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Carbon Sequestration by Curing in Concrete

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***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 CO_2 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 CO_2 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 sequestrate 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.

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2. **Physical** – the methods are biomass, ocean, deep soil. The oceans could potentially hold over a thousand billion tons of CO_2. However, the conversion of CO_2 into liquid phase under high pressure and injection to the bottom of the ocean is not economical.

3. **Geological** – in this method, CO_2 is sent deep down the earth with the help of pipes and is stored in underground rock formations. It can be done by trapping CO_2 within a cavity in the rocks or injection into gas reservoirs. But this requires a lot of energy which results in emission of more CO_2.

B. Carbonation in concrete

The most commonly used construction material is concrete and its production contributes to at least 5% of global CO_2 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 CO_2 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 CO_2 with tri-calcium silicate and di-calcium silicate is as follows-

$$C_3S + 3CO_2 + H_2O \rightarrow C\text{-}S\text{-}H + 3CaCO_3 + 347\ kJ/mol$$
$$C_2S + 2CO_2 + H_2O \rightarrow C\text{-}S\text{-}H + 2CaCO_3 + 184\ kJ/mol$$

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 M_{15} and M_{20}. 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.

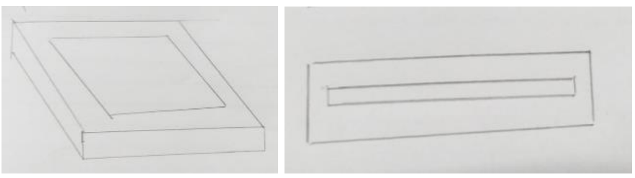

Fig 1. Cross-section of block

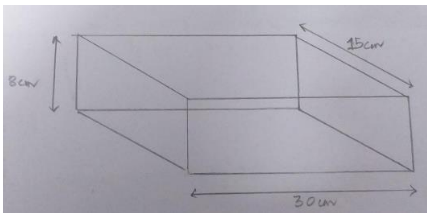

Fig 2. Dimensions of block

The next step is to find the mix design for the concrete block. M_{15} and M_{20} and cast to test the properties. The weight of materials required for casing 1 block of the above-mentioned dimensions are-

Table 1. Proportioning of Materials

	Cement	Sand Aggregate	Coarse Aggregate	Water (ml)
M15	1.11 kg	2.95 kg	4.71 kg	610.5
M20	1.45 kg	2.90 kg	4.59 kg	797.5

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 3. Carbonation chamber and Samples tested

III. TEST RESULTS

A. Test in the Carbon Chamber

Test on M15 blocks, conducted using 99.9% pure CO_2 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 2. Results of M15 blocks in Carbonation

Mass before carbonation 27.02.19 5pm	Mass after carbonation 28.02.19 5pm	Mass gain (gms)	Water loss, Assumed (gms)	CO_2 uptake (gms)
8.812 kg	8.858 kg	46	40	86
8.866 kg	8.930 kg	64	40	104
8.370 kg	8.448 kg	78	40	118

Test on M20 blocks, conducted using 99.9% pure CO_2 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 3. Results of M20 blocks in Carbonation

Mass before carbonation 7.03.19 5:30pm	Mass after carbonation 8.03.19 5:30pm	Mass gain (gms)	Water loss, Assumed (gms)	CO_2 uptake (gms)
8.510 kg	8.595 kg	85	40	125
8.321 kg	8.399 kg	78	40	118
8.511 kg	8.602 kg	91	40	131

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 foe the phenolphthalein test.

Fig 4. Compression test on blocks

Table 4. Results of Compressive strength test

S.no	Grade of Concrete	No.of Days	Load with-standed	Compressive Strength (N/mm^2)
1	M_{15}	7	28500 kg	6.21
		28	58000 kg	12.64
2	M_{20}	7	30000 kg	6.54
		28	70000 kg	15.26

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.

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.

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 CO_2. Thus, the panels can be cured by the CO_2 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.

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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.

Geetanjali Chandam, is a student of Hindustan Institute of Technology and Science, she will be completing her Bachelor's degree in May 2020. She is highly interested in gaining practical knowledge where she joins project and research works. She was selected for an Indo – German traffic Project where she accomplished a big part of the project. She has been awarded the Best Project Award for her contribution.

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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.