JOURNAL OF NANO- AND ELECTRONIC PHYSICS *ЖУРНАЛ НАНО- ТА ЕЛЕКТРОННОЇ ФІЗИКИ*
Vol. **15** No 4, 04026(6pp) (2023) Том **15** № 4, 04026(6cc) (2023)

Extract of Biomaterial as Admixture for Internal Curing Agent for Concrete

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(Received 10 June 2023; revised manuscript received 18 August 2023; published online 30 August 2023)

The demand for concrete in the construction sector is growing gradually due to its strength and durability. Concrete's interior relative humidity influences its strength and longevity. In the process of internal curing concrete along with the surface moisture, extra internal moisture is provided so that self-desiccation or dehydration can be avoided. In this paper, biomaterial extract is used to examine the performance of internally cured concrete and is compared with the performance of air-cured and conventionally cured concrete. The dosages of biomaterial extract used as internal curing agents are 0.0 %, 0.20 %, 0.40 %, 0.60 %, 0.80 %, and 1.0 % by weight of cement. This manuscript focuses on the compressive power of M-20 grade concrete and using Biomaterial extract as an internal curing agent determined for 3, 7, and 28 days and compared with air-cured and traditional cured cement concrete respectively. From the experimental test results and observations, the compressive potency of M-20 grade tangible enhances with a boost in dosages of extract of biomaterial up to 0.60% by weight of cement, if the dosage increased more than 0.60 % compressive strength decreases. The results are optimistic in bio-self-cured concrete which is environmentally friendly and low-cost and also improves the level of hydration.

Keywords: Biomaterial extract, Eco-friendly, Internal curing agents, Compressive strength, Air curing, Admixture, Hydration of cement.

DOI: 10.21272/jnep.15(4).04026 PACS number: 87.85.jc

1. INTRODUCTION

The aim of curing is to avoid the loss of moisture from the surface of the concrete, to give extra moisture as required, and to maintain the temperature of the concrete for a long period [1]. If curing is not done for a sufficient time the required strength and durability of concrete is reduced [2]. Wetness can be introduced in cement mortar by ponding, immersion, and wet covering [3]. The material is represented to air continuously evaporation of moister acquires place from the surface. The amount of evaporation depends on a number of factors, these include the size of the specimen, the type of cement, and ambient weather conditions [4]. In concrete autogenous shrinkage frequently occurs due to chemical shrinkage, decreasing relative humidity and cement requires extra water for hydration resulting in empty pores generated from self-desiccation [5]. In the hydration process, chemical shrinkage occurs, forming empty pores and bringing down relative humidity that leads to self-desiccation. Insufficient moisture in cement develops micro-cracks and capillary pores which are the matrix's weak spot [6, 7]. Self-curing refers to a procedure in which small inclusions spread throughout the concrete, hold water during mixing until setting time, then release during cement hydration[8].Using self-curing in concrete and mortar autogenous cracking is prevented microstructure and pore structure in concrete and mortar are improved [9]. Self-curing prevents water from evaporating from the surface of mortar and concrete, as well as controlling self-desiccation and shrinkage during hydration [10]. Adding different weight ratios by cement weight polyethylene glycol as self-curing agents in cement mortar results in shows a favorable effect on the strength and workability of mortar specimen [11]. Tensile stresses form in the structure when the concrete shrinks due to restrictions imposed by adjoining material, connecting parts, or the shrinkage gradient. These stresses cause the concrete to crack since they are greater its tensile strength [12]. According to a study concrete structure cracking at premature era, is one of the extremely crucial times in the cementation materials' lifetime [13]. During cement hydration, the reduction in internal relative humidity must be avoided to avoid cracking in early-age high-performance concrete [14]. To prevent desiccation and self-desiccation shrinkage, internal curing (IC) is used [15]. A chemical agent in self-cure concrete minimizes water evaporation, firstly by bringing down the vapuor pressure at the concrete pore solution surface [16]. An important step in the hardening process is the curing phase, during which cement acquires its fundamental properties under regulated circumstances.[17]. The inclusion of self-curing chemicals has improved the quality of self-compacting mortar mixtures. These mortar mixes are appropriate for use in repair and rehabilitation projects [18]. The biomaterial as self-curing agents in concrete, it must have specific characteristics of holding the water and releasing it

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The results were presented at the 3rd International Conference on Innovative Research in Renewable Energy Technologies (IRRET-2023)

whenever is needed as internal reservoirs and their microstructural properties are resembling like other chemical curing agents [19]. Internal Curing agent as an extract of vegetative material performs better strength and durability characteristics in concrete [20].

2. TECHNIQUES OF SELF-CURING

There are two main categories of self-curing techniques are:

- The water count method.
- Water retaining method.

The water-adding technique uses super absorbent polymers(SAP) and light weight saturated aggregate (LWA), which can offer an additional source of water that can replenish the water lost to chemical shrinkage during the chemical reaction of cement. The technique involves adding chemicals that help in both water retention and decrease evaporation from concrete surfaces

3. MECHANISM OF INERNAL CURING

Moisture continually evaporates from an exterior surface because of the differences in chemical potentials (free energy) between the liquid and vapour phases. The added polymers reduce the chemical potential of the molecules and create hydrogen bonds with water molecules slowing the rate of water evaporation from the surface.

4. THE EFFICACY OF INTERNAL CURING

Demand for curing water (internal or external) when admixtures in a blended cement system totally react may be significantly higher than in conventional ordinary Portland cement concrete. Cracking (Early-age) and significant autogenous deformation may occur when this water is not readily available. The cement paste develops empty pores as a result of the chemical shrinkage that takes place while the chemical reaction of cement, decreases the inside relative humidity and causes shrinkage that, could lead to early-age cracking.

5. THE SCOPE AND OBJECTIVES

- The scope of the paper is to investigate how biomaterial extracts, affect the internal curing concrete strength properties.
- The objective is to increase the compressive strength of concrete, by varying the percentage of biomaterial extract used as an internal curing agent.

6. SETUP FOR EXPERIMENT

In this paper, research work is focused on experimentations carried out on M-20 grade cement concrete. In the detailing of the experimental work, 84 cubes are cast for concrete out of which 12 numbers for each conventional and air curing (without adding an internal curing agent). In this biomaterial, extract is added from 0.0 %, 0.20 %, 0.40 %, 0.60 %, 0.80 % and 1.0 % as an internal curing agent by weight of cement. The compressive strength is measured and analyzed with the statistics of the air-cured and conventional concrete for the duration of 3, 7, and 28 days.

6.1 Method of Mixing

Assuring proper mixing of the selected materials is significant in order to get the expected results. The uniform mixing of the shortlisted materials in the mass of cement concrete gives proper results. The thorough mixing of the selected materials is ensured if the cement paste covers the concrete. In the experimentation process, the mixing of the materials is carried out on a watertight platform. The fine aggregate, coarse aggregates and binding material that is sand, 20 mm aggregate and cement, respectively, are mixed thoroughly in a strict dry condition. The process is carried out in 3-cycles. Finally, to get a consistent quality of internal curing concrete, the selected percentage of biomaterial extract in liquid form is mixed properly with water.

6.2 Concrete's Compressive Strength

In this experiment compressive force for material, with and without adding a self-curing agent was determined. The compressive test equipment having a capacity of 2000 KN was used to carry out the test on 150 × 150 mm cubes. A vibrating machine was used to achieve uniform compaction. During the compressive strength test maximum load sustained by the specimen divided by the average cross-sectional of the specimen is the compressive strength of the concrete cube. Concrete was kept in the mould with maintaining in relative humidity of 90 % at room temperature (25 to 27 °C) for a period of 24 hours and then removed from mould for curing air-cured with and without using a self-curing agent and conventional curing for 3,7, 28, and 56 days. Every compressive strength was determined using the average of three specimens.

6.3 Materials

6.3.1 Cement

Ultra Tech (OPC) 53 grade confirming to IS:12269-2015 standard is preferred for the purpose. The shortlisted cement material is kept in an airtight plastic container. According to IS:269, the cement has a fineness of 4.697, a standard consistency of 32 %, and a specific gravity of 3.15. Using Vicat's method and in accordance with IS:12269-1987, the initial setting time is 117 minutes, and the final setting time is 185 minutes.

6.3.2 Sand

As per IS:383-1970 standards, the natural river sand passing through the 4.75 mm sieve confirming to the zone-1 is used as fine aggregate.

6.3.3 Water

Water is the primary ingredient in the chemical process that occurs which is commonly known as hydration. Water is the ingredient that helps in the strength development of concrete. Water is used in the composition according to the standard IS 456-2000 for both mixing and curing of specimens. The pH value of the water used is 6.80.

6.3.4 Internal Curing Agent (ICA)

The biomaterial is used as the curing agent in the proposed self-curing process. The biomaterial with the required characteristics and in the required amount is collected from the local areas near Washim District of Maharashtra State since the laboratory where experiments are performed is in Washim. The biomaterial used as an internal curing agent is dug out of the soil and washed with water to remove the adhering soil. The materials are cut into pieces and ground well. The extracted material is collected in a container and it is added to the concrete while mixing the ingredients. The pH value of the extract biomaterial is 5.8. The 100 gms of the biomaterial around 70 ml to 75 ml of the extraction is possible. Further, the leftover material is used as animal feed.

7. RESULT AND DISCUSSION

Continual loss of moisture takes place from freshly placed cement concrete surfaces. The admixtures added in the cement concrete mix basically contain hydrogen and form bonds with the water molecule which increases the water retention capacity and minimizes loss of moisture from the exposed surface of concrete. The availability of additional water improves the hydration level and forms dense microstructure hence ultimately increasing the strength of concrete. The outcome of the experiments is concluded using concrete's compressive strength. The statistical outcome for concrete is represented in Table 1

Table 1 – Compressive strength of M-20 grade concrete

Sr. No.	Biomaterial Extract added (%)	Sample	Compressive Strength in N/mm2				Remarks
			After 3 days	After 7 days	After 28 days	After 56 days	
1	Nil *	A1 to A 4	18.25	19.75	20.44	21.20	*
2	Nil **	A 4 to A 8	15.57	16.42	16.57	16.14	**
3	0.20	A 9 to A 10	16.13	17.58	18.29	18.75	Air curing + with internal curing agents
4	0.40	A 11 to A 14	17.54	18.77	19.55	20.05	
6	0.60	A 20 to A 24	17.88	19.15	19.85	20.25	
7	0.80	A 24 to A 28	16.70	18.35	18.6	18.9	
8	1.00	A 28 to A 32	15.70	17.12	17.57	17.80	

Note: * Indicates conventionally cured concrete and ** air-cured concrete.

From Fig. 4 it was observed that with a dosage of 0.60 % of self-curing agent, the optimum compressive strength of concrete was found to be 15 %, 17 %, 20 %, 25 % which is higher than the air-cured concrete at 3, 7, 28 and 56 days respectively.

With the dosage of the self-curing agent from 0.20 to 0.60 %, compressive strength of concrete increases from 4 to 15 % at 3 days and 10 to 20% at 28 days which is higher than the air-cured concrete. If the dosages of self-curing increase beyond 0.60 % the compressive strength decrease from 7 to 1 % at 3 days and 12 to 6 % at 28 days which is also higher than air-cured material.

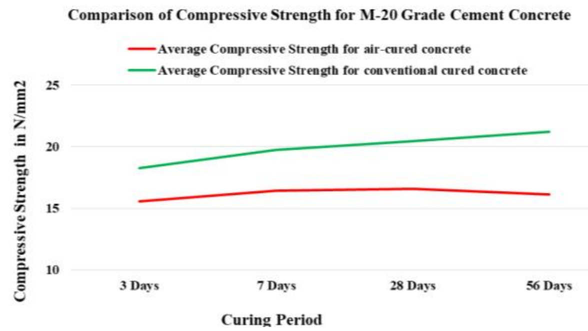

Fig. 1 – Comparison of compressive strength of air-cured and conventional cured material

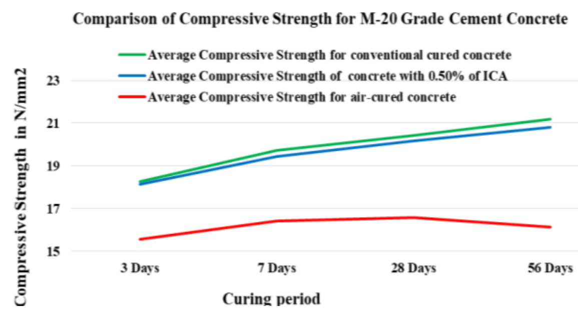

Fig. 2 – Comparison of compressive strength of air-cured, Conventional cured material with 0.50 % of internal curing agent

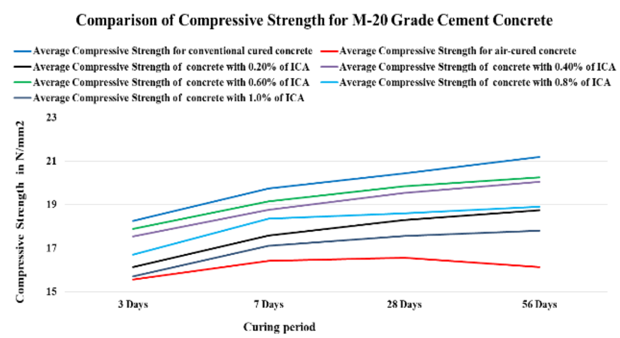

Fig. 3 – Comparison of compressive strength for conventional cured, air-cured concrete with different dosages of internal curing agent (ICA) concrete

With the dosage of the self-curing agent from 0.20 to 0.60 %, the compressive power of concrete decreases from 12 to 2 % at 3 days and 11 to 3 % at 28 days which is lower than the conventionally cured concrete. If the dosages of self-curing increase beyond 0.60 % the compressive strength decrease from 8 to 14 % at 3 days and 9 to 14 % at 28 days which is also lower than conventionally cured concrete. For conventionally cured concrete compressive strong point was establish to be 18.25 N/mm², 19.74 N/mm², 20.44 N/mm² & 21.20 N/mm² which is higher 17 to 31 % than air-cured concrete.

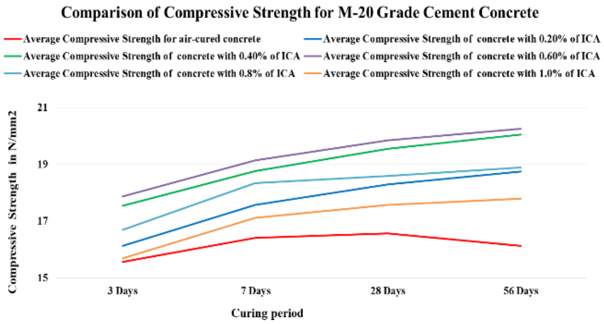

Fig. 4 – Comparison of compressive strength for, air-cured concrete with different dosages of internal curing agent (ICA) concrete

From the above experimental test results, the compressive strength of material increases with an increase in dosages up to 0.60 % by weight of cement, and if the dosage is increased beyond 0.60 % compressive strength decreases. Because initially up to 0.60 % dosage, a sufficient amount of additional internal sources of water is available for the complete hydration of cement hence strength increases, later if increase the dosages of the self-curing agent, and the strength of concrete reduces due to excess internal water.

8. A PREDICTIVE MODEL FOR COMPRESSIVE STRENGTH OF CONCRETE INTERNALLY CURED WITH BIOMATERIAL EXTRACT

8.1 Regression: Simple Linear

The statistical concept of regression is used to describe models that foresee the interrelation with the variables. The linear regression model is used to analyze a single reliant variable Y and one or more independent variables, which are denoted by X. If there is only one independent variable X Simple linear regression is used and when there is one or more dependent variables, multiple regression is used.

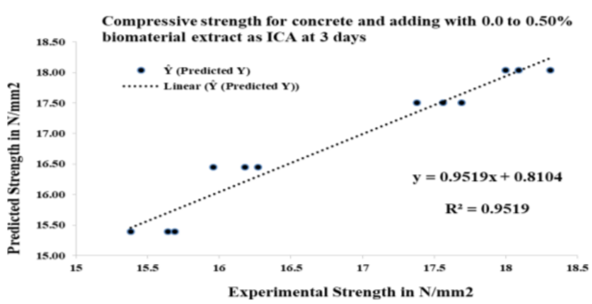

Fig. 5 – Predicted compressive strength adding 0.0 to 0.50 % dosages of ICA and Experimental compressive Strength at 3 days

Figures 5, 6, 7, 8, 9 and 10 indicate that the relation between compressive strength of material and concrete mixture mix with dissimilar dosages of biomaterial as internal curing agent (ICA) content is linear. In this presentation, the relation between compressive strength of air-cured concrete and concrete mixture mix with internal curing agent (ICA) is into two parts i.e. concrete with internal curing agent (ICA) 0.00 % to 0.50 % & 0.50 % to 1.00 % by mass of cement. The Compressive

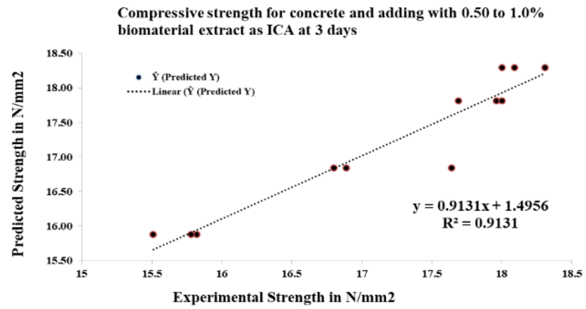

Fig. 6 – Predicted compressive strength adding 0.50 to 1.0 % of ICA and Experimental compressive Strength at 3 days

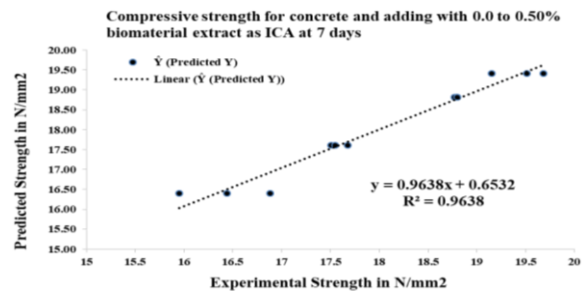

Fig. 7 – Predicted compressive strength adding 0.0 to 0.50 % dosages of ICA and Experimental compressive Strength at 7 days

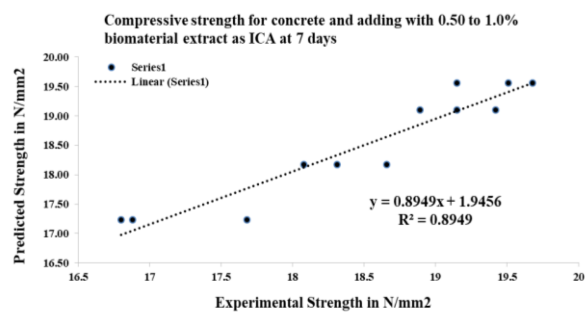

Fig. 8 – Predicted compressive strength adding 0.50 to 1.0 % of ICA and Experimental compressive Strength at 7 days

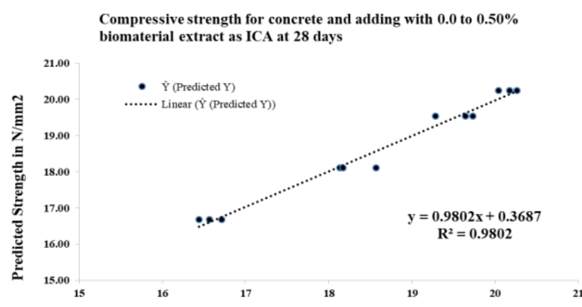

Fig. 9 – Predicted compressive strength adding 0.0 to 0.50 % dosages and Experimental compressive Strength at 28 days

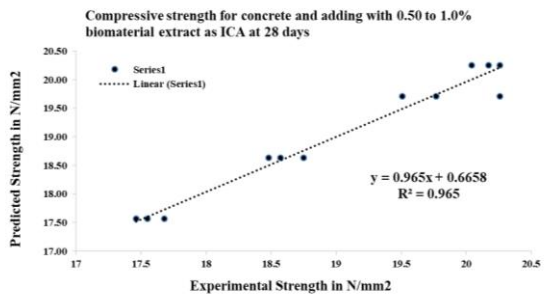

Fig. 10 – Predicted compressive strength adding 0.50 to 1.0 % of ICA and Experimental compressive Strength at 28 days

power of concrete aged 3, 7 & 28 days increased linearly with an increase in ICA. An equation can be used to express this relationship can be expressed with equations.

The simple Linear Regression equation

$$\hat{Y} = 15.3899 + 5.2944X,\ R2 = 0.95 \quad (1)$$

$$\hat{Y} = 20.7158 - 4.839X,\ R2 = 0.91 \quad (2)$$

$$\hat{Y} = 16.4019 + 6.0294X,\ R2 = 0.96 \quad (3)$$

$$\hat{Y} = 21.8865 - 4.6469\mathrm{X},\ R2 = 0.89 \quad (4)$$

$$\hat{Y} = 16.6856 + 7.1158X,\ R2 = 0.98 \quad (5)$$

$$\hat{Y} = 22.9305 - 5.3638X,\ R2 = 0.97 \quad (6)$$

Where X is the experimental compressive strength of concrete; $\hat{Y}$ is the predicted compressive strength of concrete. Equations 1, 3, & 5 show the relationship between experimental (X) and predicted ($\hat{Y}$) compressive strength of concrete when the concrete was aged 3, 7 and 28 days respectively with the dosage of an internal curing agent (ICA) from 0.00 to 0.50 %. Equations 2, 4, & 6 determine the compressive strength of concrete when age was 3, 7 & 28 days respectively concrete with an internal curing agent (ICA) 0.50 % to 1.00 %. The $R2$ values obtained in equations (1, 3, & 5) and (2, 4, & 6) ranges from 0.95 to 0.96 and 0.89 to 0.97 with an average value of 0.9625 and 0.925 respectively.

9. CONCLUSION

After going through the in-depth research work following things can be concluded:

– The maximum compressive strength for M-20 grade concrete was found with an optimum dosage of biomaterial extract at 0.60 % by cement's weight.
– The optimal compressive force was observed with a 0.60% dosage of internal curing agent (ICA) which is higher than that of air-cured concrete but lower than conventionally cured concrete.
– With the dosage of the internal curing agent from 0.20 to 0.60 %, the compressive strength of M-20 grade concrete increases from 15 to 25 % which is higher than the air-cured concrete.
– The cubes cast viewed with the naked eye for any cracks on the surface. The surface of the cubes was viewed continuously and no hair cracks were seen on the surface. This means that the concrete is durable and free from any hair cracks even if the days pass by.
– No extra curing is needed for the concrete prepared with the use of the extract of biomaterial as an internal curing agent and the material is eco-friendly and cost-effective.
– Diminishing the poor curing caused by human ignorance, insufficient availability of water in parched areas, poor accessibility of difficult structures, and place where the existence of fluoride in water, will negatively influence the quality of material, in such places internal curing concrete is used.

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Екстракт біоматеріалу як домішка для внутрішнього затверджувача бетону

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Попит на бетон у будівельній сфері поступово зростає завдяки його міцності та довговічності. Відносна вологість всередині бетону впливає на його міцність і довговічність. У процесі внутрішнього твердіння бетону разом із поверхневою вологою забезпечується додаткова внутрішня волога, щоб уникнути самовисихання або зневоднення. У цій роботі екстракт біоматеріалу використовується для перевірки характеристик бетону внутрішнього затвердіння та порівнюється з характеристиками бетону, що затвердів на повітрі та традиційного затвердіння. Дозування екстракту біоматеріалу, що використовується як внутрішній затверджувач, становить 0,0 %, 0,20 %, 0,40 %, 0,60 %, 0,80 % і 1,0 % від маси цементу. Описуються властивості бетону марки М-20 і використанні екстракту біоматеріалу як внутрішнього затверджувача, визначеного протягом 3, 7 і 28 днів і порівняного з повітряним і традиційним цементним бетоном відповідно. За результатами експериментальних випробувань і спостережень, сила стиску марки М-20 відчутно підвищується при збільшенні дозування екстракту біоматеріалу до 0,60% від маси цементу, якщо дозування збільшується більше ніж на 0,60% міцність на стиск знижується. Результати є оптимістичними для біосамотвердіючого бетону, який є екологічно чистим і недорогим, а також покращує рівень гідратації.

Ключові слова: Екстракт біоматеріалу, Екологічно чистий, Внутрішні затверджувачі, Міцність на стиск, Затвердіння на повітрі, Домішка, Гідратація цементу.