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A Review on the Application of Carbon Dioxide Gas as a Curing Compound

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***Abstract*— The rising level of carbon dioxide in the atmosphere is one of the main concerns of researchers of all the time. The high level of CO2 concentration in the atmosphere has serious effects on environment as it can make the earth warmer than it would be. Recently, there was a warning from UN weather agency's annual flagship report about the increasing level of CO2 concentration in the atmosphere. According to the report, the CO2 concentration has risen from 400 parts per million in 2015 to 403.3 parts per million in 2016, which was found to be the highest rate in past three million years. This paper discusses about reduction of CO2 emission by utilizing it in the curing process of precast concrete elements. The comparison of effect of different curing conditions on carbonation reaction was reviewed. The effect of initial curing in the water loss and carbon uptake of concrete was also discussed.**

Index Terms - Carbon Dioxide, Precast Concrete, Carbon Uptake, Initial Curing.

I. INTRODUCTION

The increasing level of carbon dioxide concentration in the atmosphere is becoming a major issue nowadays. The high level of CO2 in the atmosphere would result in an increased surface temperature and unstable climatic conditions. The main sources of human induced CO2 emissions are burning of fossil fuels, deforestation, industrial emissions and so on. It should also be noted that 5% of global CO2 emission is due to the manufacturing of cement. Construction industry is producing more that 1.6 billion tons of cement a year, which will emit about 1 ton of CO2 to the atmosphere. There would be also emission of CO2 from heavy machineries used in construction industry. The transport of materials would also result in a CO2 emission of about 6-8%. The commercial and residential sector together is contributing a CO2 emission of around 39%. The reduction of CO2 level in the atmosphere is thus the responsibility of construction industry as well. [1]

Carbonation, the process of absorption of carbon dioxide to concrete surface, is well known for the improvement of the surface hardness, strength and durability of concrete. Concrete structures absorb CO2 in its calcium bearing phases and produces calcium carbonate as shown in the equation 1.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O \qquad (1)$$

The absorption of CO2 in the concrete surface will lower the pH of the absorbed concrete portion. Carbonation in concrete seems to be advantageous in non-reinforcement structure as the reinforcements would be more vulnerable to corrosion as the pH of concrete gets lowered. Many studies have been conducted for accelerating the carbonation process in concrete structures.[2]

The implementation of carbon dioxide as a curing compound would not only helps in reducing its level in atmosphere, but will also eliminate the use of large amount of water for curing process. The CO2 curing can be done using an experimental setup as shown in Figure 1. An air tight vessel is used as CO2 chamber. The vacuum pressure before CO2 injection was made to be -0.5 bars. Also, the pressure of CO2 in the chamber was kept constant at 0.1 bars with the help of a regulator. Anhydrous silica gel was used inside the chamber to absorb water from the specimen during carbonation, which will help in maintaining the required humidity.[4][5]

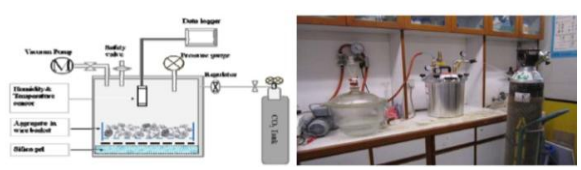

Fig 1.Experimental Setup of CO2 curing[4]

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II. CARBONATION IN DIFFERENT CURING CONDITION

The hardened properties of concrete specimen were compared under different curing conditions. The curing conditions used were moist curing room with 100% relative humidity and 0.15% CO2, drying room with 50% relative humidity and 0.15% CO2 and CO2 chamber with 50% relative humidity and 5% CO2. The Portland cement used was ASTM type 1. The fine aggregate used was river sand with specific gravity 2.6, bulk density 1790 kg/m3 and absorption 1.4%. The coarse aggregate used was of specific gravity 2.66 and bulk density 1550kg/m3.[6]

Figure 2 shows the compression strength of 100x200mm cylindrical specimen under three conditions at 3,7,28 and 91 days of curing. The specimen cured in dry room developed lowest compressive strength. Also, the specimen showed no or less strength gain after 28days. The CO2 chamber cured specimens showed same compressive strength as that of moist cured specimens.

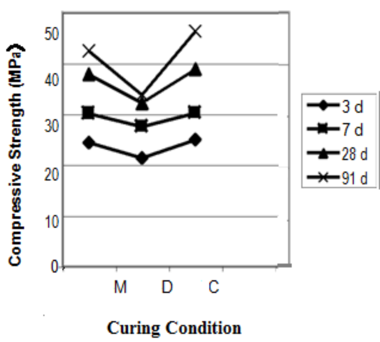

Fig 2. Compressive strength of specimens under different curing conditions.[6]

Figure 3 shows split tensile strength developed by 100x200mm cylindrical specimen at 3,7,28 and 91 days. The specimen cured in dry room showed less split tensile strength than moist and CO2 cured specimens except in the 3 day split tensile strength. The CO2 cured specimens showed approximately the same strength as that of moist cured specimens.

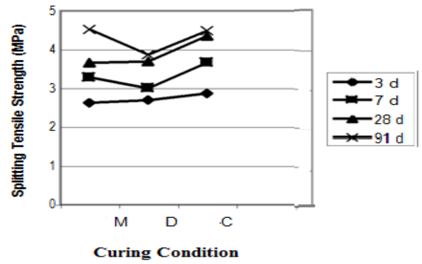

Fig 3. Split tensile strength under different curing conditions[6]

Figure 4 shows the flexural strength of 100x75x300mm concrete specimen after 7, 28 and 91 days. The specimen cured in dry room condition showed more strength initially than other conditions, but showed lower strength at 91days of curing. The CO2 cured specimen showed higher flexural strength than specimens cured under moist and dry condition.

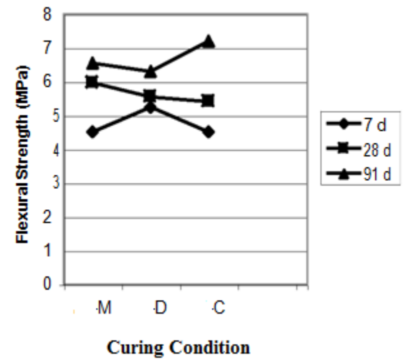

Fig 4. Flexural strength under different curing conditions[6]

A pH indicator solution of 1% phenolphthalein and 70% ethyl alcohol solution was used to measure depth of carbonation in specimens. The area which turned pink after spraying the solution was considered as non-carbonated and area which showed discoloration was considered as carbonated .Table A show the depth of carbonation in concrete at 3,7,28 and 91 days under these conditions of curing. Specimen cured under moist condition showed up carbonation. Concrete used in co2 chamber showed higher carbonation than the concrete curved in drying room.[6]

Table A. Depth of carbonation of concrete(mm) under different curing conditions.[6]

Curing Condition	Age(days)			
	3	7	28	91
Moist curing	0	0	0	0
Dry room curing	0	0	3	6
Chamber curing (CO2)	3.5	7.5	12	22

Table B. Mass loss due to abrasion of specimen (grams)[6]

Curing Conditions	Age (days)	
	28	91
Moist curing	3.1	3
Dry room curing	15.7	17.5
Chamber curing (CO2)	11.7	9.9

The top surface of specimen was abraded using rotating cutters for 6 minutes under a load of 197N. Table B shows the loss of mass in grams of specimen, due to abrasion. The specimen cured in moist condition showed more abrasion resistance than specimen in CO2 curing. The specimen cured in dry room showed more mass loss and resistance developed with age. But for CO2 and moist curing, abrasion resistance increased with age.[6][7]

III. EFFECT OF INITIAL CURING ON CARBONATION

The curing process was performed on rectangular slab. An initial air curing of 0,4,6,8 and 18 hours respectively was performed on each specimen at a relative humidity of 50% and temperature of 250 C. Carbonation was performed to the initially cured concrete for duration of 2 to 4 hours. A carbonation period of 96 hours was also given to study for the effect of extreme exposure time.

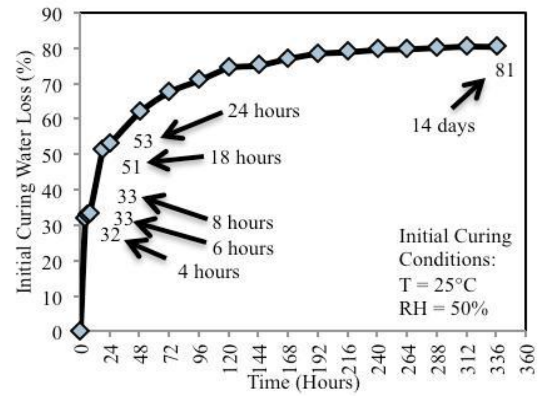

Fig 5. Water loss due to initial curing[8]

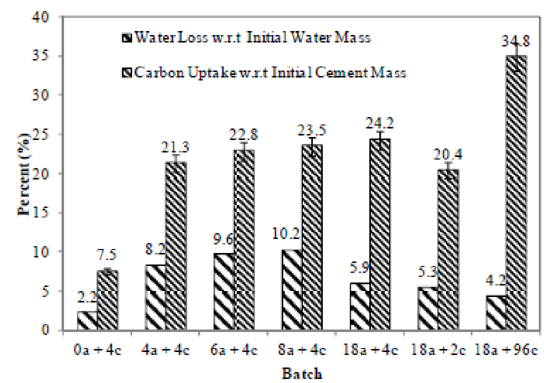

Fig 6. Water loss and carbon uptake due to carbonation[8]

Figure 5 shows the water loss due to initial curing and figure 6 shows the water loss and carbon uptake due to carbonation. For 4 hours carbonation without initial curing, the specimen resulted in a water loss of 22% and carbon uptake of 7.5%. An initial air curing of 4,6 and 8 hours resulted in a water loss of about 32-33%. The water losses due to 4 hour carbonation for these specimens were 8.02%, 9.6% and 10.2% respectively. The carbon uptake was 21.3%, 22.8% and 23.5% respectively.

It is obvious that initial curing helps to reduce water and aids in gas diffusion and calcium carbonate precipitation. But water loss due to carbonation

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decreased for 18 hours of initial curing which indicates that prolonged initial curing would not increase the reaction efficiency.

For 8 hours initial curing, 4 hours of carbonation showed more water loss and carbon uptake than 2 hours of carbonation. Carbon uptake increased by 44% for 96 hours carbonation than 4 hours carbonation. But water loss was less for 96 hour carbonation and it might be due to the reabsorption of water during the curing period.

IV.CONCLUSION

The comparison of hardened properties of concrete in moist dry room and CO_2 chamber curing were studied.

• The specimens cured in CO_2 chamber showed approximately the same compressive, split tensile and flexural strength as that cured in moist condition and showed an increased strength when compared to dry room curing condition.

• The abrasion resistance of specimen cured in CO_2 chamber was less than that of moist cured specimen and was higher when compared with dry room curing. But the abrasion resistance of CO_2 cured specimen improved with age. The abrasion resistance could be improved using proper preconditioning of the specimen.

• The depth of carbonation was higher for CO_2 chamber curing and was least for moist curing. This is because of the high relative humidity in moist curing condition. The high carbonation depth of CO_2 chamber cured can be attributed to the integration of more amount of carbon dioxide.

The effect of initial curing on the carbonation reaction was reviewed.

• It was observed that the efficiency of carbonation reaction increased with increase in initial curing but it was less for prolonged period of initial curing.

• The carbon uptake of concrete increased with increase in carbonation period. And it would also help in increasing the carbon storage capacity of concrete.

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