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Carbonation Curing of Concrete: A Review of CO_2 Based Curing Technology

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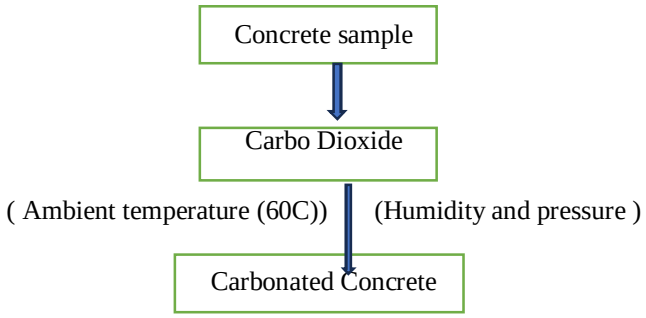
Abstract: ***Carbonation curing: CO_2 curing technology is a crucial technology for cement based material and precast materials which can help in the reduction of carbon impact on the environment . This review evaluates the environmental factors, its structural performance outcome , curing efficiencies and future scops of carbonations curing .***

Its chemical pathway states that in primary point the Carbon dioxide is reacted with the calcium silicate of concrete (i. e in fresh form or- demolded (concrete) and an exothermic rex. Takes place and hydrate gel and calcium carbonate forms. These precipitates fills the capillary pores in concrete due to which a microstructure is converted into nanopores and early age compressive strength development is fastened .

This document also compares conventional steam curing with the carbonation curing, on the basis of principle, primary agent temperature, reaction , chemistry, operation differences. Also the carbonation curing gives the advantages of lowering the carbon footprint and its practice. This paper also states the uniform treatment, industrial utilization , and on the basis of field condition to access the structural long term stability.

Keywords: Carbonation, CO_2 emission, Compressive strength, steam curing.

Flow Chart Of Carbonation Process



I. INTRODUCTION

Due to the large emission of CO_2, it has become a greatest cause of global warming. So we need to control the CO_2 emission. It is important to innovate new technologies to utilize the CO_2 emitted from major industrial sources [(1)]

Only capturing CO_2 is not enough it needs its permanent fixation in civil engineering. Carbonation curing is not a new technique it was used in the same period of steam curing but adopting it in large scale industry was difficult because of highest of CO_2.[(2)]

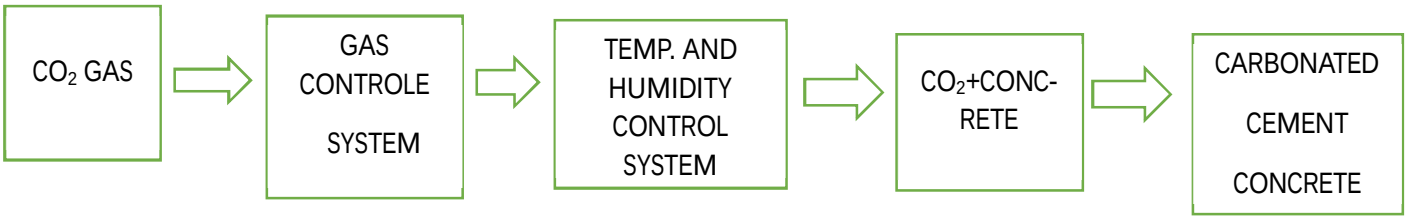
To check the feasibility of Carbon Dioxide curing recycled concrete , several blocks were constructed with 0% 50% and 100% recycled aggregate .

Two types of blocks were prepared (Load bearing and non load bearing and were cured in pressurized chambers with100% Carbon Dioxide curing for 6,24 and 12 hours humidity and temp. also was maintained . During curing temp inc. and this experiment showed that the carbonation cured block had high Compressive strength then moisture cured blocks [(3)]

Permanently storing the Carbon dioxide inside the cement and concrete is the most imp. research. It also inc. the mechanical properties of concrete [(4)]

But using the flow through curing in place of pressurized curing is more suitable [(5)] because it is more easier process in this process specimen itself emit Carbon dioxode for curing in ambient temperature and moisture.

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II. OBJECTIVE

- Using co_2 as curing agent.
- To accelerate early age hardening.
- To archive early compressive strength.
- To convert co_2 gas into stable carbonate material ($CaCo_3$)
- To densify microstructure.
- To improve mechanical properties of concrete.
- Reduction of curing time.
- Search the alternate of steam curing.
- Civilization of industrial waste.
- Optimize curing patterns.

III. METHODOLOGY

1) Search strategy: Google scholar.
2) Extraction criteria: Paper based only on carbonation curing's its invention, reaction , process and history &scopes .
3) Analysis:

- Compressive strength increases.
- Early strength .
- Improve mechanical properties .
- Alternate method of steam curing .

IV. REACTION MECHANISM

The strength development of the calcium silicate based cement material in completely related to the carbonation [(6)]
In lime mortar the strength development is based on the reaction of the atmosphere co_2 with $Ca(OH)_2$ which forms $CaCO_3$.
In normal atmosphere condition this reaction is slow because in pressure of low co_2 the partial pressure diffusion is controlled . It is very important to have aqueous film around the particles for primary reactions .

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

The Bita silicates and anhydrous Portland cement is exposed with co_2 .Several technique are used for this process such as XRD , SEM, TG , DTA e .t .c so that the changes in Calcium silicate phase should be identified [(7)].
It also shows that the polymorph carbonate formation is associated with temperature water and pore solution chemistry .

$$CSH + CO_2 \longrightarrow CACO_3 + SiO_2.nH_2O$$ [(8)].

V. FACTOR AFFECTING THE CARBONATION OF EARLY AGE CARBONDIOXIDE CURED CONCRETE

There are two main factors , one is external and one is internal . External factor means CO_2 pressure , temperature , humidity and internal include water cement ratio and water content[(1)].

1) WATER CEMENT RATIO : Moisture is required for carbonation but if water is present in very large quantity it can fill the pores and due to which co_2 diffusion will slow down [(9)].
2) CARBONDIOXIDE PRESSURE : Generally by increasing pressure carbonation strength also increase but in very high pressure the structure of paste damages and decrease the strength .
3) RELATIVE HUMIDITY / MOISTURE CONDITION : For carbonation curing moderate range of humidity is important but more high relative humidity can decrease the strength .

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4) CARBONDIOXIDE CURING TIME : In co_2 curing the strength gain is faster in first one and two hours but then generally decrease [8].
5) TEMPREATURE : 60C+7 Hours carbonation temperature is best for carbonation curing . Temperature more than this can cause damage to the structure of concrete[10].

VI. EFFECT OF CARBON DIOXIDE ON THE PERFORMANCE OF CONCRETE

1) Early Age Compressive Strength: Carbonation curing gives early strength to concrete in first one to two hours . Short term carbonation curing helps in accelerating early strength[11].
2) Drying Shrinkage: In steam curing after drying the shrinkage of concrete takes place but in carbonation curing the drying shrinkage is lower in comparison[12].
3) Carbon Dioxide Consumption: During pre conditioning optimum moisture content lose , co_2 consumption was highest and compressive strength is also highest at this point[13].

VII. COMPARION BETWEEN STEAM CURING AND CARBONATION CURING

NO.	PROPERTIES	CO_2 CURING	STEAM CURING
1.	Curing Time	Co_2 curing takes 4-8 hours	Steam curing takes 7-8 hours
2.	Early strength	In co2 curing early strength development is good	In steam curing it is faster
3.	Compressive strength	Co_2 curing gives high compressive strength	Steam curing give less compressive strength as compared to co_2 curing
4.	Co_2 emission	Co_2 curing consume carbon dioxide (0.46 Kg co_2 per blog)[14]	Steam curing release co_2(0.17 Kg per blog)

VIII. LITERATURE REVIEW

1) *Rostami Shao and Boyd (2012):*Rostami et al studied carbonation curing as an alternate method to the steam curing of the precast concrete. It was only used in that time for the curing of precast concrete but using it for large scale curing was not possible. Carbonation cured concrete showed the higher resistance to the Chloride permeability, Freeze Thaw damage and the sulphate attack in comparison with the steam curing.
2) *Zhan, Poon & Shi (2013):* This paper showed that having recycled aggregates in different proportions in the test specimen , in carbonation curing Shows that there is no impact on the compressive strength because of the recycled aggregate . Specimen showed the same strength development in concrete blocks that were cured by carbonation and more strength was attained by the specimen as compared to the steam cured concrete blocks.
3) *Shi, He & Wu (2012):* This paper investigates the strength development and weathering properties of the full size lightweight concrete blocks was similar to that of steam cured blocks. It states that steam cured blocks attained early strength but it was lesser strength as compared to the concrete cured by the help of the carbonation curing.
4) *Wang et al. (2021):* This paper shows the study of early age carbonation curing of Calcium Sulfo aluminate cement that mainly focus on the mechanical properties of the concrete and its microstructure. This study showed the several factors that were affecting the early strength of the concrete some of those factors are water cement ratio, water content, pressure, humidity .
5) *Zhan el at. (2016):* This study shows the parameters that influence the carbonation curing of concrete blocks (mainly recycled aggregates concrete blocks). With all the parameters , attaining the higher early age strength in 2 to 4 hours was obtained.
6) *Xuan Zhang & Poon (2018):* This paper shoes the development of the maturity approach of the compressive strength development of the CO_2 cured concrete blocks.

High CO_2 concentration, fast gas flow rate and moderate RH value were found to enhance maturity and strength development.

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IX. APPLICATION OF CARBONATION CURING

1) PRECAST CONCRETE: The major role of carbonation curing is precast concrete and this carbonation curing was invented firstly especially for the precast concrete.[11]
2) CONCRETE BLOCKS: To make the high strength load bearing and non load bearing concrete blocks, CO2 curing is applicable.
3) RECYCLED AGGREGATE CONCRETE: In steam curing the strength difference between recycled aggregate and normal aggregate was very large but CO_2 curing provides equal strength with both types of aggregate.[12]

X. LIMITATIONS OF CARBONATION CURING

1) After carbonation the long term strength gain is limited.[12]
2) The microstructure of the concrete is not fully understood so the engineering applications of carbonation curing are limited.[7]
3) The response of carbonation curing depends on the type of cement material Calcium silicate shows rapid strength but Calcium Aluminate have negligible strength development.[15]
4) In comparison to steam curing the early strength development by carbonation curing is slower.[16]

XI. DISCUSSION

This paper shows that carbonation curing of cement based materials utilize Carbon Dioxide to accelerate early age strength. During carbonation the Calcium compound react with Carbon Dioxide to form Calcium Carbonate that makes the concrete structure more denser and refine the pore structure.
Overall study shows that the Carbon dioxide curing and Carbon Dioxide utilization.

XII. CONCLUSION

The conclusion of this study is that it is very important for reducing Carbon Dioxide impact on the environment. In Civil Engineering curing is a factor in which Carbon Dioxide can be reused for increasing the strength of concrete as compared to the concrete cured by steam curing.
It also shows that the high early strength of concrete by carbonation curing depends upon the external and internal factors such as; temperature, humidity, pressure, and water cement ratio. Very high temperature can cause the damage of the structure of the concrete. More humidity can slow down the early high compressive strength gain of the concrete e .t .c

XIII. FUTURE SCOPES

1) Long Term Performance: More studies are needed for the long term performance of concrete that is cured by using Carbon Dioxide curing .
2) Carbon Dioxide Utilization: More research needs to be done for the usage of large amount of industrialized Carbon Dioxide emission.
3) Durability Under The Different Environment Conditions: Carbon Dioxide curing of concrete needs to be studied more so that it can be used in several harsh places e. g : Freeze Thaw conditions.
4) Carbonation Curong With Other Curing Methods: Mixing the Carbon Dioxide curing with water curing needs to be studied for its early strength. Only using water curing can cause shrining of concrete after drying but combining both curing is beneficial for early high strength and less shrinking of concrete after drying and also in a very short period of time.

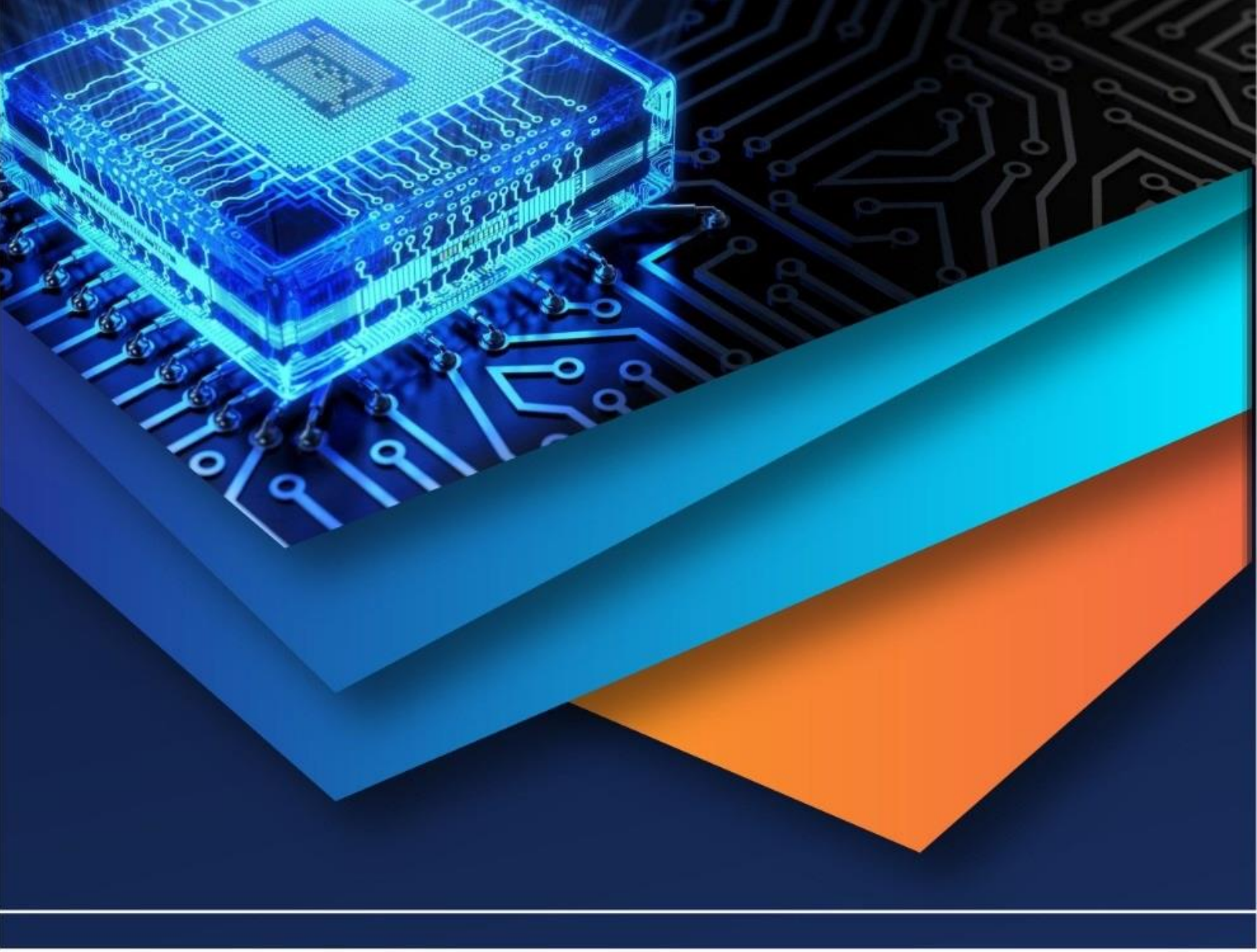
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