantly influence the production of concrete. The cement employed for SCC should have good flow and setting properties. It should intensify the fluidity of concrete and should be free from invalid setting due to unanticipated stiffening within a few minutes of mixing with water. The cement used in this study has the following characteristics, and the consistency is 33%, the fineness is 252 m^2/kg, initial and final setting time of 38 minute and 270 minutes respectively.

The chemical tests of Portland cement have unveiled that it principally consists of several oxide compounds. The principal oxide compounds are lime, silica, alumina, and iron. In extension, two minor oxides namely sodium and potassium oxides hold importance, in particular with consideration to alkali-aggregate reactions in concrete. In continuance, magnesia and sulfuric anhydride can be present, while they are not helpful ingredients of cement. The chemical composition of the cement is found to be, it has 19.42% of Silicon-di-oxide (SiO_2), 5.42 % of Aluminium oxide (Al_2O_3), 5.23% of Iron oxide (Fe_2O_3), 61.34% of Calcium oxide(lime) Cao, 2.7% of Sulphur-tri-oxide(SO_3), 9.91% of Magnesia (MgO) and 2.05% of Loss on ignition

2.2. Metakaolin as SCM

Metakaolin is taken by calcination of true kaolin clay at a temperature in between 650^{o}C and 850^{o}C, succeeded by grinding to accomplish a fineness of 15000 m^2/kg. The color of the metakaoline is found as white, its specific gravity is found as 2.50, its specific surface area is found as 327 m^2/kg. Fine Aggregates (Sand)Locally accessible sand in the form of natural sand by the reference is employed as the fine aggregate (FA). The sand is analyzed for mass passing 4.75 mm sieve. The property test on the fine aggregates designates the following details. The zone of sand is found as Zone II, the specific gravity is found as 2.55, the fineness modulus is found as 2.87, the bulk density is found as 1776 kg/m^3 and the water absorption is found as 1.873%.

2.3. Coarse Aggregate

Coarse aggregate is a granular material which can be among coarse sand and pebbles. In the current situation with the development in block paving designations, it has displayed a viable alternative bedding material for pervious paving and other kinds of elemental paving employed in areas of high water intrusion. The examination results for the characteristics of grit are as follows. The specific gravity is found as 2.71, the fineness modulus is found as 5.33, the bulk density is found as 1748 kg/ m^3 the water absorption is found as 1.28% and surface moisture is found as 0.11%.

2.4. Water

Water is an indispensable element of concrete as it actively engages in the chemical reaction with cement. Water with pH value among 6 to 8 is adequate but the best way to find out whether a particular source of water is fit for concrete or not. We have employed regular tap water for preparing concrete. The tap water did not hold any unwanted substances causing color or odor.

2.5. Sea Water

Nowadays, as a course of development, lots of engineering construction including high rise building, bridges, etc. is going on accompanying the coastal belt of the country. Also, it is economical to use sea water that is accessible near the construction site rather of plain water to be conveyed from other sources. So it is required to examine the effect of sea salts on strength characteristics of different kinds of concrete while using sea water for casting and curing of concrete particularly impact on SCC. A laboratory testing is conducted at the environmental laboratory for a sample. The properties of the sea water are as follows. The pH is found as 7.8, the salinity is determined as 3.57, the chloride content is found as 7.89 mg/l, the nitrogen dioxide content is found as 0.01 mg/l, nitrogen trioxide content is found as 0.16 mg/l, and phosphate content is found as 0.14 mg/l.

2.6. Admixtures

The characteristics of the superplasticizer, Polycarboxylic either based, Glenium Sky-784, is as follows. The color is found as a light brown liquid, the relative density is determined as 1.10 ± 0.01 at 25° C, pH is found to be greater than or equal to 6 and chloride ion content is found as less than 0.2%.

3. DESIGN MIX

3.1. Trial Mix Design for SCC

The mix proportions of the connecting SCC mix, many test mixes were prepared and tested for the fresh property tests as per EFNARC designations, and 28 days compressive strength is examined. The final mix proportion or the reference mix of SCC is shown in Table.

Table 1 Mix proportions for M30 & M50 grade SCC reference mix, Materials/m^3

Reference Mix	Cement Kg	Metakaolin Kg	Fine Aggt. Kg	Coarse Aggt. in Kg		Water Lit.	SP
				Grit	Gravel		
M30 SCC	373	174	781	731	0	212	1.05%

3.2. Acid Attack and Sulphate Resistance

SCC cubes of size 150x150x150mm and after 24 hours the specimen were demoulded and subjected to various types of curing. Subsequent 28 days of various curing techniques, the dry weights of the each cured cube is measured, and then the cubes were dipped in water adulterated with 5 % sulphuric acid for 30 days. The characteristics of the solution were preserved throughout this phase by adjusting the solution from time to time. Then the cube samples were taken out, and the surface of the cubes was washed to remove the surface sediments, dried and weighed once again. Then the percentage of weight damage due to acid attack is estimated. Compression strength and the deterioration of the strength due to acid attack were also determined. Likewise, for sulphate resistance test 5% of ferrous sulphate by weight of water is added with water and the cube samples were cured in it for 30 days. The concentration of the solution is sustained entirely this period by adjusting the solution systematically. The cube samples were taken out from the ferrous sulphate solution after 30 days. The surface of the cubes was rubbed to skim the surface sediments, dried and weighed once again. Then the percentage of weight decline due to sulphate attack is determined, and the cube samples are again examined for compression strength and the deterioration of the strength due to sulphate attack is determined as shown in below Tables.

Table 2 Loss of weight in concrete after Acid resistance and Sulphate Resistance Test

S No.	Method of Curing	Weight of cube Before immersion (kg)	Weight of cube After immersion in Acid Solution (kg)	% Weight loss in Acid Solution	Weight of cube After immersion in Sulphate Solution (kg)	% Weight loss in Sulphate Solution
1	Immersion	8.21	8.16	0.61	8.17	0.49
2	Hot water	8.22	8.14	0.97	8.16	0.73
3	Ice	8.23	8.14	1.09	8.16	0.85
4	Sea water	8.21	8.11	1.22	8.14	0.85
5	Polyethylene Film	8.24	8.17	0.85	8.2	0.49
6	Wet Covering	8.19	8.1	1.10	8.11	0.98
7	Curing compound	8.22	8.09	1.58	8.11	1.34

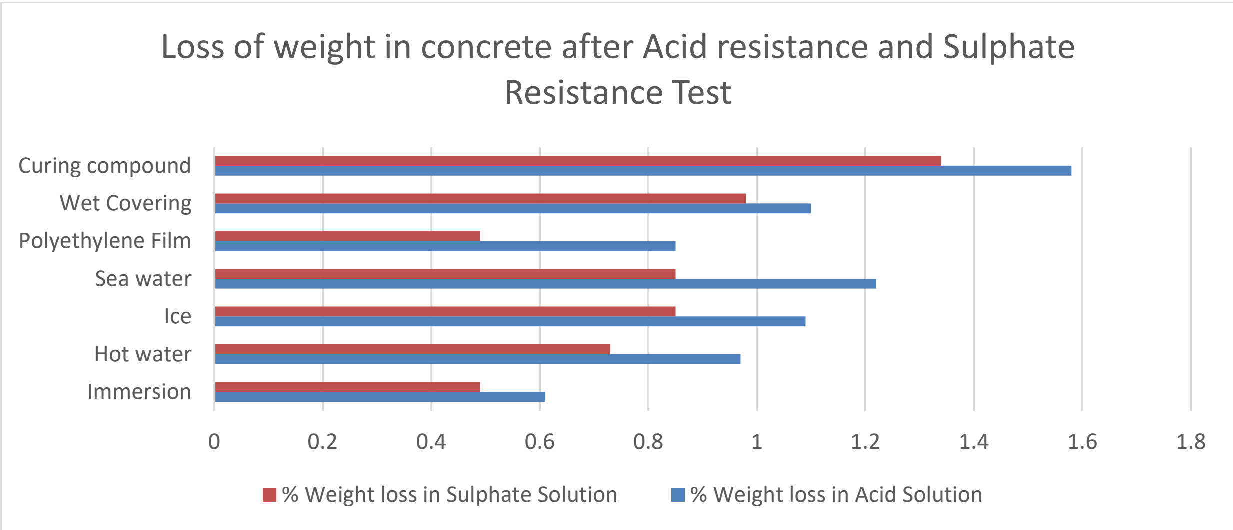

Figure 1 Loss of weight in concrete after Acid resistance and Sulphate Resistance Test

Table 3 Compression strength of concrete before & after acid and Sulphate Resistance Test

S No.	Method of Curing	Compression Strength in N/mm^2 before immersion	Compression Strength in N/mm^2 after immersion in Acid Solution	% loss of Compressive Strength in Acid Solution	Compression Strength in N/mm^2 after immersion in Sulphate Solution	% loss of Compressive Strength in Sulphate Solution
1	Immersion	34.5	32.78	4.99	33.12	4.00
2	Hot water	32.67	29.73	9.00	29.73	9.00
3	Ice	28.73	24.71	13.99	25.28	12.01
4	Sea water	34.17	31.44	7.99	32.12	6.00
5	Polyethylene Film	34.13	31.54	7.59	32.08	6.01
6	Wet Covering	33.2	30.88	6.99	31.54	5.00
7	Curing compound	33.33	30.66	8.01	31.33	6.00

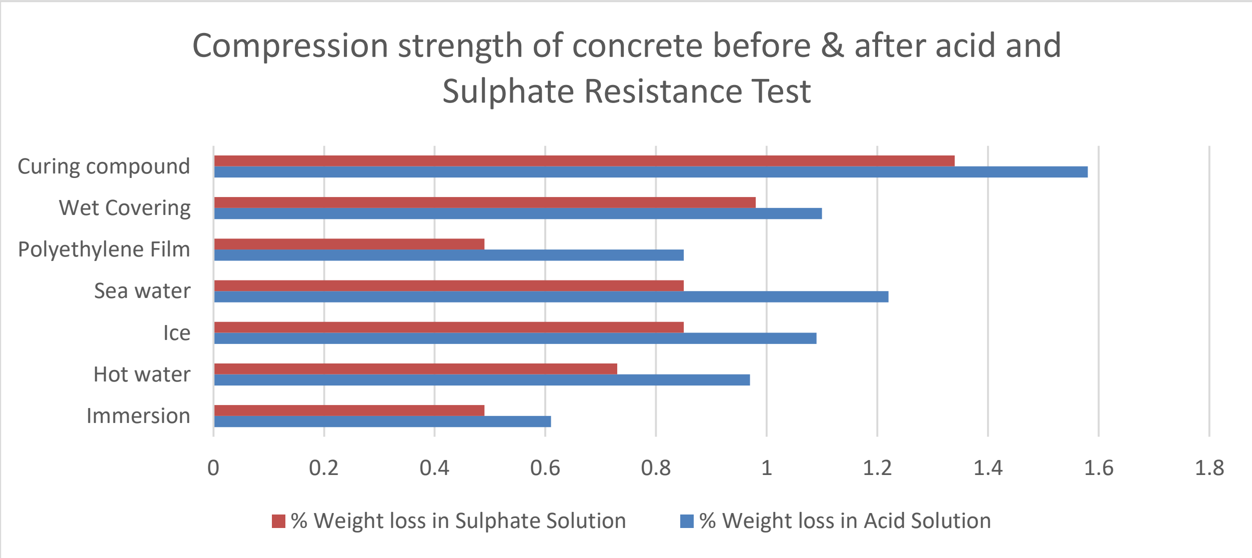

Figure 2 Compression strength of concrete before & after acid and Sulphate Resistance Test

4. CONCLUSIONS

- Immersion curing shows better curing than all other curing techniques as expected though Polyethylene Film curing has only a marginal difference which compared to that of the immersion curing.
- Durability results of hot water curing shows that the technique may be helpful for precast industry where controlling a controlled temperature is achievable.
- The durability properties of the ice curing technique is not poor in both weight loss and compression strength. Certain forethoughts should be used while casting in low-temperature areas.
- Polyester film wrap is also an efficient way of curing providing very good durability features for the SCC.
- Wet Covering and Curing compound technique does not make any comparable durability properties and hence it is not advisable for severe exposure areas.

REFERENCES

[1] Abdelaziz G., "Effect of application time of water-based curing compound on strength, hardness, sorptivity and porosity of blending concretes", Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference, Kualaumpur, Malaysia, 2006.

[2] Bairagi N. K. and Modhera C. D., "Shear strength of fibre reinforced concrete", ICI Journal, 1(4), 2001, pp. 47-52.

[3] Cabrera J. G., Gowripalan N. and Wainwright P. J., "An Assessment of Concrete Curing Efficiency Using Gas Permeability", Magazine of Concrete Research, 41(149), 1989, pp. 193-198.

[4] Dehn F., Holschemacher K. and Weiße D., "Self-compacting concrete (SCC) time development of the material properties and the bond behaviour", Selbstverdichtendem Beton, 2000.

[5] Dhir R. K. and Dyer T. D., "Modern concrete materials: binders, additions and admixtures", International conference held at the University of Dundee, Scotland, UK, Thomas Telford, 1999.

[6] Gebler S. H. and Klieger P., "Effect of fly ash on physical properties of concrete", ACI Special Publication, USA, 91, 1986.

[7] Gram A., "Numerical Modelling of Self-Compacting Concrete Flow -Discrete and Continuous Approach", Royal Institute of Technology (KTH), Stockholm, Sweden, 2009.

[8] Hameed M. A., "Study of mix design and durability of self compacting concrete", Master of Science, King Fahd University of Petroleum and Minerals , Dhahran, Kingdom of Saudi Arabia, 2005.

[9] IS:383-, "Specification for coarse and fine aggregates from natural sources for concrete", Bureau of Indian Standards, New-Delhi, India: 1970.

[10] IS:456-, "Plain & Reinforced concrete-Code of Practice", Bureau of Indian Standards, New-Delhi, India: 2000.

[11] IS:1489-Part-1, "Specification for Portland pozzolana cement - Flyash based ", Bureau of Indian Standards, New-Delhi, India: 1991.

[12] IS:2386-, "Method of test for aggregates for concrete", Bureau of Indian Standards, New-Delhi, India: 1963.

[13] IS:3812-Part-I, "Fly ash as a pozzolanic material", Bureau of Indian Standards, New-Delhi, India: 2003.

[14] IS:3812-Part-II, "Fly ash as an admixture", Bureau of Indian Standards, New- Delhi, India: 2003.

[15] Kosmatka S. H., Panarese W. C. and Association P. C., "Design and control of concrete mixtures", 2002.

[16] Kosmatka W. C. and Panarese S. H., "Text book - Design and control of concrete mixtures", 2002, Chapter-12-Curing

[17] Kulkarni S.B. P. C., "Significance of Curing of Concrete for Durability of Structures", NBM Construction World, New Delhi, India, August 2011.

[18] Neville A. M., "Concrete technology", Pearson Education, India, 2008.

[19] Okamura H. and Ouchi M., "Self-compacting concrete", Journal of Advanced Concrete Technology, 1(1), 2003, pp. 5-15.

[20] Phelan W. S., "Self-Consolidating Concrete (SCC): Today and Tomorrow", STRUCTURE magazine, Michigan city, USA, Sept. 2011, pp. 33-35.

[21] Sonu Pal, M. K. Mishra and V. Pandey, Effects of Al kaline Curing on The Properties of Polyester Fibre Reinforced Concrete. International Journal of Civil Engineering and Technology, 7(4), 2016, pp.432–439

[22] Remya R Nair and Rama Mohan Rao. Pannem, Structural Performance of Recycled Coarse Aggregate Concrete by Different Curing Regimes. International Journal of Civil Engineering and Technology, 8(4), 2017, pp. 1167–1175