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Determination of Flexural Strength of Concrete Beams Using Carbon Dioxide Curing

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ABSTRACT
The current inquiry was conducted to ascertain the flexural strength of both plain cement concrete beams & reinforced cement concrete beams using carbon dioxide curing. The concrete M25 grade mix was developed and beam specimens of size 114mm x 114mm x 495mm were casted. The carbon dioxide curing was conducted for 2hours, 4hours, 6hours and 8hours, 3 beam specimens of PCC and RCC were cured for each hour of carbon dioxide curing and flexural strength of those were determined and compared with 7days, 14days and 28days flexural strength of water cured specimens. 8hours CO2 cured PCC specimens have achieved 92.89% of flexural strength in contrast to 28 days' strength achieved by water cured PCC beams. The 8hours CO2 cured RCC specimens have achieved 98.04% of strength in contrast to 28 days' strength achieved by water cured RCC beams.

Keywords - Carbon dioxide, Carbonation, CO2, Plain cement concrete and Reinforced cement concrete.

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I. INTRODUCTION

Carbonation is the process by which CO2 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+ CO2→ CaCO3+ H2O

C3S + 3CO2+ H2O → C-S-H + 3CaCO3

C2S + 2CO2+ H2O → C-S-H + 2CaCO3

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 CO2 gas with calcium hydroxide (Ca(OH)2) and the bogeus compounds named tri-calcium silicate (C3S) and di-calcium silicate (C2S) to form calcium carbonate (CaCO3) 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.

II. REVIEWE OF LITERATURE

Vijaya Kumar et al. (2021), The current research was done on the comparison of compression strength between moisture cured and CO_2 cured specimens. The outcome shows that 4hours CO_2 cured M25 and M30 grade of concrete were of higher strength than 7days water cured specimens. 70% strength was achieved by M25 grade of concrete and 65% strength was achieved when compared to 28days moisture cured cubes.

Vijay Kumar et al. (2021), Present study is on the comparison of compression strength between CO_2 cured concrete with the traditional concrete. The moisture curing and CO_2 curing were carried out for two mixes M25 and M30, the outcome shows that 76.28% strength was achieved by CO_2 curing within 2hours and 75.8% target strength was achieved by moisture cured concrete in 7 days for M25.

Santhosh Kumar et al. (2019), The study was carried on the mechanical characteristics of concrete after CO_2 and dry ice curing. It was tested for compressive strength, split tensile strength, and flexural strength. Results indicate that, in contrast to the control samples, CO_2 cured specimens had a 90% compressive strength of 28days strength achieved by moisture curried specimens.

Vibhas Bambroo et al. (2017), In this study, Impact of accelerated carbonation curing on both reinforced and unreinforced concrete elements (cubes) was examined (prisms). The prisms, each measuring (150 x 150 x 1200) mm, were poured. They underwent CO_2 curing for 4 and 8 hours before being put through compressive and flexural strength tests. The strength of cubes and prisms improved after CO_2 curing, by 27.7% and 1.8%, respectively, when compared to specimens that had been moisture-cured.

Hilal El-Hassan et al. (2014), It was investigated how initial curing affected the masonry units made of lightweight concrete are carbon dioxide-cured (CMU). The initial curing process took between 4 and 18 hours. Based on cement composition, concretes that underwent four hours of carbonation curing were able to absorb 22-24% of initial curing and 8.5 percent carbon dioxide without initial curing, but concretes that underwent protracted 4-day carbonation absorbed 35 percent of CO_2. To speed up hydration and recycle CO_2 from the cement kiln, carbonation curing can take the role of steam curing in the manufacture of CMU.

James et al. (2011), Here in research, 72 3D structures with a mix ratio of 1:2:4 were investigated after being subjected to various relieving conditions. The findings demonstrated that ponding, after being exposed to various relieving conditions for 7, 14, 21, and 28 days, had the highest compressive excellence and thickness.

2.1 Research Objectives

1. Determination of flexural strength of beams (PCC and RCC) by water curing.
2. Determination of flexural strength of beams (PCC and RCC) by carbon dioxide.
3. To compare both the results.

III. METHODOLOGY

3.1 Materials used

Concrete's strength is mostly influenced by the characteristics of the materials used to make it. Properties of ingredients materials are as follows,

1) Portland Pozzolana Cement
2) Manufacture sand (M sand)
3) Coarse aggregates
4) Steel rods
5) Water

3.2 Cement

Throughout the test, Portland Pozzolana Cement (PPC), which conforms with IS 1489 Part II was employed. Physical properties of cement were tested according to Bureau of Indian Standards specification. The physical properties are listed below in the table.

Table 3.1: Physical Properties of Cement (PPC)

SL No.	Material property	Requirement as per IS: 1489 part II	Results obtained
1	Specific gravity	3	2.9
2	Fineness	Not more than 10%	6%
3	Normal consistency	-	33%
4	Initial setting time	Minimum 30min	45 minutes
5	Final setting time	Maximum 600min	405 minutes

3.3 Fine Aggregate (Manufactured Sand)

Manufactured sand is known to increase the strength and durability of concrete while decreasing its workability. The manufactured sand was bought in the area. According to IS 383-2016, the manufactured sand utilised is zone-II-specific, and IS 2386-1975 is used to test the physical characteristics of fine aggregate.

Table 3.2: Physical properties of fine aggregate

SL No.	Material property	Requirements as per IS 383-2016	Result obtained
1	Specific gravity	Not more than 2.75	2.6
2	Grading zone	Zone II	Zone II
3	Bulk density(kg/m3)	Maximum 1250	1247
4	Water absorption(%)	Maximum 2	1.7

3.4 Preparation of specimen

3.4.1 Mix Proportioning

In this project, the concrete is thought to be designed for M-25 grade. The mix design is made by referring to IS 10262-2019, and the calculation for the mix design is presented in the appendix. The water to cement ratio is 0.43. The material proportion per cubic meter is mentioned in below table.

Table 3.3: M25 grade Mix Design

Materials	Quantity(kg/m3)	Proportion
Cement	399.125	1
M-Sand	653.48	1.63
Coarse aggregate	1107.21	2.77

3.4.2 Casting of Specimen

In this project concrete beams of both PCC and RCC were casted, the beams were having size of 114mm x 114mm x 495mm. Concrete was mixed and poured into the mould in accordance with Bureau of Indian Standards. The number of specimens casted for both water curing and CO_2 curing is mentioned in the below table.

Table 3.4: Number of PCC and RCC beams casted

Water curing			
SL No.	Time period (days)	PCC	RCC
1	7	3	3
2	14	3	3
3	28	3	3
Total		9	9
CO_2 curing			
SL No.	Time period (hours)	PCC	RCC
4	2	3	3
5	4	3	3
6	6	3	3
7	8	3	3
Total		12	12

3.5 CO_2 Curing

The process of carbon dioxide curing involves (including) the exposure of concrete beams to carbon dioxide gas. In order for the reaction to occur, CO_2 is often released into a closed chamber and left for a set amount of time under particular circumstances. The water that evaporated as a result of the exothermic reaction was factored into the assessment of the degree of carbonation in this closed-loop carbonation method. The method (procedure) followed is as follows;

1. Both PCC and RCC beams of M-25 grade concrete is removed from the mould without any damage after 24 hours of casting and placed right away in the CO_2 curing chamber.
2. Three concrete beams of each PCC and RCC type positioned inside a CO_2 curing chamber.
3. To prevent any CO_2 gas leaks, the CO_2 chamber was sealed airtight.
4. CO_2 gas is released to the inlet of the chamber by operating pressure gauge attached to the CO_2 cylinder. The pressure maintained was 25Psi.
5. The experiment is made for 2-8 hours.
6. After definite hours for example 4 hours, close the valve and leave the container for 4 hours.
7. The curing of concrete beams is done by absorbing CO_2 gas.
8. The CO_2 chamber is opened and the beams are taken out.
9. Flexural strength test is done on concrete beams to check the flexural strength of CO_2 concrete beams.
10. Compare the outcomes of the CO_2 and water curing processes for flexural strength.

3.6 Flexural strength

Beams are consumed for testing flexural excellence. The beams are tried in a flexural testing machine of limit of 40 tones. Two point loads are applied at the distance of L/3. The load is increased gradually and the load at failure is noted. Flexural quality is determined by capacity by territory of the example.

$fb = p \times l/b \times d^2$ (IS 516-1959)

Were,
Load = p
Length of beam= l
Width of beam=b
Depth of beam=d

Normally 3 beams are tested for each hours of CO_2 curing and water curing at the respective age. For the assurance of flexural quality (114x114x495) mm size standard moulds are utilized to set up the solid shapes.

IV. RESULTS AND DISCUSSION

4.1 Flexural strength of specimens

Table 4.1: Results of the water-cured flexural strength test

Time Interval (days)	Flexural strength (MPa)	
	PCC	RCC
7	3.01	12.85
14	3.28	13.33
28	3.38	13.81

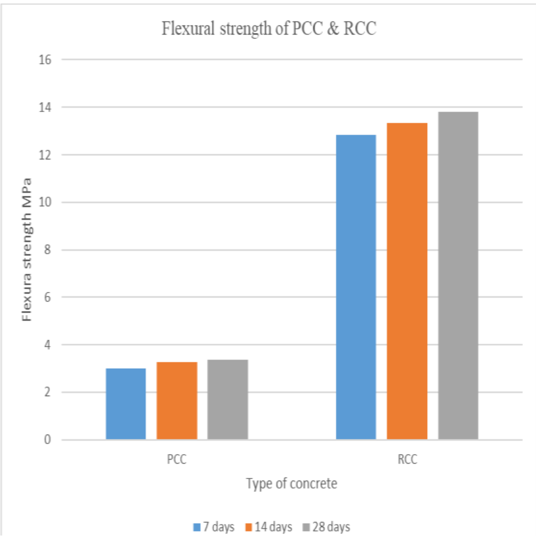

Fig 4.1: Moisture-cured PCC and RCC have flexural strength after 7, 14, and 28 days.

Observation: It is observed that the flexural strength of moisture cured PCC and RCC gradually increases over time from 7 days to 28 days. The flexural strength of RCC is higher than PCC specimens due to the addition of tensile properties in the form of steel reinforcement.

Table 4.2: CO_2 cured flexural strength test results

Time Interval	Flexural strength (MPa)	
	PCC	RCC
2 hours	0.26	0.52
4 hours	1.88	3.93
6 hours	2.49	8.46
8 hours	3.14	13.54

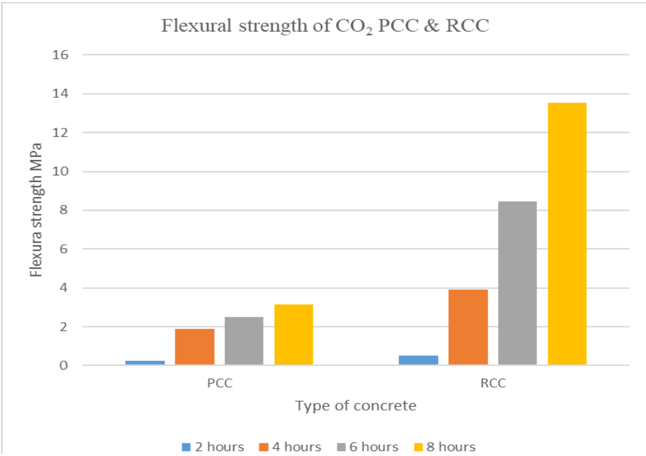

Fig 4.2: Flexural strength of CO_2 cured PCC and RCC.

Observation: It is observed that the flexural strength of CO_2 cured PCC and RCC gradually increases over time from 2 hours to 8 hours. The flexural strength of RCC is higher than PCC specimens due to the addition of tensile properties in the form of steel reinforcement.

Table 4.3: Comparison of flexural strength of PCC between water cured and CO_2 cured specimens.

Flexural strength PCC			
Time intervals	Water curing (MPa)	Time intervals	CO2 curing (MPa)
		2h	0.26
7 days	3.01	4h	1.88
14 days	3.28	6h	2.49
28days	3.38	8h	3.14

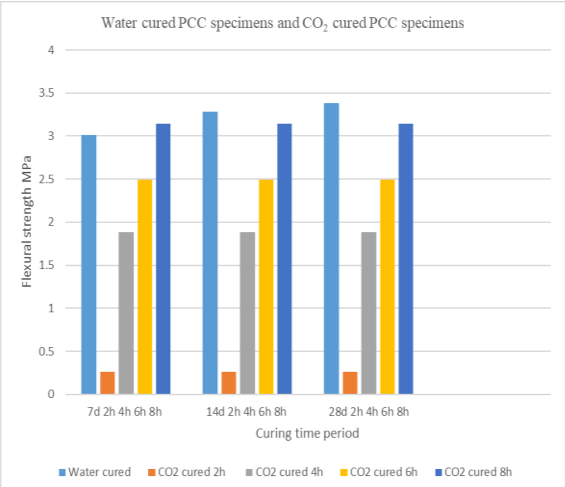

Fig 4.3: Comparison of flexural strength of PCC between water cured and CO_2 cured specimens.

Observation: PCC specimens cured in CO_2 for 8 hours are found to have a little lower flexural strength than specimens cured in moisture for 28 days.

Table 4.4: Comparison of flexural strength of RCC between water cured and CO_2 cured specimens

Flexural strength RCC			
Time intervals	Water curing (MPa)	Time intervals	CO_2 curing (MPa)
		2h	0.52
7 days	12.85	4h	3.93
14 days	13.33	6h	8.46
28days	13.81	8h	13.54

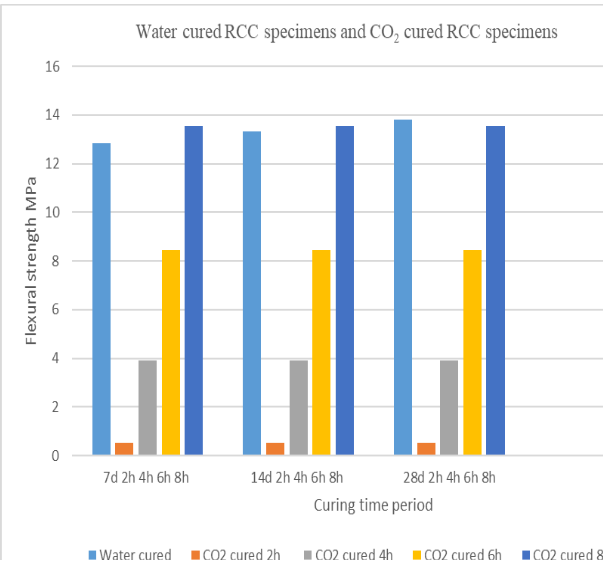

Fig 4.4: Comparison of flexural strength of RCC between water cured and CO_2 cured specimens.

Observation: Flexural strength of 8h CO_2 cured specimens is found to be somewhat weaker than that of 28days moisture cured RCC specimens.

V. CONCLUSION AND SCOPE OF FUTURE WORK

5.1 Conclusions

Following are the some of important conclusions arrived as a result of this experiment

1. Flexural strength of water cured PCC beams for M25 grade for the duration of 7, 14 and 28 days are 3.01MPa, 3.28MPa and 3.38MPa respectively.
2. Flexural strength of water cured RCC beams for M25 grade for the duration of 7, 14 and 28 days are 12.83MPa, 13.33MPa and 13.81MPa respectively.
3. Flexural strength of CO_2 cured PCC beams for M25 grade for the duration of 2hours, 4 hours, 6hours and 8hours are 0.26MPa, 1.88MPa, 2.49MPa and 3.14MPa respectively.
4. Flexural strength of CO_2 cured RCC beams for M25 grade for the duration of 2hours, 4hours, 6hours and 8hours are 0.52MPa, 3.93MPa, 8.46MPa and 13.54MPa respectively.
5. From the above results we can conclude that the 8hours CO_2 cured PCC specimens have achieved 92.89% of strength compared to 28 days' strength achieved by water cured PCC specimens.
6. From the above results we can conclude that the 8hours CO_2 cured RCC specimens have achieved 98.04% of strength compared to 28 days' strength achieved by water cured RCC specimens.

5.2 Scope of future works

1. Durability of CO_2 cured concrete can be studied.
2. The effect of CO_2 curing on concrete added with mineral admixtures can be studied and the reactions between the CO_2 and mineral admixtures can be monitored

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