CARBON UPCYCLING: AN EXPERIMENTAL STUDY

Sahad V Sageer[1], Shahanaz T.S[2], Thansy K.P[3], Sony Syed[4]

[1] Student, Civil Engineering, KMEA Engineering College, Kerala, India
[2] Student, Civil Engineering, KMEA Engineering College, Kerala, India
[3] Student, Civil Engineering, KMEA Engineering College, Kerala, India
[4] Asst. Prof, Civil Engineering, KMEA Engineering College, Kerala, India

ABSTRACT

In order to cope up with the intense climatic changes, deep reductions in CO_2 emission are required within the coming decades. CO2 absorption is one in all the key technologies to regulate warming. CO_2 is mainly emitted from the production of cement in the building industry. This can be made eco friendly by the introduction of zeolite materials into the concrete which absorbs carbon dioxide from the atmosphere. One potential method to enhance the environmental profile of concrete is to up cycle CO_2 into concrete products by treating them with CO_2 before the top of their processing, like during the curing stage. If the use of of CO_2 as feedstock in concrete products become successful, carbon utilization would be widely disturbed that can close the loop for the carbon dioxide emission during cement production. Our experimental study is to analyze the potential of carbon up cycling thereby reducing atmospheric greenhouse emission concentration by partially replacing cement with zeolite powder and by carbon curing process. There are several construction technique similarly as construction materials used presently. Most of the materials are detrimental to the environment which is that the reason for several calamities. The foremost disastrous gas which gets emitted from construction is CO_2. CO_2 which act as backbone of worldwide warming similarly as reason for several maladies expel from constructions. Such a large amount of remedies are implied as a fabric, instruments, etc. These materials include differing types of polymers, purifying machines, refineries, but still we are unable to cut back percentage emission of CO_2. Because it is been found that obtuse quantity of CO_2 get expelled from construction; impending it'd definitely reduce total percentage of CO_2 emission. This CO_2 emission should be stopped and CO_2 from the air must be diminished putting this as main soul, a feasibility study is formed to use zeolite as a partial replacement to cement in concrete. IS method of M20 is adopted and considering this a basis, mix design for replacement method has been made. An endeavor has been made to analyze the strength parameters of concrete. Acid attack resistances by zeolite concrete were also studied. We've got also tried to sequestrate CO_2 into concrete by carbon curing, i e the concrete cube was cured within the presence of solid during a sealed chamber. solid is that the purest kind of CO_2. The employment of natural or artificial (by products) pozzolans as partial replacement of cement (PC) has economic and environmental benefits and positive effects on durability properties of concrete structures. Natural zeolites are hydrated aluminosilicate minerals of alkali and alkaline-earth metal metals. They carries with it an open three-dimensional network of silicon-oxygen and aluminum oxygen tetrahedra. Crystals of natural zeolite have a honeycomb like structure with small channels and pores, which results in its large extent. Natural zeolites even have ability to absorb and lose water up to 30% of their dry weight and exchange extra framework cations, with none change of crystal structure.

Keyword: - *Concrete, CO_2, Zeolite, Up cycling, Global warming, Cement and Dry ice*

---

1. INTRODUCTION

Carbon up cycling basically means CO_2 reuse in such a way as to create a product of higher quality than the original. Carbon dioxide sequestration can also be carried out by these methods:

1. Carbon curing
2. Carbon Injection
3. Accelerated Carbonation Process

4. Mineral addition to absorb CO_2

Carbon Curing

The carbon cure technology injects a precise dosage of carbon dioxide into ready mix concrete and concrete masonry products, where the CO_2 becomes chemically converted into a mineral. Carbonation is normally considered to be detrimental to concrete as it may increase the risk of reinforcement corrosion. However, carbon curing (with CO_2) have for a long time been known to have a positive effect on e.g. lime mortar. This has been found to improve strength and reduce porosity. This beneficial effect can then be used to reduce the cement content and thus two positive effects are achieved.

Carbon Injection

Activated carbon injection systems are the most established commercial technology for reducing emmissions from flue gases. ACI has been proven, through numerous full-scale demonstrations to be the most cost effective, cost-efficient way to reduce dioxin, furan, and mercury emissions from most boilers. Depending upon the type of fuel being burned and the type of air pollution control equipment installed at the plant, the ACI system can reduce by more than 90%.

Accelerated Carbonation Process

The accelerated carbonation curing process of concrete is a process in which carbon dioxide sequestration is allowed to take place into precast concrete products during their production. This includes a set of processes by which an alkaline material reacts with carbon dioxide to form the corresponding carbonate. This process is applied at pilot scale or full scale for carbon capture from diluted CO_2 sources using hydroxides or carbonates of alkaline metals.

1.1 SCOPE

Production of cement is not only energy intensive but it presents also one of the most important CO_2 emission sources in the world. Depending on the production technology, the CO_2 emissions ranges from 0.73 to 0.99t of CO_2 per tonne of cement. Therefore there have been a lot of attempts to use supplementary cementitious materials (SCMs) which can replace at least a part of cement in concrete by more environment friendly materials. Cement industry contributes to 5% of global carbon dioxide emissions. To mitigate pollution, there is a need of carbon dioxide sequestration into stable forms. In order to overcome serious climate change, deep reduction in CO_2 emission will be required in the coming decades. CO_2 absorption is one of the key technologies to control the global warming. The main scope of this study is focused on carbon dioxide being channelized into an important construction practice.

1.2 OBJECTIVES

- To determine the optimum level for replacement of zeolite to attain maximum compressive strength.
- To investigate the potential of carbon dioxide absorption in concrete by zeolite.
- To perform a comparative study on compressive strength of water cured and carbon cured concrete cubes.

2. MATERIAL AND METHODOLOGY

Prior to the actual beginning of the experimental works, the properties of cement, coarse aggregate and fine aggregates were investigated in the laboratory. These results were used for the mix design. The mix design trial was conducted and finally a suitable concrete mix was fixed.

2.1 Materials Used

a) Cement

Ordinary Portland cement is the cement used for normal construction. Ordinary Portland cement of grade 53 is adopted for casting specimens throughout the experiment. The cement used here has been tested for various properties as per IS: 4031-1988 and found to be confirming to various specifications of IS: 12269-1987. Specific gravity and standard consistency of cement obtained as per the test are 3.1 and 34% respectively. Initial setting time of cement is 40 minutes.

b) Sand: M Sand is chosen as fine aggregate which is obtained through processing the metal quarry dust. The sand is tested as per IS: 2386 (Part III) -1963. Specific gravity of fine aggregate obtained as per test was 2.6.

c) Coarse aggregate: Locally available crushed coarse aggregate of size 10 mm is used for the work. Sieve analysis of the coarse aggregate was performed in the laboratory as per IS 383 and tested as per IS 2386. Specific gravity of coarse aggregate obtained as per test was 2.73.

d) Water: In line with IS 3025 water used for mixing and curing are free from injurious or deleterious materials. Potable water is usually considered satisfactory. In this investigation, tap water is used for all mixing and curing purposes.

e) Zeolite: Zeolites are aluminosilicates of alkaline and alkaline earth cations (potassium, calcium and sodium). They have a porous structure. Their main features are an open structure and their ability to accommodate water and cations within its structure and give them up without changing its structure significantly. Structurally they are considered hydrated aluminium tectosilicates where aluminium is replacing silicon (Si) at the center of structural tetrahedrons with alkaline and alkaline earth cations forming open structures.
The general chemical formula of zeolite is: $XaYbO_2c.nH_2O$.
Where, X= Na, Ca, K, Ba, Sr
Y= Si and Al
The Si to Al ratio is less than 1, n is a variable number which depends on the type of zeolite.
The Si+Al to O ratio is 0.5.

3. RESULTS AND DISCUSSIONS

3.1 Properties of raw materials and concrete

Table - 1 Properties of cement

PROPERTIES	OBTAINED VALUE	STANDARD VALUE
Specific Gravity	3.1	2.9 – 3.2
Fineness (%)	1	<10
Consistency (%)	34	25 – 35
Initial Setting Time	40 min	>30 min
Compressive Strength (7 days)	38 N/mm^2	37N/mm^2
Compressive strength (28 days)	54N/mm^2	53 N/mm^2

Table – 2 Properties of coarse aggregate

Sl. No.	PROPERTIES	OBTAINED VALUE
1	Specific Gravity	2.73
2	Bulk Density	1633 kg/m^3
3	Water Absorption	0.352 %

Table – 3 Properties of fine aggregate

Sl. No.	PROPERTIES	OBTAINED VALUE
1	Specific Gravity	2.6
2	% water required for bulking	4%

Table – 4 Properties of zeolite

SPECIFIC GRAVITY	DENSITY	FINENESS
2.1	0.895 g/cm3	3%

Table – 5 Properties of fresh concrete

PERCENTAGE OF ZEOLITE	SLUMP VALUE (mm)
0	130
5	120
10	116
15	110
20	107

3.2 Compressive strength

The slight decrease in strength observed for specimens with 20% zeolite was probably mainly due to the excessive formation of $Ca(OH)_2$. During the hydration of calcium silicate which was more than the amount of $Ca(OH)_2$ in the pozzolonic reaction.

Table – 6 Compressive strength results

% REPLACEMENT BY ZEOLITE	COMPRESSIVE STRENGTH (28 DAYS)(N/mm^2)
0	20
5	23.4
10	26.67
15	28.8
20	24.88

3.3 Split Tensile Strength

It is conducted in cylinder of 15 cm diameter and 30 height .The split tensile strength obtained is given in table – 7

Table – 7 Split Tensile Strength results

% REPLACEMENT BY ZEOLITE	SPLT TENSILE STRENGTH (28 DAYS)(N/mm^2)
0	2.68
5	1.48
10	1.69
15	2.54
20	1.98

3.4 Flexural Strength

Modulus of rupture (extreme fibre stress in bending) was found out by testing beams under three-point loading. The test is conducted on beam of size 15cm x 10cm x 10cm.

Table-8 Flexural strength results

% REPLACEMENT BY ZEOLITE	FLEXURAL STRENGTH (28 DAYS) (N/mm^2)
0	3.13
5	3.386
10	3.615
15	3.756
20	3.491

3.5. Carbon Curing and Water Curing

Results show that much more strength is achieved by 2 hours carbon curing than by 7 day water curing which is due to the formation of $CaCO_2$. $CaCO_2$ present in cement is unstable so use of CO_2 gas makes the $CaCO_2$ stable, resulting in binding of cement to other components of concrete. The carbonation products are primarily calcium carbonates and silica gel. The carbonated concrete products increase performance such as achieving strength, durability and stabilizing dimensions by completely depleting calcium hydroxide when reinforcing steel is not to be used. This can be used in concrete products such as blocks and cement boards.

Table - 9 Curing Comparison

SPECIMENS	DURATION OF CURING	COMPRESSIVE STRENGTH (N/mm^2)
Carbon Cured Concrete Cube	2 Hours	19.55
Water Cured Concrete Cube	7 Days	16.8

This early age strength through waste gas proves beneficial in terms of reducing in atmospheric pollution and saving the water which is a critical resource now-a-days.

4. CONCLUSION

The compressive strength of zeolite concrete by 15% replacement was beyond other replacement levels. Direct use of natural zeolites as partial replacement for ordinary Portland cement in concrete above 15% by mass didn't considerably improve the concrete compressive strength. Thus, it can be concluded that the compressive strength kept decreasing with increase in zeolite content. Adding natural zeolite to concrete resulted in reduction of slump value of fresh concrete which is because of its cubical shape and rough surface.

In the beginning the rate of penetration of carbon dioxide and the gain in strength of concrete was quite quick. So in the precast industry carbon dioxide can be useful resource in terms of construction. The carbonation products are primarily calcium carbonate and silica gel. The carbonated concrete products increase performance such as achieving strength, durability and stabilizing dimensions by completely depleting calcium hydroxide when reinforcing steel is not to be used. This can be e used in in concrete products such as blogs and cement boards.

The increment in early compressive strength of of carbon dioxide cured cubes was significantly higher. CO_2 curing can be more effectively done for precast building products cured in a controlled environment. If CO_2 is is applied forcefully in moist temperature the results would be better for CO_2 curing. Pollution can be reduced in many ways one of which is by channelizing the waste CO_2 for curing of concrete in precast plant for better and stable sequestration.

5. REFERENCES

[1]Sean Monkman, Mark MacDonald and Doug Hooton(2016), 'The Durability of Concrete Produced Using CO2 as an Admixture', Fourth International Conference on Sustainable Construction Materials and Technologies.

[2]Balraj More, Pradeep Jadhav (2014), 'Carbon Absorbing Block Produced Using Zeolite', International Journal of Technology Enhancements and Emerging Engineering Research, Vol: 2, Issue 7, Pg 147-151.

[3]Tiana Milović, Miloš Šešlija (2015), 'Influence Of Natural Zeolite On Some Properties Of Mortar/Concrete', International Conference contemporary achievements in civil engineering, Pg 61-66.

[4]Pranav Tagwale, Vibhas Bambroo (2015), 'Potential of Carbon dioxide Absorptionin Concrete', International Journal of Students Research in Technology & Management, Vol 3(05), Pg 369-372.

[5]Yoshiokaa, D. Obata (2013), 'New ecological concrete that reduces CO2 emissions below zero level -New method for CO2 capture and storage', Energy Procedia,Vol 37, Pg 6018– 6025.

[6]M. Sedlmajer, J. Zach (2015), 'Possibilities of Utilization Zeolite in Concrete', International Journal of Civil and Environmental Engineering, Vol 9, Pg 525-528.

[7]Jan Małolepszya, Ewelina Grabowskaa (2015), 'Sulphate attack resistance of cement with zeolite additive', Procedia Engineering, Vol 108, Pg 170 – 176.

[8]Anila Mary Jacob, Lakshmi G Das (2017), 'Ecofriendly Concrete by Partial Replacement of Cement by Zeolite', International Journal of Innovative Research in Science, Engineering and Technology,Vol 6, page no:8194-8200.

[9]Mohd Tanjeem Khan, Khan Rahim Saud (2018), 'Curing of Concrete by Carbon dioxide', International Research Journal of Engineering and Technology, Vol 5, Issue 04, Pg 4410-4414.

[10]Warda Ashraf (2016), 'Carbonation of Cement-Based Materials: Challenges and Opportunities', Construction and Building Materials 120 558-570, Elsevier, 558–570.

[11]Pranav Tagwale, Vibhas Bambroo (2015), 'Potential of Carbon dioxide Absorption in Concrete', International Journal of Students Research in Technology & Management, Vol 3(05), Pg 369-372.