

Influence of Dry Ice on Performance of Fresh Concrete

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ABSTRACT: During its life, structure must resist various aggressions or loadings, physical, mechanical or chemical, while preserving its overall durability and aesthetics as much as possible. Structural durability must be justified by considering a set of technical recommendations in a normative context. Amongst these specifications, besides those in relation with the rebar corrosion issues, particular attention must be paid to a better control of concrete thermal behaviour to prevent both self-induced expansions (i.e. Delayed Ettringite Formation) and excessive temp. Differentials within the structure to prevent early-age thermal cracking risk that have proved to play an important role in the service life control of a structure. This article describes the global approach implemented by Contractor during the construction of a major structures. Different methods to manage concrete thermal risks have been used on site and choices have been made considering local availability of raw materials, concrete production means and placing methods, size, shape and location of structural elements to be poured, and local climate. The advantages and drawbacks of each possible mitigation measure including concrete post-cooling but also fresh concrete temperature cooling down means are described and discussed in this paper. A particular focus is made on the technical investigations carried out and operational precautions taken prior to the setup of dedicated facilities for cooling down fresh concrete delivered at pouring points with Dry Ice.

In experimental study for Concrete I have used beams of size 500mm X150mmX 700mm and concrete cylinders of 150mm diameter and 300mm length were used for and concrete cubes of size 150mm X150mmX 150mm were used for strength test. The results of the Dry Ice adding gave good result and reduced heat of hydration.

KEYWORDS: Massive concrete structures, hydration heat, temperature reduction, crack risk, mineral additions, concrete cooling.

I. INTRODUCTION

Concrete is a composite of aggregates, mixed/binder and water. This is one of the most used building materials. As a material, it is good durable, workable and resistant to attacks such as corrosion, frost and fire. Concrete is especially used when a building and large structures, for example dams and hydro plants which are expected to be resilient and require high durability. For those constructions, very huge amounts of concrete are needed, contributing and it results to significant heat generation during the cement hydration. This hydration heat may lead to temperature increase in the structure and in combination with restrained edges, it may cause thermal issues such as cracks which may affect the safety of the structure and durability of structure. For those structures which are exposed to direct water pressure thermal cracking may cause leakages and reinforcement corrosion.

To lower risk of thermal cracking the concrete temperature has to be reduced. Many methods can be applied to reduce the temperature in massive concrete structure. These methods can be divided in pre-cooling and post-cooling methods. Pre-cooling methods mainly consists in reducing the amount of heat generated by cement with substituting materials or by lowering the concrete temperature at casting. The post-cooling methods is used to lower temperature of the concrete body while hydrating. In this Post-cooling is adopted in which the Dry ice is added to Concrete and lowered the temperature of concrete while heat of hydration.

II. INTRODUCTION TO DRY ICE

2.1 Physical properties:

Dry ice is the solid form of carbon dioxide (CO₂), a molecule consisting of a single carbon atom bonded to two oxygen atoms. Dry ice is colorless, non-flammable, with a sour zesty odor, and can lower the pH of a solution when dissolved in water. At pressures below 5.13 atm and temperatures below $-56.4\text{ }^{\circ}\text{C}$ ($-69.5\text{ }^{\circ}\text{F}$) (the triple point), CO₂ changes from a solid to a gas with no intervening liquid form, through a process called sublimation. The opposite process is called deposition, where CO₂ changes from the gas to solid phase (dry ice). At atmospheric pressure, sublimation/deposition occurs at $-78.5\text{ }^{\circ}\text{C}$ ($-109.3\text{ }^{\circ}\text{F}$) or 194.65 K



Figure1- Dry Ice

2.2 Handling:

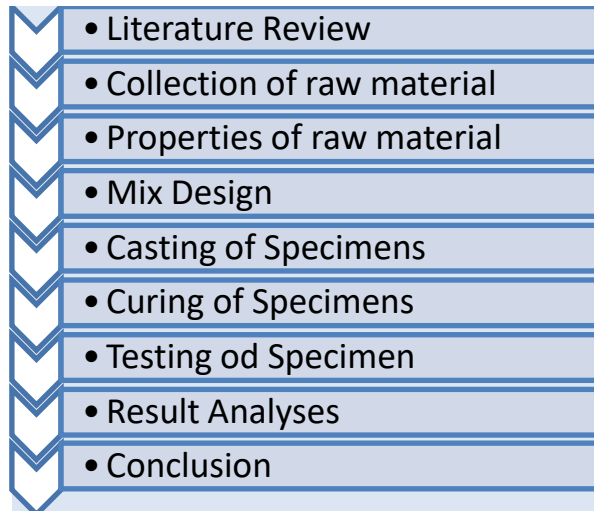
As a Dry ice that rapidly convert to gases and burns, its handling and storage require thermal insulation. It can be stored and transported in vacuum flasks, the temperature. Depending on size and design, the holding time of vacuum flasks ranges from a few hours to a few weeks. The development of pressurized super-insulated vacuum vessels has an enabled Dry ice to stored and transported over longer time periods with losses its property.

2.3 Use of Dry ice:

Dry ice can be used for so many of things, such as a Dry ice can be used for loosening asphalt floor tiles or car sound deadening material making it easy to prise off, as well as freezing water in valve less pipes to enable repair. Dry ice can be used for varies places such as industrial, scientific, Dry ice bombs, Ice creams industries, etc.

III. METHODOLOGY

A one-half-batch mix was used to prime the mixer and stabilize the temperature of the mixer drum. The control mix, without the addition of dry ice, was mixed first followed by the dry-ice mixture. While mixing the concrete employing dry ice, a dense white cloud rolled from the mixer during the first 2-1/2 minutes and a 6-minute mixing period was required before all the dry ice particles disappeared. Mixing action was unaffected and there was no appreciable color change or any other noticeable change in the concrete, either at the time of mixing or after hardening



IV. EXPERIMENTAL PROGRAM

4.1 Materials used

4.1.1. Fine Aggregate

The fine aggregate used in this investigation is clean river sand passing through 4.75 mm sieve and conforming to grading zone II. The fine aggregates were tested as per Indian standard specifications IS 383-1970.

4.1.2 Coarse Aggregate

Locally available coarse aggregates having the maximum size of 10 to 20mm was used in this present work.

4.1.3 Cement

The cement used in this study is 53 grade OPC manufactured by UltraTech cements.

4.1.4 Water

The potable water available in the college premises.

4.1.5 Dry Ice

The Dry ice is in form of solid blocks.

4.2 Casting of Specimens

The Concrete cube specimens (150 × 150 × 150 mm size), Beam specimens (100 x 100 x 700 mm) & Cylinder specimens (150mm dia, 300mm height) were casted by replacing water with 0.8 w.t%, 1.0 w.t%, 1.2 w.t% of dry ice. Dry ice was added while mixing in mixer and were pond cured in room temperature.



Figure2- Casting of Specimens



4.3 Test Setup

4.3.1 ASTM C064 Standard test:

ASTM C064 Standard test is used to measure the internal temperature of fresh concrete. This test is performed on controlled concrete and dry ice dosages concrete of (0.8 w.t%, 1.0 w.t%, 1.2 w.t%) and performed after mixing of concrete. With the help of ASTM C064 apparatus and measured the temperature of concrete. Test results are compared with control concrete specimen with the same grade of concrete (M60).

4.3.2 Workability Test:

For workability test slump cone test is adopted. This test is performed on controlled concrete and dry ice dosages concrete of (0.8 w.t%, 1.0 w.t%, 1.2 w.t%) and performed after mixing of concrete. With the help of standard slump cone apparatus and measured the workability of concrete. Test results are compared with control concrete specimen with the same grade of concrete (M60).

4.3.3 Compressive Strength Test:

The experiment was done by varying the dry ice in the concrete with respect to cement with dosages of (0.8 w.t%, 1.0w.t%, 1.2 w.t%). The water content was maintained at 0.5. Cubes are tested in Compression testing machine (CTM). The specimens of standard cubes of dimensions 150 x 150 x150 mm are preferred. Compression testing machine (CTM) was used to test 7th, 14th and 28th day compressive strength. Test results are compared with control concrete specimen with the same grade of concrete (M60).

4.3.4 Split tensile test:

This test is also known as, “Brazilian Test” The test is carried out by placing a cylindrical specimen of dimension of 150x300mm was casted with various dosages of (0.8 w.t%, 1.0w.t%, 1.2 w.t%) and placed horizontally between the loading surfaces of a compression testing machine (CTM) and the load is applied until failure of the cylinder, along the vertical diameter. This test was carried on 7th, 14th and 28th day split tensile strength. Test results are compared with control concrete specimen with the same grade of concrete (M60).

4.3.5 Flexural strength test:

The beam specimen of dimension 150mm x 150mm x700mm was casted with various dosages of (0.8 w.t%, 1.0w.t%, 1.2 w.t%). The water content was maintained at 0.5. Cubes are tested in Compression testing machine (CTM). The Flexural strength of the beam was carried on 7th, 14th and 28th. Test results are compared with control concrete specimen with the same grade of concrete (M60).

V. RESULT AND DISCUSSION

5.1 ASTM C064 Standard Test

In this study, fresh concrete was tested for 3 mixing variables of dry ice in the concrete with dosage of (0.8 w.t%, 1.0w.t%, 1.2 w.t%) and one convention concrete and compared with each other.

Table No.1 ASTM C064 Standard Test Results (°C)

Test No.	Conventional M60	0.8 w.t% Dry Ice	1.0 w.t% Dry Ice	1.2 w.t% Dry Ice
1	38.6	35.9	34.8	34.0
2	39.1	35.3	34.7	34.5
3	38.5	35.6	34.6	33.2

5.2 Slump Cone Test

In this study, fresh concrete was tested for 3 mixing variables of dry ice in the concrete with dosage of (0.8 w.t%, 1.0w.t%, 1.2 w.t%) and one convention concrete and compared with each other.

Table No.2 Slump cone test (mm)

Test No.	Conventional M60	0.8 w.t% Dry Ice	1.0 w.t% Dry Ice	1.2 w.t% Dry Ice
1	56	48	42	35
2	48	46	48	40
3	51	43	42	39

It indicates the slump cone test of concrete specimen decreases when the quantity of dry ice increase from (0.8 w.t%, 1.0 w.t%, 1.2 w.t%). The minimum was in was in 1.2 w.t% dosage as compared to control concrete.

5.3 Compressive Strength Test

In this study, cube was tasted for three mixing variables with dosage of (0.8 w.t%, 1.0 w.t%, 1.2 w.t%) and one convention concrete and compared with each other. This test was carried on compression testing machine (CTM).

Table No.3 Compressive Strength Results (N/mm²)

Days	Conventional M60	0.8w.t% Dry Ice	1.0 w.t% Dry Ice	1.2 w.t% Dry Ice
7 days	44.72	47.17	48.52	47.63
14 Days	51.26	56.96	57.06	53.75
28 Days	63.96	67.34	70.52	67.11

This indicates the compressive strength of concrete specimen increase for 1.0 w.t% of Dry ice in concrete and for 0.8w.t% and 1.2w.t% it decreases as compared to control concrete.

5.4 Split Tensile Test

In this study, cylinder test for three mixing variables with dosage of (0.8 w.t%, 1.0 w.t%, 1.2 w.t%) and one convention concrete and compared with each other. This test was carried on compression testing machine (CTM).

Table No.4 Split Tensile Strength Results (N/mm²)

Days	Conventional M60	0.8w.t% Dry Ice	1.0 w.t% Dry Ice	1.2 w.t% Dry Ice
7 days	3.32	3.40	3.42	3.38
14 Days	3.57	3.58	3.62	3.57
28 Days	4.61	4.50	4.75	4.68

This indicates the split tensile strength of concrete specimen increase for 1.0 w.t% of Dry ice in concrete and for 0.8w.t% and 1.2w.t% it decreases as compared to control concrete.

5.5 Flexural Strength Test

In this study, Beam tested for three mixing variables with dosage of (0.8 w.t%, 1.0 w.t%, 1.2 w.t%) and one convention concrete and compared with each other. This test was carried on compression testing machine (CTM).

Table No.5 Flexural Strength Results (N/mm²)

Days	Conventional M60	0.8 w.t% Dry Ice	1.0 w.t% Dry Ice	1.2 w.t% Dry Ice
7 days	3.68	3.72	3.84	3.80
14 Days	4.06	4.08	4.20	4.20
28 Days	5.48	5.51	5.64	5.58

This indicates the flexural strength of concrete specimen increase for 1.0 w.t% of Dry ice in concrete and for 0.8w.t% and 1.2w.t% it decreases as compared to control concrete.

5.6 Graphical Representation

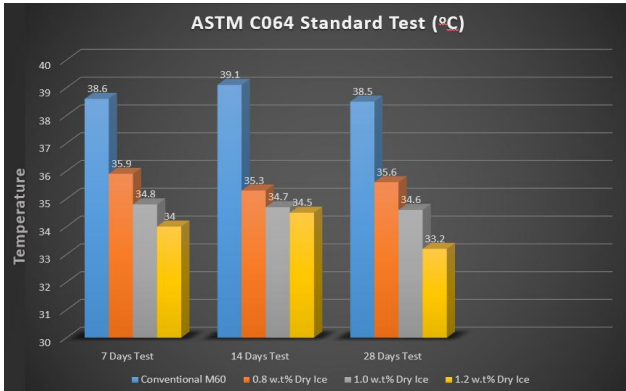


Figure3- ASTM C064 Standard Test (°C)

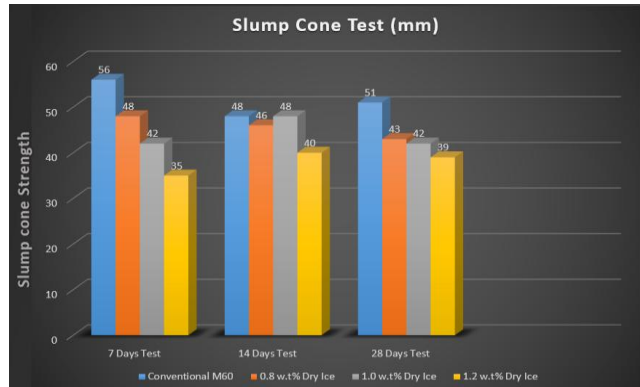


Figure4- Slump Cone Test (mm)

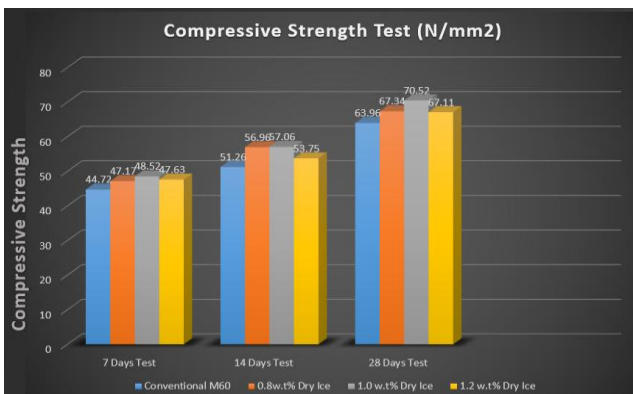


Figure5- Compressive Strength Test

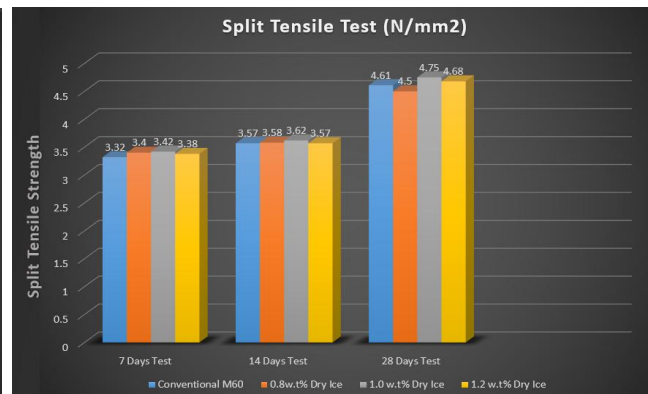


Figure6- Split Tensile Test

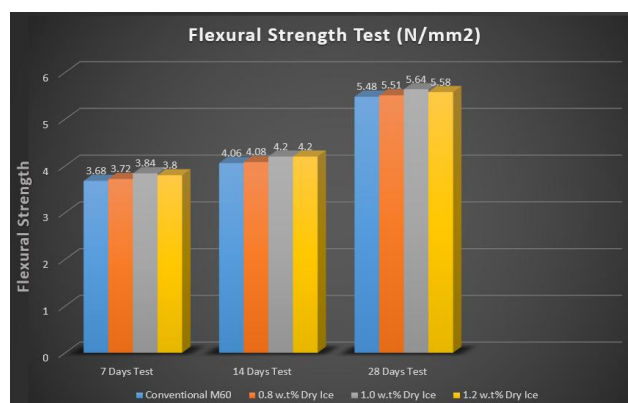


Figure7- Flexural Strength Test

5.7 Testing



Figure 8- Testing of ASTM C064 Standard Test



Figure 9- Testing of Cube for compression test

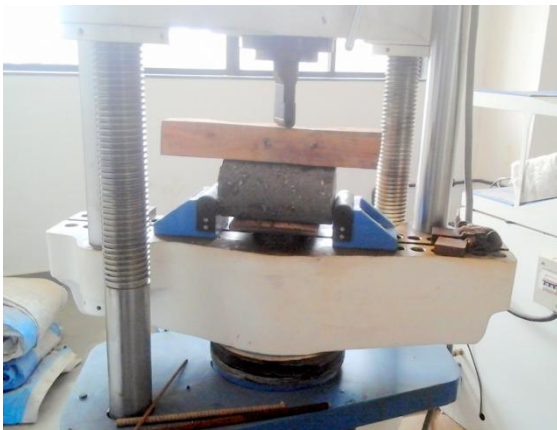


Figure 10- Testing of Cylinder for split tensile strength

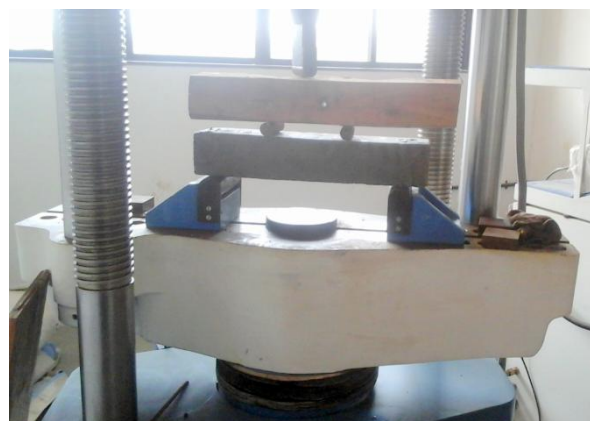


Figure 11- Testing of Beam For Flexural Strength

VI. CONCLUSIONS

From the experimental work and testing of specimen following conclusions have been concluded:

- i.** After 28 days concrete gaining highest compressive strength when 1.0 w.t % of Dry ice is added and increase compressive strength up to 10% as compare to conventional concrete.
- ii.** After 28 day concrete attaining highest Split Tensile strength when 1.0 w.t % of Dry ice is added and increase Split Tensile strength upto 4% as compare to conventional concrete.
- iii.** After 28 day concrete attaining highest Flexural strength when 1.0 w.t % of Dry ice is added and increase Flexural strength upto 3% as compared to conventional concrete.
- iv.** Concrete temperature were measured with the help of ASTM C064 Standard test method. After concrete mixing test were performed in result concrete have gain best lowest temperature which was 34.7° C as compared to normal concrete this was 4.1° C low temperature which is 10% low temperature.

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