Carbon Sequestration by Curing in Concrete

P. Pooja, Geetanjali Chandam, Yanchen Oinam, Pratheeba Paul

Abstract: The growing concerns about climate change and global warming, resulting from the increased concentrations of carbon-di-oxide in the atmosphere have created considerable interest in carbon sequestration. Carbon is usually sequestered in oceans or deep in the earth’s crust. But these processes require a lot of time and need additional energy investments for carbon to be sequestered. It is noted that cement industries contribute to 5% of global CO₂ emission and it is estimated that 50% of global cement production will be from India and China by 2050. Also, in the current time, when trees are being cleared for the construction of buildings, which is estimated to release 1.5 billion tons of CO₂ into our atmosphere every year, some measures must be taken to give back to the environment. Thus, if carbon is stored in concrete it is likely to stay for longer time, without any changes in its state. An attempt has been made in this study to sequester carbon in concrete. The study concentrates on estimating the carbon uptake in percentage in various mixes of concrete under favourable conditions. M15 and M20 mixes are cured by carbonation and the strengths are tested. In addition, the depth of carbonation and the strength gain due to carbonation are determined. Efforts are done to identify the other physical properties of the blocks cured in this manner.

Keywords: Carbon sequestration, concrete, carbon uptake, depth of carbonation.

I. INTRODUCTION

A. Carbon Sequestration

The long-term storage of carbon in plants, soils, geological formations or the ocean is known as carbon sequestration. The usual methods for carbon sequestration are as follows:

1. Biological – this is done by methods like forestry, peat production, seaweed farming, wetland restoration etc. Research shows that, 1.2 trillion trees can be the sequester of 160 billion tons of carbon. But this method requires a lot of time and only if the trees are long lived and the wood is sequestered itself, this will be effective.

2. Physical – the methods are biomass, ocean, deep soil. The oceans could potentially hold over a thousand billion tons of carbon. But this method requires a lot of energy which results in emission of more CO₂.

3. Geological – in this method, CO₂ is sent deep down the earth with the help of pipes and is stored in underground rock formations. It can be done by trapping CO₂ within a cavity in the rocks or injection into gas reservoirs. But this requires a lot of energy which results in emission of more CO₂.

B. Carbonation in concrete

The most commonly used construction material is concrete and its production contributes to at least 5% of global CO₂ emissions. Concrete gains strength after carbonation. The usual process involves hydration (use of water), which leads to curing of concrete. Out of its components, only calcium silicates contribute to strength, tricalcium silicate is responsible for most of the early strength.

Carbonation is a process which takes place when Ca(OH)₂ present in the concrete reacts with CO₂ available in the air (0.033% by volume or 350 ppm), right from the starting of mixing operation. The mechanism of accelerated carbonation due to the reaction of CO₂ with tri-calcium silicate and di-calcium silicate is as follows:

\[ CaO + CO_2 \rightarrow CaCO_3 \]

This project tries to combine both the above-mentioned phenomenon and results of various tests are studied.

II. METHODOLOGY

To test the carbon uptake, blocks are cast with M₁₅ and M₂₀. Various tests are conducted to analyze the properties after carbonation such as carbon uptake, depth of penetration etc. The first step involves choosing the grade of cement to be used for the concrete. Later, the size of the block must be set. Based on the general carbon penetration data, the dimension is taken as 30cm x 15cm x 8cm. To reduce the weight of the block, a thermocol layer is inserted in between. The dimension of the thermocol layer is 22cm x 7cm x 2cm, leaving 4cm from the concrete edges on all sides. It is shown in the diagram below.

Fig 1. Cross-section of block
Carbon Sequestration by Curing in Concrete

The next step is to find the mix design for the concrete block. M₁₅ and M₂₀ and cast to test the properties. The weight of materials required for casing 1 block of the above-mentioned dimensions are-

<table>
<thead>
<tr>
<th>Materials</th>
<th>Cement (kg)</th>
<th>Sand (kg)</th>
<th>Coarse Aggregate (kg)</th>
<th>Water (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M₁₅</td>
<td>1.11</td>
<td>2.95</td>
<td>4.71</td>
<td>610.5</td>
</tr>
<tr>
<td>M₂₀</td>
<td>1.45</td>
<td>2.90</td>
<td>4.59</td>
<td>797.5</td>
</tr>
</tbody>
</table>

The concrete is filled in the mold with the thermocol intact in between. Full compaction is not done and formation of a few pores is permitted, since it increases the carbonation.

![Fig 2. Dimensions of block](image)

III. TEST RESULTS

A. Test in the Carbon Chamber

Test on M₁₅ blocks, conducted using 99.9% pure CO₂ with 3 bar pressure and the mode of experiment is dynamic. The starting pressure is 3 bar and after 24 hours, the final pressure is 1.25 bar.

<table>
<thead>
<tr>
<th>Mass before carbonation</th>
<th>Mass after carbonation</th>
<th>Mass gain (gms)</th>
<th>Water loss, Assumed (gms)</th>
<th>CO₂ uptake (gms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.03.19 5:30pm</td>
<td>8.510 kg</td>
<td>85</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>8.321 kg</td>
<td>8.399 kg</td>
<td>78</td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>8.511 kg</td>
<td>8.602 kg</td>
<td>91</td>
<td>131</td>
<td></td>
</tr>
</tbody>
</table>

B. Compression Test on Blocks

Three cubes for each mix are tested on a UTM and the respective compressive strength values are found out. The values for day 7 and day 28 are tested. The remains of the tested cubes are then taken for the phenolphthalein test.

<table>
<thead>
<tr>
<th>S.no</th>
<th>Grade of Concrete</th>
<th>No. of Days</th>
<th>Load with-stan</th>
<th>Compressive Strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M₁₅</td>
<td>7</td>
<td>28500 kg</td>
<td>6.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>28</td>
<td>58000 kg</td>
<td>12.64</td>
</tr>
<tr>
<td>2</td>
<td>M₂₀</td>
<td>7</td>
<td>30000 kg</td>
<td>6.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>28</td>
<td>70000 kg</td>
<td>15.26</td>
</tr>
</tbody>
</table>

C. Phenolphthalein Test for Carbon Penetration

Phenolphthalein indicator turns pink in the absence of carbon and remains colourless if carbonation is completed. The blocks are broken and drops of phenolphthalein are sprinkled on the surface and the center parts of the block to identify the extent of carbonation. The blocks show little patches of pink in the center and none on the edges.

![Fig 4. Compression test on blocks](image)
The surface is very clean and appears to be smooth. The images below show the results in M15 and M20 blocks, when phenolphthalein is sprinkled on them.

![Image of M15 and M20 blocks with phenolphthalein test results]

Fig 5. Phenolphthalein test

IV. DISCUSSIONS AND CONCLUSIONS

From the following results, it can be concluded that this technique for the curing on concrete and especially the sequestration of carbon is very efficient. The compressive strength values are expected to increase when proper admixtures are used.

Other observations made after carbonation include, the filling of pores on the surface of the concrete blocks. They have a perfect smooth surface and look aesthetic. Carbon has penetrated deep into the center of the blocks. The concrete is best suited for panels on outer walls which are exposed to air and have less load directly acting on them. We propose that the manufacturing site of the panels can be situated near a cement factory or any industry which emit CO₂. Thus, the panels can be cured by the CO₂ which can be transported though pipes. By this technique we find a way to sequestrate carbon in a safe and easy method benefiting both the people and the environment.

REFERENCES


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AUTHORS PROFILE

P. Pooja, is a B.Tech, Civil Engineering student (2020 Pass out) who is very keen in practical aspects of the concepts. She has attended various conferences, seminars and workshops. She has published a paper in Materials Today Proceedings, Elsevier. She has completed internships at reputable organizations – RWDI, L&T, F. L. Smidth. She is also the recipient M. Visvesvaraya Award in the MEMSAAS -2020. She is known for her leadership and time management skills.

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Dr. Pratheeba Paul, is a Professor at Hindustan Institute of Technology and Science. She has a teaching experience of over 24 years. Her area of interest includes Application of Sustainability Concepts in the field of Civil Engineering, Carbon Sequestration, Optimization and Water Management. She has published around 30 papers in Journals and Conferences. She has received a best Researcher award from IJRULA in 2018.