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Experimental Investigation on Self Curing Concrete with Partial Replacement of Cement with Metakaolin

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ABSTRACT: Proper curing of concrete structures plays a vital role to meet performance and durability requirements. In conventional curing this is achieved by external curing applied after mixing, placing and finishing. Lack of sufficient and efficient curing may result in autogenous shrinkage or early age cracking in concrete. Current situations pose a lot of difficulty in availability of fresh water for curing purposes. Thus researchers around the world are looking forward into a new curing technique. Self-curing or internal curing is a technique that can be used to provide additional moisture in concrete for more effective hydration of cement and reduced self-desiccation. The ACI-308 Code states that "self-curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water." Conventionally, curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen 'from the outside to inside'. In contrast, self-curing is allowing for curing 'from the inside to outside' through the internal reservoirs. These internal reservoirs can be of various forms including self curing agents or shrinkage reducing admixtures. In the present work the efficiency of self-curing agents are investigated and further the effect of partial replacement of cement in self curing concrete with metakaolin is studied for M20 grade concrete. The optimum percentage of self curing agent required in concrete to attain considerable strength is experimentally found. Further cement is partially replaced with metakaolin in range of 0% to 25% in addition to self curing agent and tests are conducted. The work includes strength tests and tests to check self compacting properties.

KEYWORDS: Concrete, Self curing, Metakaolin, Shrinkage reducing admixture

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I. INTRODUCTION

Concrete is still the most depended and versatile building material used in the construction field. It is well known for its strength and durability. The strength attained by concrete depends on the rate of hydration which is attained by sufficient and efficient curing. Lack of curing may cause a lot many problems, however the scarcity of water calls out for new curing techniques and thus an innovative idea of self curing concrete was developed and even now many researches are being done on it. Efficient curing of concrete structures has an important role in meeting performance and durability requirements. In conventional curing this is achieved by external curing that is applied after mixing, placing and finishing. Self-curing or internal curing is a technique that can be used to provide additional moisture in concrete for more effective hydration of cement and reduced self-desiccation.

1.1 SELF CURING CONCRETE AND ITS NECESSITY

Curing is the process of controlling the rate and extent of moisture loss from concrete during hydration of cement. This also controls the temperature of hydrating concrete since this affects the rate of hydration. It also keeps the concrete moist by preventing the loss of moisture from concrete during the period of gaining strength. Lack of curing shall adversely affect the strength and durability of concrete and may result in its quick shrinkage and early age cracking too. Curing is done primarily to keep the concrete moist by preventing the loss of moisture from the concrete during the period of gaining strength. Curing must be provided for a sufficient period of time so as to achieve its potential strength and durability. However this era is witnessing serious water scarcity. It is also said that a third world war will be witnessed for this inevitable natural resource. In this circumstances construction field cannot demand large amount of water for curing and other purposes so to

overcome the lack of availability of fresh water for curing a newly developed approach is introduced known as internal curing or self curing.

Self-curing is a technique that can be used to give extra dampness in cement to the more effective hydration of concrete and decreased self-desiccation. As per ACI 308 code- *Internal curing is the process by which hydration of cement due to the availability of additional internal water that is not part of the mixing water.* It is one of the special concrete in mitigating in sufficient curing due to human negligence paucity of water in arid areas, inaccessibility of structure in difficult terrains and in areas where the presence of fluorides in water will badly affect the characteristics of concrete [6]. This project looks forward onto the comparison of self curing concrete with conventional concrete. Moreover, it is found that the usage of cement in concrete has demanded for very high production of cement. On view of the environmental conditions it is said that the CO2 emission from the concrete production is directly proportional to the cement content used in the concrete mix; 900 kg of CO2 are emitted for the fabrication of every ton of cement [9]. The usage of cement can be reduced by using the other possible cementing materials without compromising the strength and durability. Thus in this work the suitability of partially replacing cement with metakaolin in self curing concrete is also studied.

1.2 Mechanism of Self Curing

It is important to know the mechanism behind the process of internal curing. In normal concrete what usually happens is the continuous evaporation of moisture from an exposed surface due to the difference in chemical potentials (free energy) between the vapour and liquid phases. However when polymers are added in the mix they tend to form hydrogen bonds with water molecules and reduce the chemical potential of the molecules which in turn reduces the vapour pressure thereby reducing the rate of evaporation from the surface.

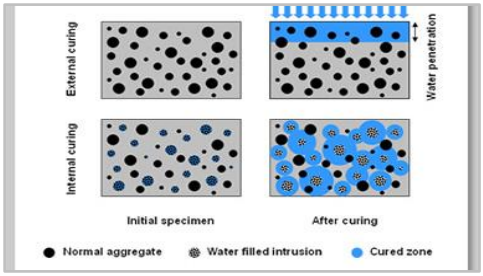

Fig 1: Mechanism of internal curing

1.3 Materials Used For Internal Curing

There are lot many materials used for internal curing purpose. These materials act as water filled intrusions and cure the concrete from inside to outside. The various materials commonly used include the following:

- Natural or Synthetic Light Weight Aggregate Fines
- Expanded shale with higher water absorption capacity
- Super Absorbent Polymers (SAP)
- Sodium salts of poly-acrylic acid, polyacrylamide, ethylene maleic anhydride, cross-linked carboxy methyl cellulose, polyvinyl alcohol
- Shrinkage Reducing Admixture (SRA) - polyethylene glycol
- Saturated Wood powder

Now the in the present work, the use of polyethylene glycol as self curing agent is studied. Polyethylene glycol (PEG) is a condensation polymer of ethylene oxide and water with the general formula H-(OCH2CH2)n-OH, where n is the average number of repeating oxy-ethylene groups typically from 4 to about 180. One of the salient features of PEG is the water soluble nature. Polyethylene glycol is nontoxic, odorless, neutral, lubricating, non-volatile and nonirritating and it is used in a variety of pharmaceuticals [5].

The importance of incorporating self curing technique in concrete includes the following:

- Eliminates autogenously shrinkage,
- Reduces permeability
- Protects reinforcing steel
- Increases mortar strength
- Provides greater durability
- Greater utilization of cement
- Lower maintenance
- Higher modulus of elasticity
- Reduces the effect of insufficient external curing

Thus internal curing may be chosen as a suitable alternative for conventional curing techniques and the current work includes the investigation done on self curing concrete. The project also includes the study of effect of partially replacing cement with metakaolin in self curing concrete.

II. OBJECTIVE

The focus of the work is to investigate the suitability of incorporating a new curing technique namely internal curing or better known as self curing in the construction field. Curing is always a vital part of strength gaining in concrete and insufficient curing pose a lot many problems. Further the work navigates into the possibility of partially replacing cement in the self curing concrete by metakaolin. Metakaolin is dehydroxylated form of the clay mineral kaolinite. Thus the project also checks the improvement in strength of self curing concrete when added with metakaolin.

So the main objectives of the present experimental work are discussed below:

- To study suitability of self curing technique
- To evaluate the optimum percentage of PEG (self curing agent) to be used to get best strength results
- To compare the results with that of conventional concrete
- To find the effect of partially replacing cement with metakaolin in self curing concrete
- To determine the optimum percentage of metakaolin to replace cement so as to get the best results.

III. MATERIALS

3.1 Cement

Ordinary Portland cement of grade 53 is used with specific gravity 3.15, fineness 1% and initial and final setting time as 122 minutes and 329 minutes respectively.

3.2 Fine aggregate

Clean and dry M sand was used as fine aggregate with a specific gravity of 2.82 and fineness modulus as 2.98.

3.3 Coarse aggregate

20 mm size aggregates are used with specific gravity 3.128, fineness modulus 3.89 and water absorption 2%.

3.4 Self curing agent-Polyethylene Glycol 600

The condensed polymer of ethylene oxide and water is polyethylene glycol. PEG 600 is used in this study where 600 is the molecular weight. It has general formula H (OCH2CH2) nOH. They are soluble in water. It is nontoxic, odourless, non-volatile and non-irritating. It has wide variety of uses in medicine.

3.5 Metakaolin

Metakaolin is dehydroxylated form of the clay mineral kaolinite. When added with cement it combines with the calcium hydroxide and produce added cementing compounds, which makes the concrete stronger by pozzolanic action. Metakaolin can also be obtained by the calcination of indigenous lateritic soils.

3.6 Water

Potable water is generally considered satisfactory for mixing concrete Mixing and curing with sea water shall not be permitted. The pH value shall not be less than 7.

IV. PROJECT METHODOLOGY

In the project material tests are done and the design mix is obtained. The amount of materials required for the casting of specimens is found following by casting of specimens. From the calculations the design mix was obtained as 1:1.84:3.33 with a w/c ratio of 0.5 for M20 mix concrete. The total amount of material required for 1m³ concrete is shown.

Table 1 : Amount of materials required for 1m³ concrete

Water	Cement	Fine aggregate	Coarse aggregate
197 L	394 kg	726.544 kg	1314.88 kg
0.5	1	1.84	3.33

V. OPTIMIZATION OF SELF CURING AGENT IN CONCRETE

The present work is to be initiated with the optimization of the use of self curing agent in concrete. Hence the suitable percentage of self curing agent that has to be added to concrete so as to obtain the optimum results is to be determined. This is done by performing strength tests on concrete specimens added with varying percentage of self curing agent. In the study compression strength tests are relied upon for the purpose and Polyethylene Glycol is added as self curing agent. Hence the concrete specimens are added with varying percentage of PEG namely 0.5%, 1%, 1.5 % and are compared with conventional concrete or control specimen for compression test.

5.1 Compressive strength test

The test is carried out on 150x150x150 mm size cubes, as per IS: 516-19599. A 3000 KN capacity Compression Testing Machine (CTM) is used to conduct the test. The specimen is placed between the steel plates of the CTM and load is applied at the rate of 140 Kg/Cm2/min and the failure load in KN is observed from the load indicator of the CTM. For the same cubes were casted and the ones added with self curing agent was left for air curing and the control specimen or plain cubes were left for water curing. Later 7 day and 28 day was tested. The results are shown below.

Fig 2: Compression testing machine

Table 2: Cube Compressive strength of cubes with varying % of PEG 600

Percentage of PEG added	7 day strength(N/mm²)	28 day strength(N/mm²)
CS	19.55	29.78
M0.5	21.78	30.66
M1	22.22	31.12
M1.5	19.55	28.88

From the tests performed the maximum compression strength is obtained for mix M1 that consist of 1% of PEG as self curing agent for M20 grade concrete. It is evident that PEG 600 may be used in concrete as an alternative to conventional curing method thereby enhancing internal curing mechanism. Considerable strength is found to be achieved by the addition of self curing agent and is in par with normal concrete.

5.2 Addition of Metakaolin to Self Curing Concrete With 1% Peg

Now onwards the project proceeds by adding metakaolin to concrete mix with a fixed percentage of PEG, which gave the optimum results and this is found to be 1%. Thus all specimens are added with 1% PEG and then cement is replaced by 10%, 15%, 20% and 25% metakaolin. Now the strength tests are conducted and results are studied.

5.2.1 Compressive strength test

The compressive strength of concrete is measured by the compression strength tests performed on concrete cubes of size 150mm X 150mm X 150mm. The test is conducted on Compression Testing Machine (CTM) of capacity 3000 KN. The cubes are casted with 1% PEG and varying percentages of metakaolin and are compared with the control specimen with 1% PEG alone. The cubes are left for air curing for both 7 days and 28 days. Once the cubes are placed in the CTM the load is applied at a rate of 140Kg/cm2. The ultimate load applied is noted and compressive strength is determined.

Compressive strength (N/mm²) = ultimate load/ area of cross section = P/A

Table 3: Compression strength of self cured concrete with metakaolin

Percentage replacement of cement by metakaolin	7 day(N/mm²)	28 day(N/mm²)
CS	22.22	31.11
10MK	29.33	37.33
15MK	34.22	38
20MK	36	45.33
25MK	30.17	40.13

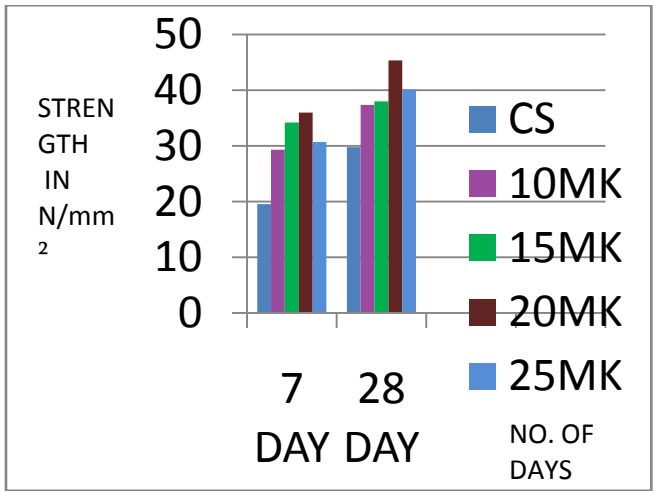

Fig 3: Graph showing cube compression test

5.2.2 Split Tensile Strength

Split tensile strength is obtained indirectly by subjecting cylinder specimens to compression along two opposite generators. It is tested in a universal testing machine of capacity 1000 KN .Cylinders of 150mm diameter and 300mm height are casted and tested after 28 days. The strength is calculated as, $\sigma = 2P/\pi DL$.

Fig 4: Split tensile strength testing machine

Table 4: Split tensile strength test

Percentage of cement replaced by metakaolin	Strength at 28 days (N/mm²)
CS	3.11
10MK	3.5
15MK	3.536
20MK	4.03
25MK	3.45

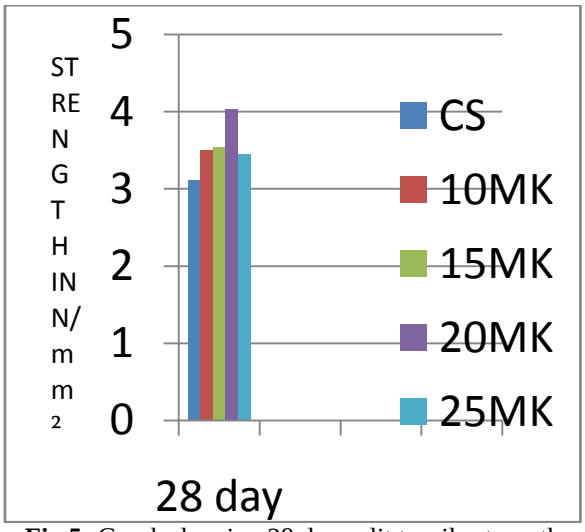

Fig 5: Graph showing 28 day split tensile strength

Here max increase in strength is attained for 20% replacement of cement with metakaolin for compression and split tensile strength.

5.3 TESTS TO CHECK SELF COMPACTING PROPERTY

Studies reveal that the addition of metakaolin imparts self compacting property to concrete. Hence EFNARC has laid certain guidelines to study this behavior and certain tests are mentioned. We are ought to perform some among these tests to confirm the self compacting behaviour of the mix. These tests check the filling ability, passing ability and segregation resistance. The tests performed are shown below.

5.3.1 V funnel test

The equipment consists of a V-shaped funnel. The funnel is filled with concrete and the time taken by it to flow through the apparatus measured. This test gives account of the filling capacity (flow ability). Then again flow time is taken after waiting for 5 minutes once the concrete is filled and this is called v funnel test at T5 minutes. This test checks the segregation resistance.

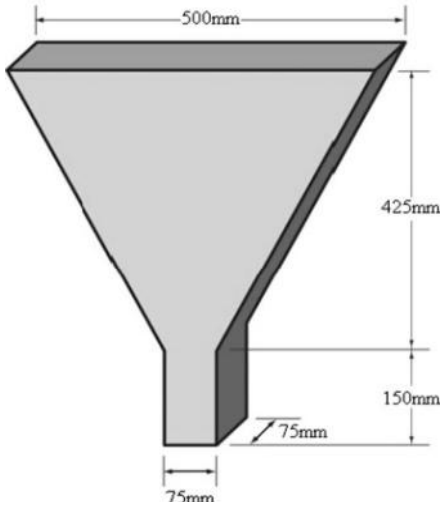

Fig 6: V funnel test

5.3.2 The L-box test method

It comprising of a vertical section and a horizontal trough into which the concrete is allowed to flow on the release of a trap door from the vertical section passing through reinforcing bars placed at the intersection of the two areas of the apparatus The concrete ends of the apparatus H1 and H2 measure the height of the concrete at both ends. The test can give an indication as to the filling ability and passing ability.

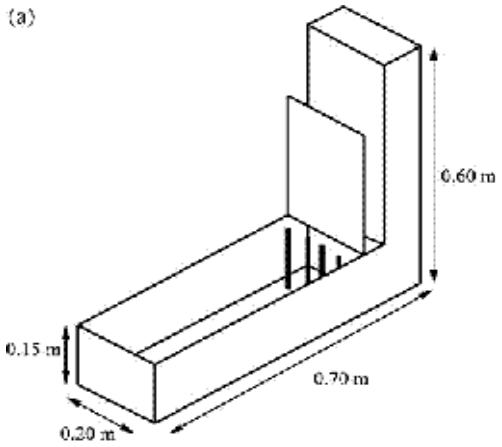

Fig 7: L box test

Thus two test results are obtained to check the self compacting property of the mix.

Table 5: Results of V funnel test and L box test

Test	Property tested	Range of values(as per EFNARC)	Result obtained for 20% metakaolin mix
V funnel test	Filling ability (viscosity)	8-12 sec	8.46
V funnel at t5 minutes	Segregation resistance	8-15 sec	12.29
L box test	Passing ability	0.8-1	0.9

The results indicate that the mix do possess self compacting property as per EFNARC guide lines. Thus addition of metakaolin imparts self compacting property to concrete.

Self-compacting concrete (SCC) is a flowing concrete that does not require vibration and, indeed, should not be vibrated. It uses super plasticisers and stabilisers to significantly increase the ease and rate of flow. It achieves compaction into every part of the mould or formwork simply by means of its own weight without any segregation of the coarse aggregate. 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.

In the study thus we are getting a new material that pose both self curing and self compacting properties. The addition of metakaolin to self curing concrete imparts self compacting properties. Thus the new concrete requires no external vibration or compaction and not even a single drop of water is required for curing purpose.

VI. CONCLUSIONS

- From the present work it may be concluded that internal or self curing technique is an alternative to conventional curing methods
- The strength parameters is in par with normal water cured specimens and hence may be used for normal concreting works
- An optimum strength result was obtained for 1% addition of PEG and this is used for further work
- A max of 31.12N/mm² was obtained for compression tests
- Later on the study was conducted by replacing cement with metakaolin
- It was concluded from the strength tests that there is considerable increase in strength of specimens when cement is partially replaced with metakaolin
- Hence the usage of cement can be reduced by the replacement of metakaolin
- It was found that strength increases considerably for compression test and split tensile strength, and a max value was obtained for 20% replacement of cement by metakaolin
- A percentage increase of 52.2 and 29.58were obtained for both tests respectively
- The addition of metakaolin to concrete mixes impart self compacting properties to the mix
- The mix was found to obey the guidelines laid by EFNARC

- Thus finally we introduce an innovative new material with Self Curing Self Compacting property

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