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An Experimental Study on Curing of Mortar Cubes by Carbon Dioxide

Seema B S[1], Vijaya Kumar Y M[2], Yashaswini L[3] & Natraj R L[4]

[1]*Assosiate Professor,* [2]*Assistant Professor,* [3,4]*PG Scholars*
[1-4]*Department of Civil Engineering, Adhichunchanagiri Institute of Technology, Karnataka, India.*

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ABSTRACT

Carbon dioxide (CO_2) is the predominant greenhouse gas resulting from human industrial Activities. A significant fraction of CO_2 discharged into the atmosphere comes from Industry point sources. Cement production alone contributes approximately 5% of global CO_2 emissions. This emitted carbon dioxide, however, can be partially recycled into mortar through early age curing to form thermodynamically stable calcium carbonates. The carbonation reaction between carbon dioxide and appropriate calcium Compounds results in permanent fixation of the carbon dioxide in a thermodynamically stable calcium carbonate. Carbon dioxide and water can be found in almost every environment and thus all concretes will be subjected to carbonation. The experimental study on water cured and CO_2 specimens for compression strength were carried out. The results show that mortar cubes has achieved increasing value as comparing with water curing.

Keywords: *Concrete, CO_2, Compression strength, Carbonation.*

1. Introduction

Earth's atmosphere acts like a blanket to absorb the sun's solar radiation, which heats the earth's surface and keeps it warm. Due to human and anthropogenic activities, the increasing carbon dioxide gas concentration in the atmosphere is currently disturbing the natural composition of the CO_2 greenhouse gases. Furthermore, some argue that the atmospheric CO_2 increase is causing a global temperature increase. As the temperature increases, more water vapor, which is also a greenhouse gas is released into the atmosphere. Most scientists agree that the earth is warming at a faster rate than at any time in the last 10,000 years, and that this warming is caused by increasing amounts of carbon dioxide and other greenhouse gases in the earth's atmosphere. There are many potential effects and consequences expected to result from a rise in global temperature. The impact of global warming on people and nature is severe, and will disturb the viable and comfortable environment.

Carbon dioxide is the dominant greenhouse. Finding beneficial uses of as-captured or recovered CO_2 is challenging and critical to greenhouse mitigation. One potential technology is to use the captured or recovered CO_2 as a curing agent in production of carbonated concrete products. The process is called curing carbonation. Carbonation is the process by which CO_2 is absorbed in the concrete. Uncarbonated concrete units contain the typical cement hydration products of calcium silicate hydrates and calcium hydroxide. As concrete carbonates, calcium hydroxide and calcium silicates are converted to calcium carbonate, as shown in following equations:

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H2O$

$C_3S + 3CO_2 + H2O \rightarrow C\text{-}S\text{-}H + 3CaCO_3$

$C_2S + 2CO_2 + H2O \rightarrow C\text{-}S\text{-}H + 2CaCO_3$

Carbonation curing requires only 4 to 8 hours of curing time under controlled conditions to get the strength which the conventional water cured concrete specimen require 28 days. This early age strength is because of the reaction of CO_2 gas with calcium hydroxide ($Ca(OH)_2$) and the bogue's compounds named tri-calcium silicate (C_3S) and

di-calcium silicate (C_2S) to form calcium carbonate ($CaCO_3$) and calcium silicate hydrate gel (C-S-H). The gel imparts strengths to concrete and the latter helps in pore refinement of concrete. The reinforced concrete elements undergo corrosion when placed in the corrosive atmosphere. This corrosion is prevented by placing an appropriate cover or protective coatings on reinforcement. This helps in protecting steel in acidic environment.

2. Literature Review

Vijaya Kumar & Seema [1], the experimental study on water cured and CO_2 specimens for compression strength were carried out. The results show that for M25 and M30 grade of concrete has achieved increasing value as comparing with 7 days of water curing and the duration of 4hour CO_2 curing. For M25 grade of concrete has achieved 70% of compression strength and M30 grade of concrete has achieved 65% of compression strength in the duration of 4hours of CO_2 cured specimens when compared to 28 days of water cured specimens.

Vijay Kumar et al. [2], the study is carried to evaluate the carbon dioxide cured concrete over traditional curing of concrete. Two mix designs M25 and M30 are considered for curing. Different samples were prepared and cured for both the cases. The periodical observation is done to find the compressive strength at 7 days to 28 days for normal cured 2 hours to 4 hours for CO_2 cured. The results show that CO_2 cured concrete achieves 76.28% target strength within 2 hours and normal cured 75.8% target strength in 7 days for M25. For both M25 and M30 grade concrete with water curing achieved compressive strength more than the target strength.

Santhosh Kumar et al. [3], they have studied the CO_2 cured concrete mechanical properties. They are experimented by dry ice and CO2 cured blocks by using the compressive strength, split tensile and flexural Value were conceded out for 4, 6, 8 hours. The experimental study on water cured, CO_2 cured and dry ice cured specimens for compressive strength, split tensile strength and flexural strength were carried out.

The outcomes show that 90% of compressive strength, 89% of flexural strength and 92% of tensile strength was achieved, comparing with 28 days water cured blocks and 8 hours of CO_2 cured blocks.

Rakesh et al. [4], they have studied use of CO_2 mitigation responses in concrete and cement products is one of the possible technologies as carbon sink through the fast curing in early age, used bamboo fiber was a replaced material for cement as 1% with the water cement ratio was 0.53. In order to find out the Carbonation curing, they are compared with fiber and without fiber. They have tested both water curing and carbon curing for 3, 7, 14, 21, 28 days, finally they have got more strength in with fiber used specimen and also get more strength in CO_2 cured specimen when comparing conventional cured specimen.

Lee Ming Gin et al. [5], this study was conducted to assess the acceleration of strength development by CO_2 curing and to evaluate the strength and microstructure of two cement mortars. Three curing pressures (1, 5, 8 bars), three curing time (20, 120, 180 minutes) and four CO_2 concentration (0%, 25%, 50% and 100%) were used in this investigation. The three-hour mortar samples had a high percent strength development. The increasing of CO_2 concentration results in higher carbonation degree of mortar, more mass gain, and a stiffer and denser material.

Ming-Gin Lee et al. [6], this paper summarized the CO_2 cured cylinder with 3 different sizes and the compressive strength with various curing timings and finally compared with 28 days of water cured cylinder with different sizes.

The results of CO_2 cured concrete ratio or longer CO_2 curing time produced higher early strength. The concrete specimen mixed with CO_2 under 0.2 to 0.6 Mpa pressure produced lower compressive strength the results show like cylinder has got higher compressive strength when comparing conventional cured blocks.

Gowsika et al. [7], they have concentrated to assess viability of various curing methods and study the impact of atmosphere on the quality properties of cement. The examples were thrown for the testing of compressive quality at 7, 14 and 28 days of relieving. Individually they were utilizing seven restoring techniques, to be specific Ponding, Immersion, Oven relieving, Air Drying, calcium chloride (random), Membrane relieving and Pack (Plastic sheeting) restoring. Test outcomes demonstrate that water restoring quality was improved up to 26.67% than film and shows 93% of traditional relieving. All through this investigation it is done over the solid has enormous impact on its quality properties on various techniques for restoring.

Vibhas Bamboo et al. [8], they have Conducted test research to discover the ingestion of CO_2 in solid shafts. For this situation a metallic relieving chamber was set up with the vent and channel regulators. A weight measure was connected to the weight privileged the chamber. The examples were thrown and set in CO_2 relieving chamber for 4 hours and 8 hours. What's more, they were contrasted and the examples in a customary technique for the 28 days. After 4hours and 8 hours of CO_2 restored tests are tried, the compressive quality was show to increment by 12.3% and 27.7% and for 8 hours of CO_2 relieving the flexural quality was appeared to increment by 1.8% than tests restored in water.

Don MacMaster & Oscar Tavares [9], they have considered that compute the carbon allocation levels in concrete by making different relieving procedures. An extraordinary CO_2 relieving chamber was orchestrated to empower speeding up response by the utilization of carbon sequestration. They have arranged CO_2 restoring chamber with a thermocouple and vacuum framework are given, thermocouples are only for watching temperature, dampness and weight. Tests were thrown and relieved in CO_2 restoring chamber for 2 hours as it were. At first, tests were contrasted and conventional oven restored examples at 100% CO_2 and at the weight was 20 psi. In this time of relieving time (2 hours).

Ceaseless examination of comparative moistness, temperature and weight expansion was achieved. At 2-hours of CO_2 relieving, the most extreme temperature was reached to 30°C from 18.9°C and stayed consistent till the end. The virtual moistness arrived at a greatest at the beginning of the relieving test and diminished at 30 min and increments following 30 min till the finish of 2 hours.

Hilal El-Hassan & Yixin Shao [10], they Studied the method of carbon curing he found that it will successively replace steam curing by its unique advantages like accelerated the hydration. Comparing the method of CO_2 and stream got the result like increasing the hydration.

Zhan Baojian et al. [11], they have developed blocks using recycled aggregate. Located in a pressed 100% of Curing chamber for 6 and the 12 after those 14 hours, meanwhile he conducted experiment on the moisture cured blocks also. Initial and final relative humidity and temperature were noted. He measured the strength. Outcome of experiment showed CO_2 cured block have got high compressive strength was compared to moisture cured block.

Ajay Goel et al. [12], the normal compressive quality of cement at various ages for example 3, 7, 28 and 56 days affected by three sorts of restoring techniques specifically air, plastic film and relieving by Water relieving is more quality when looking at all three kinds relieving.

Vahid Rostami et al. [13], they have studied that the performance of carbon cured concrete was compared with steam curing and hydrated curing and the effect of carbonation was studied in terms of carbon uptake acceleration strength and durability they found that carbonation promotes early strength development and durability also compared they obtain results as they observed that carbon cured has more resistance to chloride permeability ion migration, sulphate attack, etc.

Shao et al. [14], this paper summed up that the achievability of utilizing reused CO_2 in solid squares through the relieving procedure. This kind of relieving process is conveyed to two different ways one is Open-gulf framework and shut channel framework utilizing pressurized pipe gas of low fixation. Precast examples were relieved in the chamber, in open-delta framework CO_2 gas with great virtue is approved into the shut chamber at a weight of 21 pound square inches and in a shut framework vent gas comprising 14% of CO_2 is passed at a weight of 72 psi. The CO_2 gas was passed in 7 cycles with a time span of 30 to 40 min. The outcomes show that the solid items relieved in CO_2 show's superior outcomes for mechanical properties.

Satoshi Teramura et al. [15], they have used ALC as clasp in the CO_2 development. The excess ALC were sieved by 1.8 mm and a short time later handled by a ball-plant for sixty min. The liquid to solid extent was in the extent of 25 to 65% by the weight. The wet excess ALC was compressed in the shape under 10 MPa strain to outline the plate 100mm x l00mm x 12mm. This technique they were used 100% centralization of CO_2 and gas force from air to 0.4 MPa. They in like manner test air carbonation by using 3% CO_2 obsession and 3% of pneumatic stress.

The carbonated models were drying in an oven at 60°C for the duration of 24 hours afterward carbonation. Three-point bowing test were used for those plates and the cross-head pace of 0.2 mm/min.

Simatupang & Habighorst [16], they have advanced an industrialized method for cement particle boards in order to decrease the pressing duration. Wood elements were saturated in the water, then additional to Portland cement and mixed well. Different stainless steel equipment was used to do quick CO_2 curing. The press sleeve to take up the moist wood/cement mixture and the piston to condense the mortar.

The compaction pressure was 4 MPa. Press plate used for CO_2 was injected top and bottom into the specimen. The w/c ratio was varied. And that is from 0.1-0.6, account the water. Better results were obtained.

Bukowski & Berger [17], they have tried of University was used the C_2S, C_3S and Portland concrete as clasp to examine CO_2 gas soothing. The extent of clasp to sand was composed by weight, and the extent of water to sheet was by mass was 0.202, 0.206 and 0.191 for C_2S, C_3S and ordinary concrete, independently.

They have used hand mixing for nearly 3min and a while later trodden at 26 MPa load into 15.9 mm in expansiveness loads around 20 mm height. After compaction was done, the chamber was kept in a container by 95% relative tenacity for 2 hours earlier carbonation. They have furthermore used calcium silicate powders for carbonation with a comparable water and cement extent as the preservationist mortars.

3. Conclusion

After studying the journal papers, the feasibility of carbon dioxide uptake by mortar products through early age curing is studied to conclude the amount of strength gained at early stage of CO_2 curing is greater when compare to water curing.

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Consent for publication

Authors declare that they consented for the publication of this research work.

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