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A Review Paper on the Use of Carbon Dioxide gas to Shorten the Curing Time of Concrete

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ABSTRACT:Carbon dioxide (CO2) is the predominant greenhouse gas resulting from anthropogenic activities. A significant fraction of CO2 which is discharged into the atmosphere comes from the point sources of Industry. Cement production alone contributes approximately 7-9% of global CO2 emissions. This emitted CO2, however, can be partially recycled into concrete through early age curing to form thermodynamically stable calcium carbonates. The carbonation reaction between CO2 and appropriate calcium compounds results in permanent fixation of the CO2 in a thermodynamically stable calcium carbonate. CO2 and water can be found in every environment and thus the concrete will be subjected to carbonation. The potential for CO2 absorption in concrete is summarised in this publication. It also emphasizes on the study of optimization of concrete by curing it by using CO2 gas whichcan be beneficially used in the manufacturing of concrete to reduce carbon emissions, increase early strength, and improve the concrete's durability. In accordance with cement content and cement type, carbon uptake in 2 hours, 4 hours, 6 hours and 8 hours will be tested for mechanical and durable properties. Ultimately comparative study will be conducted on concrete curing by conventional method and by carbon dioxide curing method.

KEYWORDS: Carbonation, CO_2 Concrete Curing, SCM, Blended Cement, Composite cement

I. INTRODUCTION

Greenhouse gas emissions are considered to be responsible for global warming and climate change. It is mentioned the percentage contribution of major greenhouse gases. It can be seen that carbon dioxide accounts for about 60% of the greenhouse effect which is also crucial to climate change.

The greenhouse gas effects have significantly increased because of human induced activities since the industrial revolution began. Changes in the levels of greenhouse gas and its concentration in the atmosphere's lifespan since pre-industrial times. The concentration of carbon dioxide in the atmosphere has increased approximately 30% as high as pre-industrial levels. The current situation level of carbon dioxide is 365 ppm and is rising at a rate of 1.5 ppm per year. (IPCC 2020)

The emitted carbon dioxide can be partially reused as a curing agent in concrete by initial age curing which results in the formation of thermodynamically stable compounds of calcium carbonates.Concrete is known for its ability to absorb carbon dioxide from the atmosphere.Carbonation is the process of CO2 being absorbed into concrete. Early-age CO2 curing develops strength, increased surface hardness, and reduced surface permeability to water, as well as the reduction of efflorescence to concrete products. The reactions of carbonation between carbon dioxide and calcium compounds result in the formation of stable calcium carbonate as a permanent fixture.

II. LITERATURE REVIEW

Alex Neves Junior, et. al(2013), author describes the research done on the cement paste with the help of co2. The paste was made with 0.70 W/C ratiocaptures the highest amount of CO2 after the previous 6 h of hydration. The RH of 60% is an optimum condition for carbonation treatment.

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Thermogravity(TG)&n derivativethermogravity(TDG) were done to evaluate the mass gain. Calcium carbonate decomposition & its reverse kinetics were studied by the thermogravity& derivate thermogravity. The carbonation on the fluid cementitious paste was tested with the help of TG & DTG.

Yixin Shao, et. al(2006), researchers found that the calcium silicate concrete is a preferred form of calcite to convert gaseous CO2 to solid calcium carbonate. OPC can take much more CO2 than its theoretical capacity. The uptake of co2 will be 9-16% by the mass of the concrete. The carbon dioxide sequestration of the concrete is similar to the small geologic storage project. The co2 gas has been acquired from the cement kiln which is one of the most co2 emitters.

Yixin Shao, et. al(2006), author describes the experimental studies on the accelerated curing of the concrete with the use of the co2 gas. They have experimented the accelerated curing by using 100% & 25% purity co2 gas. It was found that the carbonated concrete could consume up to 16% & 9.7% respectively, mass gain of CO2 in two-hour carbonation curing at 0.5 MPa pressure. Higher the co2 content then higher will be the generation of the calcium carbonate which will lead to faster curing of the concrete in less time and pressure. Both the test implies the carbon dioxide intake in the concrete specimen with the different amount of the purity of gas. They were able to test the potential of the cement to absorb the co2 due to which it will lead to reduction of global warming.

Alex Neves Junior, et. al(2014), The mechanical results after 28 days of hydration indicate that,vone hour of carbonation enhances the mechanical resistance of an HS SR PC paste under the same operating circumstances. Research shows that the 60 mins of carbonation would not change the degree of polymerization of the cementitious matrix. By increasing the time of the carbonation, it will also increase the porosity &pores of the paste. 1 hour carbonation shows that porosity leads to good durability. 1 hour carbonation enhances the properties of the cement paste.

Seong Ho Han, et. al(2020), researchers found out that CO2 can accelerate and improve the strength of cement-based materials via cement carbonation. In this study, 3 bar CO2 curing was applied to premature cement paste and mortar for 3 h and then successive conventional curing followed for cement hydration. Greenhouse gas emission reduction was significantly being tested by the curing of concrete. They have tested on the cement paste with different water cement ratio. Accelerated curing strengthens the cement paste within a few hours.

Bao Jian Zhan, et. al(2016), accelerated curing effects on the various chemicals present in the concrete & their capacity for holding the carbon dioxide gas. The reaction between carbon dioxide gas and the calcium components in the concrete. The compressive strength of the concrete blocks increased significantly in the first 2 h of CO2 curing, but slowed down after that. 2 h of pressurized CO2 curing produced concrete blocks with compressive strength compared to that of 28 days of conventional cured blocks. Increasing in gas pressure enhanced the CO2 diffusion, dissolution and carbonation reactions, and as a result, the concrete blocks' curing degree and compressive strength were greatly boosted. But further increase in gas pressure was less effective.

H.E. Pingping, et. al(2016), XRD tests were done to study the effect of the accelerated curing done by carbon dioxide on the concrete specimen. Microscopic observations were done to analyse the microstructure of the concrete surface atvarious time intervals and also beingcompared with the conventionally cured one.

Zhenjun Tu, et. al(2018), studies of the limestone powder were done after curing by the carbon dioxide gas. A longer period of curing led to a higher water loss and lower remaining water-to-binder ratio. There appeared to be an optimal remaining water-to-binder ratio for which fast diffusion and dissolution of CO2 results in the longer curing of concrete. The addition of limestone powder as cement replacement seems to increase the value of the optimal remaining water-to-binder ratio gradually. Limestone powder content positively affects the CO2 curing degree of concrete. Such an improvement was likely because the limestone powder was used instead of cement.

Xiaoxiao Jia, et. al(2020), The aim of this paper is to investigate the effect of carbonation on the microhardness and mechanical properties of carbonated and non-carbonated layers of cement paste.Microhardness and mechanical property changes were investigated one day after demolding, then three, seven, fourteen, and twenty-eight days later with additional CO2 and water curing.By consuming calcium hydroxide and producing calcium carbonate, CO2 treatment had a significant impact on the microstructure and densification ofthe paste's surface layer. By comparing the features of its internal and surface layers, the effect of CO2 on the microhardness and mechanical properties of 0.35 w/c cement paste was investigated. Cement paste samples were cured for 3, 7, 14, and 28 days with water and CO2, and

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TGA-DTG analysis, microhardness, and compressive strength tests were done after 28 days.

J.H.M. Visser, et. al(2013), Carbon dioxide's effect on concrete's carbonation resistance Carbonation at an early age aid in the constructive resistance against later-stage carbonation, which is damaging to concrete. A high CO2 concentration has no effect on the carbonation process because carbonation happens instantly, keeping the CO2 concentration at the reaction front at zero. The only consequence of a high CO2 concentration is faster CO2 molecule transit to the pore air–pore solution interface, resulting in a faster reaction process.

T. Santhosh Kumar, et. al(2019), The findings of an experimental investigation conducted to assess the mechanical properties of specimens cured in water, CO2. When compared to water-cured specimens, CO2 cured specimens reached early strength. When compared to water cured specimens, the compressive strength of CO2 cured specimens after 8 hours has achieved 90% of the strength. When compared to specimens cured in water, split tensile strength of CO2 cured specimens for 8 hours obtained 92 percent of tensile strength. When comparing the flexural strength of CO2 cured specimens to those cured in water, the CO2 cured specimens reached 89 percent of the flexural strength.The CO2 cured specimens have achieved slightly higher compressive strength with an increase when compared to water-cured specimens, the curing time is 8 hours.

Caijun Shi, et. al(2012CO2-cured blocks were comparable in strength to steam-cured blocks. The former, on the other hand, fluctuated across a wider range due to differences in moisture content in blocks prior to CO2 curing, which resulted in various CO2 curing degrees. Due to the additional hydration of unhydrated or unreacted cement particles within the blocks after steam and CO2 curing, the strength of the blocks grew progressively in a damp environment. Steam-cured blocks, on the other hand, acquired strength faster than CO2-cured blocks. The compressive strength of CO2-cured concrete blocks reacted similarly to steam-cured concrete blocks when exposed to winter weather.As a result, CO2-cured blocks exhibit similar weathering resistance to steam-cured blocks. After 180 days of outdoor winter weather exposure, CO2-cured blocks showed less drying shrinkage and water absorption than steam-cured blocks. The difference in drying shrinkage and water absorption between steam- and CO2-cured concrete products is related to the reaction products.

MohdTanjeem Khan, et. al(2018), In full-scale concrete production using carbonation curing, the continuous CO2 delivery approach proven to be technically viable and practically feasible. The continuous CO2 supply in the carbonation process compensated for the CO2 depletion that occurred naturally, promoting maximal CO2 absorption by concrete.

Björn Lagerblad, et. al(2005)Concrete's carbon dioxide consumption over its lifetime is investigated. Time, concrete use, concrete end use, exposure condition, surface area, cement or concrete amount, and carbonation speed all influence carbon dioxide consumption. The major influencing factors are those listed above.

Isabel Galan, et. al(2013), The greater combination and smaller carbonation depth in specimens not sheltered from the rain is assumed to be a result of soaking and drying in natural carbonation. Although CO2 diffusion is inhibited while the pores are clogged with rainwater, the process is aided in the accessible zones by the more favourable conditions. Higher w/c leads to higher combination rate but not necessarily higher CO2 mixed in slow accelerated carbonation, 0.5 percent CO2. Higher porosity facilitates diffusion, although the 'carbon' material may decline with the w/c. The greatest values achieved in 100% CO2 accelerated carbonation are in the same range as natural carbonation, which is roughly 23–25%.

III. OBSERVATIONSIN LITERATURE REVIEW

According to the preliminary research, concrete has the ability to absorb carbon dioxide during its early curing stages. The method has the potential to assist in the resolution of a serious environmental problem Caused by the greenhouse effect and global warming. It was discovered that a carbonated concrete might use up to 16 percent CO2 in just two hours of curing at 0.5 MPa pressure. Their strength developed after two hours of curing outperformed controls after seven days or 60 days of traditional curing.With a cost of less than $10 per tonne of CO2, CO2 can be utilised through the concrete curing process. For large-scale production, an efficient fan drying system is essential. The cost of CO2 capture can be decreased to $40 per tonne of CO2. With a capture cost of $40 per tonne of CO2 and a utilisation cost of $10 per tonne of CO2, concrete blocks can be cured for $0.018 each block. It's based on the idea that each block can hold 0.36 kg of CO2. It corresponds to a 20 percent cement mass intake.

It is possible to replace traditional steam curing of precast concrete with carbonation curing.

It has the potential to lower concrete's embodied energy, improve durability, and provide a CO2 usage option. The initial curing of concrete in a controlled setting created capillary gaps for CO2 to infiltrate, allowing it to carbonate. Based on cement mass, the proposed short-term carbonation-curing process has the ability to absorb 8% carbon dioxide.

The relationship between carbonation reaction and pozzolanic reaction in fly ash concrete was studied through the quantitative analysis of fly ash reaction degree and cement reaction degree. It was found that pozzolanic reaction of fly ash in a FA-OPC system was hindered by early carbonation reaction. The higher the early carbonation degree, the lower the pozzolanicreactionofflyash.

It is required to undertake controlled carbonation on concrete with enough fly ash content in order to reap the benefits of both reactions. If the carbonation reaction is confined to 12 hours, concrete containing 20% fly ash can have stronger early strength by carbonation reaction, comparable late strength by pozzolanic reaction, and improved durability performance.Even with a low water to cement ratio, carbonation could not take place in raw concrete without pre-conditioning. The carbon di-oxide was unable to diffuse through the matrix due to surface saturation caused by vibration producing. To eliminate free water and make room for carbonate precipitation, preconditioning is essential.

Even after precondition drying removed 55 percent–65 percent free water, the relative humidity inside concrete remained above 90% in its fresh form. Within 24 hours, equilibrium with ambient RH could not be achieved, even at a depth of 10 mm from the drying face. As a result, relative humidity is insufficient to represent the status of fresh concrete carbonation curing.

It is advised that cement-bonded fibreboards be pre-dried for 18 hours (overnight) to achieve a water content of 40% and carbonated for 0.5 hours to achieve a CO2 absorption of 20%. The flexural strength of the so-produced fibreboards (CFB 7) will be 8.3 MPa after 20 hours and 12.2 MPa after 28 days, meeting the ISO strength criterion with significantly increased freeze-thaw resistance.

Curing with carbon dioxide is more energy efficient than curing with an autoclave. Fiberboard production in the United States has a CO2 sequestration potential of 360,000t CO2 per year. CO2 recovered from carbon capture and storage projects can be put to good use in the construction industry.

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