Impact of Carbon di-oxide Curing on Basalt Rock Fibre Reinforced Concrete

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Abstract: Concrete is the fundamental element in the construction activity which advancement enhances the durability properties. To achieve the strength of concrete within short time various curing techniques are available. One such curing technique is exposing concrete to carbon dioxide gas. Carbon dioxide gas is the abundantly released gas from the industries which pollutes the environment & also a main reason for the greenhouse effect. By utilizing carbon dioxide gas in construction activities, environmental pollution can be minimized. This study is about the investigation of mechanical properties of basalt fibre reinforced concrete subjected to conventional and carbon dioxide curing methods. Specimens are prepared of M25 grade concrete with 0, 1, 2, and 3, 4 Kg/m\textsuperscript{3} basalt fibres. Compressive strength and split tensile strength tests are performed to specimens after 28 days of conventional curing and 2.5 hours of carbon dioxide curing.

Key-words: Carbon di-oxide curing, Basalt rock fibres, Conventional curing, Tensile strength.

1. Introduction

Carbon dioxide gas is the predominantly released gas from the industries to the atmosphere. It is non-eco-friendly because it causes air pollution. Generally, percentage of CO\textsubscript{2} present in the earth’s atmosphere is 0.0350\%. To produce various goods in industries they use to burn raw materials like lime stone etc., which releases carbon dioxide gas. The number of industries is increasing because of the urbanization as well as percentage of releasing carbon dioxide also increasing. This gas is mainly responsible for the greenhouse effect. Use of the waste gas released from the industries for construction purpose as a curing agent mitigates air pollution [1-4].

Concrete has weak tensile strength. To enhance tensile strength of concrete reinforcement should be done with a material has strong tensile properties. By and large, steel is used as reinforcement material because of its high tensile strength. But steel exhibits corrosion when exposed to atmosphere, which leads to damage of the structural elements. Basalt rock fibers are preferable as a auxiliary for steel because of its high tensile strength, thermal properties, and anti-corrosion properties & also it does not show noxious reaction when combined with any other materials [5, 6]. Origination of Basalt rock forms from the volcanic magma expulsion. These fibers are extracted from the basalt rock melted at a temperature of about 1500\textdegree C to 1700\textdegree C and drive them through platinum/rhodium crucible bushings. These fibers show better resistance to chemical attack, thermal and vibration than glass fibers. The table 1 depicts the properties of basalt fiber. The Fig.1 illustrates the pectoral view of basalt fibers. These can be used at any temperatures i.e. -200\textdegree C and 700\textdegree C to 800\textdegree C. It acts as a better insulator to sound. Because of these reasons basalt fibers are used as a good reinforcing material to concrete [7, 8].

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Fig. 1 Basalt rock fibers

Table 1 - Properties of Basalt rock fibers

| PROPERTY                | UNIT     | VALUE        |
|-------------------------|----------|--------------|
| Density of unsized filament material | Kg/m3    | 2.70 +/- 5%  |
| Moisture content of basalt rock       | %        | 0.1 +/- 0.05 |
| Melting point             | Centigrade Degrees | 1350 +/- 100 |
| Diameter                 | µm       | 13           |
| Length                   | mm       | 6-18 +/- 5%  |
| Sizing type              |          | silane       |
| Moisture content         | %        | < equal 0.30% |
| Loi, also sizing content |          | < equal 0.50% |

1.1. Carbonation curing process:

The conventional curing takes place for the hardened concrete. When cement is mixed with water, the hydration products naturally react with atmospheric carbon dioxide to form calcium silicate hydrate gel helps to strengthen the concrete. This is a slow process.

Curing with carbon dioxide gas is entirely different from conventional curing. Carbonation curing is rapid process; it can be adopted where emission of CO$_2$ from industries is more. Initially it decreases the pH which leads to corrosion of steel. Carbon dioxide gas is released into an air tight vessel where the specimens are kept for the carbonation process with a control valve to adjust pressure of CO$_2$. The Fig.2 depicts the arrangement for carbonation curing process.

1.1.1 Steps involved in carbonation curing:

1. Construct an air tight vessel with an inlet.
2. Attach the cylinder containing carbon dioxide gas to inlet of the air tight vessel.
3. Place the concrete specimens in the vessel.
4. Close the container tightly as there is no chance of any leakage of CO$_2$ gas.
5. Let the CO$_2$ gas pass in to container under constant pressure for 2.5 hours.
6. Close the valve after 2.5 hours and leave the specimens to absorb CO$_2$ gas completely for 4 hours.
7. Remove the specimens and test for compressive strength, split tensile strength.
2. Materials

2.1 Cement

The cement used in this experimental work is Ultra tech Ordinary Portland Cement of grade 53. Properties of the cement are specified in the table 2.

Table 2 - Properties of cement

| S.No. | Particulars                      | Experimental values |
|-------|---------------------------------|---------------------|
| 1.    | Fineness of grinding            | 1%                  |
| 2.    | Normal consistency (%)          | 32%                 |
| 3.    | Setting time                    |                     |
|       | Initial setting time            | 35min               |
|       | Final setting time              | 600min              |
| 4.    | Compressive strength of cement  | 53 N/mm$^2$         |

2.2 Fine Aggregate

Locally available river sand is used in the experimental work. The properties of Fine aggregate were determined as per IS 383:1970, and they are tabulated in table 3.

Table 3 - Properties of Fine aggregate

| S.No. | Particulars     | Experimental values |
|-------|-----------------|---------------------|
| 1.    | Bulk Modulus    | 2.65                |
| 2.    | Specific gravity| 2.75                |
| 3.    | Finess Modulus  | 2.8                 |
| 4.    | Zone            | II                  |
2.3 Coarse Aggregate
Crushed angular coarse aggregate passing through 20mm sieve and retained on 16mm sieve was used in this experimental works. The properties of Coarse aggregate are tabulated in table 4.

Table 4 - Properties of Coarse aggregate

| S.No. | Particulars         | Experimental values |
|-------|---------------------|---------------------|
| 1.    | Particle shape, size| Angular, 20mm       |
| 2.    | Specific gravity    | 2.75                |
| 3.    | Water absorption    | 0.5%                |
| 4.    | Impact value        | 13.59%              |

3. Concrete Mix design
Mix design is calculated as per IS 10262. The quantities of materials are listed in the table 5.

Table 5 - Mix Proportions

| Grade | Cement Kg/m³ | F.A Kg/m³ | C.A Kg/m³ | w/c ratio | Target strength N/mm² |
|-------|--------------|-----------|-----------|-----------|-----------------------|
| M25   | 360          | 609       | 1245      | 0.4       | 31.6                  |

4. Test procedure
Firstly, take all the weights of coarse aggregates, fine aggregates, cement, basalt rock fibers and water using digital weighing machine. Mix all the ingredients in a proper manner and test it for workability like slump cone test, compaction factor test and vee-bee test. Cubes of size 150 X 150 X 150 mm & cylinder moulds of size 150 X 200 mm were used to cast the specimens. Grease moulds with oil then transfer concrete into moulds in three layers; each layer is given by 25 blows. Remove specimens from moulds after 24 hours and keep them for immersion curing a conventional method of curing shown in Fig.3 and also for carbon di-oxide curing. Compression test and split tensile strength has to be conducted on the specimens once the curing is done at 7 days & 28 days respectively.

Fig. 3 Cubes kept for conventional curing
5. Results and Discussions

Specimens kept for conventional curing and carbon dioxide curing were taken out from the curing tank and wipe surface with a cloth then allowed to dry under shade. Take weight of specimens using digital weighing machine. These specimens were kept in a Compression testing Machine and apply the load gradually until failure occurs as depicted in Fig. 4. Note the maximum load taken by the concrete and also the load where failure occurs.

![Specimens Testing under CTM](image)

Dividing failure load by area of face of three concrete cubes gives average Compressive strength after 28 days of conventional curing & carbon dioxide curing. Average Split tensile strength of cylinders is calculated by dividing the failure load by area of face of the cross-section of three concrete cylinders after immersion curing of 28 days & after 6.5 hours of carbon dioxide curing. The results are listed in Table 6 and Table 7.

### Table 6 - Results obtained for Conventional curing

| S.No | Quantity of Fibers (Kg/m³) | Compressive strength 7 days | Compressive strength 28 days | Split tensile strength 7 days | Split tensile strength 28 days |
|------|---------------------------|-----------------------------|-----------------------------|----------------------------|-------------------------------|
| 1.   | 0                         | 20.5                        | 32.5                        | 3.2                        | 4.8                           |
| 2.   | 1                         | 23.4                        | 35.4                        | 5.1                        | 7.2                           |
| 3.   | 2                         | 25.2                        | 38.2                        | 6.4                        | 9.5                           |
| 4.   | 3                         | 27.6                        | 40.2                        | 7.1                        | 11.6                          |
| 5.   | 4                         | 29.8                        | 42.1                        | 8.6                        | 12.9                          |

### Table 7 - Results obtained for Carbon di-oxide curing

| S.No | Quantity of Fibers (Kg/m³) | Compressive strength (MPa) | Split tensile strength (MPa) |
|------|---------------------------|-----------------------------|------------------------------|
| 1.   | 0                         | 28.4                        | 3.8                          |
| 2.   | 1                         | 30.1                        | 6.1                          |
| 3.   | 2                         | 31.5                        | 8.4                          |
| 4.   | 3                         | 32.3                        | 10.8                         |
| 5.   | 4                         | 34.2                        | 11.5                         |
From the Fig.5 and Fig.6 it is noticed that the compressive strength and split tensile strengths are gradually increased from fibres quantity of 0Kg/m³ to 4Kg/m³ with an interval of 1. Compressive strength rises from 32.5MPa to 42.1MPa for 28days curing, in case of split tensile strength minimum is obtained as 4.8MPa and maximum of 12.9MPa for 28days curing. Carbon dioxide curing has not reached the strength that attain for conventional curing. But within 2.5 hours of curing it reaches to 28.4MPa in compression and 3.8MPa in tension for 0Kg/m³ concentration of fibres. Maximum of compressive strength and tensile strengths are obtained as 34.2MPa and 11.5MPa respectively for fibres concentration of 4Kg/m³.

**Fig. 5** Graph of quantity of fibres VS compressive strength

**Fig. 6** Graph of quantity of fibres VS Split-tensile strength

**Conclusions**

1. Carbon dioxide curing gives the 90% of compressive strength with in 2.5 hours curing.
2. Addition of 1kg/m³ of basalt rock fibres improves the 30% of tensile strength of concrete.
3. Practically CO₂ released from cement kiln is collected and used for curing which reduces the effect of global warming.
4. In general, higher CO$_2$ concentration and longer carbonation time increases absorption of CO$_2$ results in producing stronger products.

5. The benefit of using basalt fibre is that it is non-corrosive. The strength is very good. It shows better resistance to heat which is extremely important for every building. Due to high rigidity and low elongation, it is a useful reinforcement material in the present scenario and also for the future era to come and a potential replacement for steel.

References:

1. Bukowski, J.M. and Berger R.L. (1979), "Reactivity and Strength Development of Activated Non-Hydraulic Calcium Silicates", Cement and Concrete Research.Vol.9, pp57-68.
2. Simatupang, M.H. and Habighorst, C. (1995), Investigations on the Influence of the Addition of Carbon Dioxide on the Production and Properties of Rapidly Set Wood-Cement Composites, Cement &Concrete Composites, 17, pp 187-197.
3. Teramura, S. and Isu, N. (Nov.2000), "New Building Material from Waste Concrete by Carbonation", Journal of Materials in Civil Engineering, pp288-293.
4. Yixin Shao and Hilal El-Hassan (CO2 Utilization in Concrete-McGill University, Canada, American University of Dubai, UAE Department of Civil Engineering, McGill University, Montreal, Canada H3A2K6).
5. J. Monkman and A. J. Boyd (Recycling Carbon Dioxide into Concrete: A Feasibility Study-Berger, R. L., Young, J.F., and Leung, K. 1972. Acceleration of hydration of calcium silicates by carbon-dioxide treatment. Nature: Physical Science, 240: 16-18.)
6. Kou Shi-Cong, Zhan Bao-jian, Poon Chi-Sun (Use of a CO2 as curing agent- Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong, Cement & Concrete Composites 45 (2014) 22–28
7. Carbon Dioxide Information Analysis Centerhttp://cdiac.ornl.gov/pns/faq.html Marceau, Medgar L., Nisbet, Michael A., and VanGeem, Martha G. Life Cycle Inventory of Portland Cement Manufacture, SN2095b, Portland Cement Association, Skokie, IL, 2006, 69 pages.
8. Rostami, V., Shao, Y. and Boyd, A. (2012) Carbonation curing versus steam curing for precast concrete production, Journal of Materials in Civil Engineering, 24(9), 1221-1229.