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A STUDY ON CRYOGENIC CONCRETE BY USING LIQUID NITROGEN

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Abstract – Concrete is one of the most widely recognized development and construction material for the most part delivered by utilizing locally accessible ingredients. This is to identify and evaluate the different methods available to limit and control the temperature rise during hydration within massive concrete structures. The aim is to identify the potential for reducing heat generation and crack risk during hydration for different types of methods and to find alternatives to conventional concrete. The main aim is to different ratio of Liquid nitrogen and determine which ratio provides best results. By adding Liquid nitrogen to concrete (10-15%) by volume of water were used in experimental study for Concrete beams of size 150mmX 150mm X 700mm and concrete cylinders of 150mm diameter and 300mm length were used for and concrete cubes of size 150mmX150mmX 150mm were used for strength test. The results of the Liquid nitrogen adding gave good result and reduced heat of hydration.

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

1.0 Introduction

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

To lower the risk of thermal cracking the concrete temperature has to be reduced. Several methods can be applied to reduce the temperature in massive concrete structure. Those 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 are used to lower temperature of the concrete body while hydrating. In this Post-cooling is adopted in which liquid nitrogen is added to Concrete and lowered the temperature of concrete while heat of hydration.

2.0 Introduction to Cryogenic Fluid (Liquid Nitrogen)

Physical properties

Temperature of liquid nitrogen can be readily be reduced to its freezing point 63 K (−210 °C; −346 °F) by placing it in a vacuum chamber pumped by a vacuum pump. The liquid nitrogen efficiency as a coolant is limited by fact that it boils quickly on contact with a warm object, enveloping the object in insulating nitrogen gas. This effect, known as the Leiden frost effect, applies to any liquid in contact with an object significantly hotter than its boiling point. The faster cooling may be obtained by plunging an object into a slush of liquid and solid nitrogen rather than liquid nitrogen alone.

Handling

As a cryogenic fluid/liquid that rapidly freezes living tissue, its handling and storage require thermal insulation. It can be stored and transported in vacuum flasks, the temperature being held constant at 77 K by slow boiling of the liquid. 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 liquefied nitrogen to stored and transported over longer time periods with losses reduced to 2% to 3% per day or less.

Use of liquid Nitrogen

Liquid nitrogen has a boiling point of (-210 °C), is used for so many of things, such as a coolant for computers, in rockets as a cooling substance in medicine to remove waste skin, warts and pre-cancerous cells, and in cryogenics, and scientists study the effect and behavior of very cold temperatures on material

3.0 Methodology

- Literature Review
- Collection of raw material
- Properties of raw material
- Mix Design
- Casting of Specimens
- Curing of Specimens
- Testing od Specimen
- Result Analyses
- Conclusion

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 liquid nitrogen, was mixed first followed by the liquid nitrogen mixture. While mixing the concrete employing liquid nitrogen, 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 liquid nitrogen 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

4.0 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 Liquid Nitrogen

The liquid nitrogen is cryogenic liquid which is used in rockets and hospital purposes and for preserving/ freezing things.

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 and 300mm height) were casted by replacing water with 10%, 12.5%, 15% liquid nitrogen. Liquid Nitrogen were added while mixing in mixer and were pond cured in room temperature.

Figure1- 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 liquid nitrogen dosages concrete of (10.0%, 12.5% & 15.0% w.r.t. water) 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 liquid nitrogen dosages concrete of (10.0%, 12.5% & 15.0% w.r.t. water) 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 liquid nitrogen in the concrete with respect to cement with dosages of (10.0%, 12.5% & 15.0% w.r.t. water). The water content was maintained at 0.5. Cubes are tested in Compression testing machine (CTM). The specimens of standard cubes of dimensions 150mm x 150mm x 150mm 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 (10.0%, 12.5% & 15.0% w.r.t. water) 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 x150mm x700mm was casted with various dosages of (10.0%, 12.5% & 15.0% w.r.t. water). 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).

5.0 Results

5.1 ASTM C064 Standard Test

In this study, fresh concrete was tested for 3 mixing variables of liquid nitrogen in the concrete with dosage of (10.0%, 12.5% & 15.0% w.r.t. water) and one convention concrete and compared with each other.

Table No.1 ASTM C064 Standard Test Results

Test No.	Conventional M60	10% Liquid Nitrogen	12.5% Liquid Nitrogen	15% Liquid Nitrogen
1	38.6	35.6	34.2	34.1
2	39.1	34.9	34.6	34.7
3	38.5	35.1	34.8	34.0

5.2 Slump Cone Test

In this study, fresh concrete was tested for 3 mixing variables of liquid nitrogen in the concrete with dosage of (10.0%, 12.5% & 15.0% w.r.t. water) and one convention concrete and compared with each other.

Table No.2 Split Tensile Strength Results

Test No.	Conventional M60	10% Liquid Nitrogen	12.5% Liquid Nitrogen	15% Liquid Nitrogen
1	56	45	45	30
2	48	42	49	38
3	51	48	39	36

It indicates the slump cone test of concrete specimen decreases when the quantity of liquid nitrogen increase from (10.0%, 12.5% & 15.0% w.r.t. water). 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 liquid nitrogen (10.0%, 12.5% & 15.0% w.r.t. water) and one convention concrete and compared with each other. This test was carried on compression testing machine (CTM).

Table No.3 Compressive Strength Results

Days	Conventional M60	10% Liquid Nitrogen	12.5% Liquid Nitrogen	15% Liquid Nitrogen
7 days	44.72	49.31	50.60	48.28
14 Days	51.26	57.49	59.26	54.68
28 Days	63.96	68.35	74.75	69.80

This indicates the compressive strength of concrete specimen increase for 12.5% of liquid nitrogen in concrete and for 10% and 15% it decreases as compared to control concrete.

5.4 Split Tensile Test

In this study, cylinder test for three mixing variables with dosage of (10.0%, 12.5% & 15.0% w.r.t. water) and one convention concrete and compared with each other. This test was carried on compression testing machine (CTM).

Table No.5 Split Tensile Strength Results

Days	Conventional M60	10% Liquid Nitrogen	12.5% Liquid Nitrogen	15% Liquid Nitrogen
7 days	3.32	3.42	3.45	3.44
14 Days	3.57	3.61	3.64	3.69
28 Days	4.61	4.63	4.83	4.76

This indicates the split tensile strength of concrete specimen increase for 12.5% of liquid nitrogen in concrete and for 10% and 15% it decreases as compared to control concrete.

5.5 Flexural Strength Test

In this study, Beam tested for three mixing variables with dosage of (10.0%, 12.5% & 15.0% w.r.t. water) and one convention concrete and compared with each other. This test was carried on compression testing machine (CTM).

Table No.4 Flexural Strength Results

Days	Conventional M60	10% Liquid Nitrogen	12.5% Liquid Nitrogen	15% Liquid Nitrogen
7 days	3.68	3.71	3.89	3.86
14 Days	4.06	4.10	4.25	4.23
28 Days	5.48	5.53	5.71	5.68

This indicates the flexural strength of concrete specimen increase for 12.5 % of liquid nitrogen in concrete and for 10% and 15% it decreases as compared to control concrete.

5.6 Graphical Representation

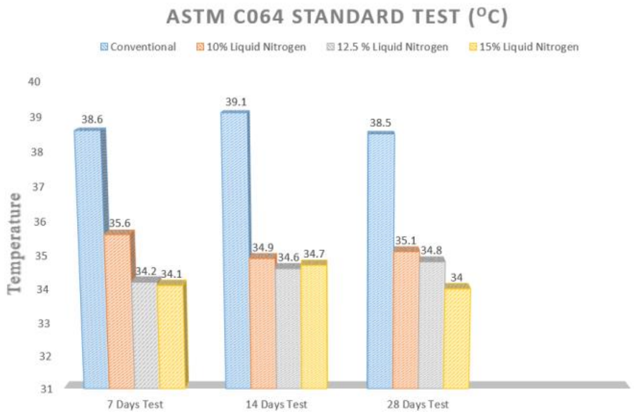

Figure2- ASTM C064 Standard Test

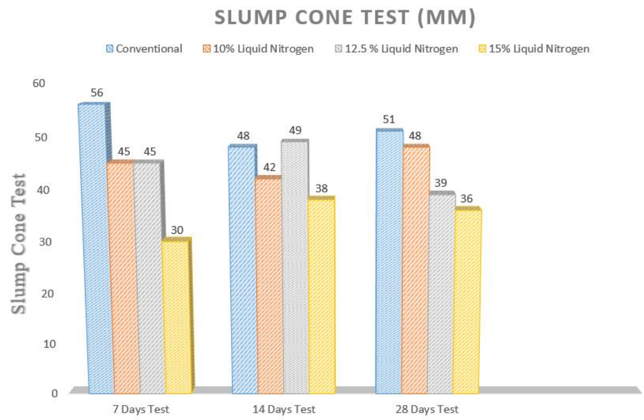

Figure3- Slump Cone Test

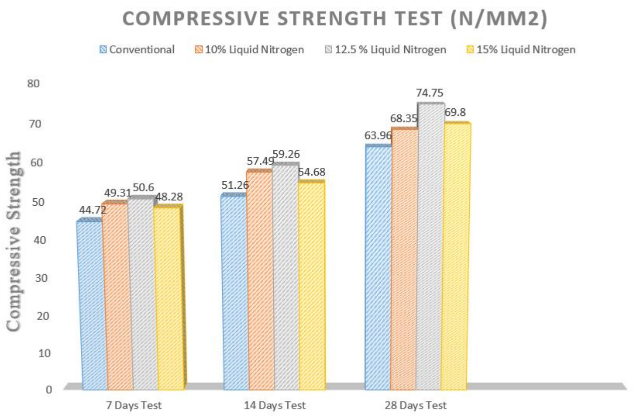

Figure4- Compressive Strength Test

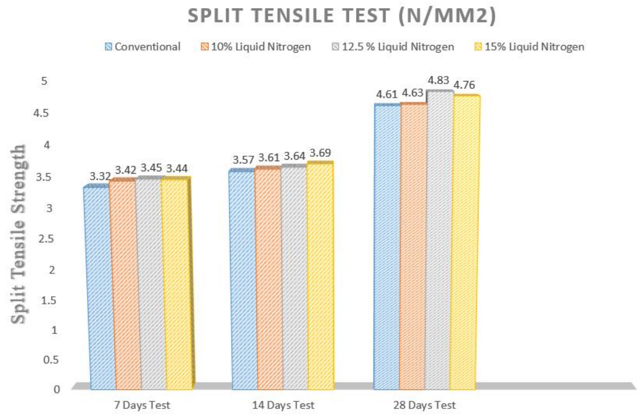

Figure5- Split Tensile Test

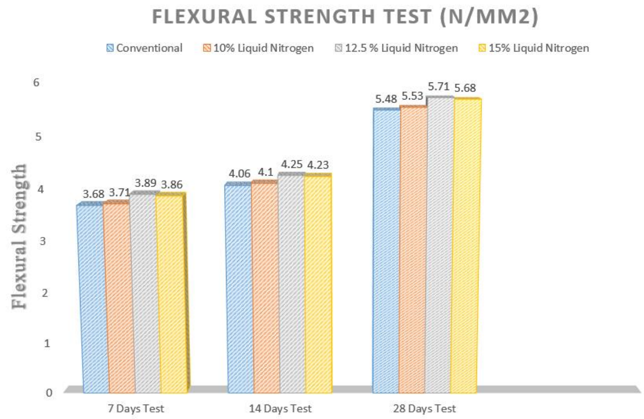

Figure6- Flexural Strength Test

5.7 Testing

Figure7- ASTM C064 Standard Test

Figure8-Testing of Cube for compression test

Figure9-Testing of Cylinder for split tensile strength

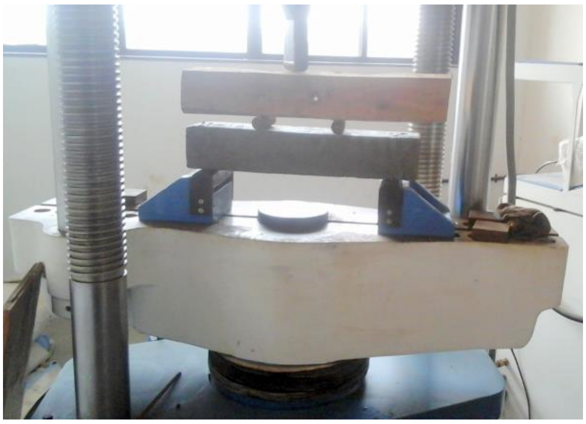

Figure10-Testing of Beam for Flexural Strength

6.0 CONCLUSIONS

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

i. After 28 day concrete gaining highest compressive strength when 12.5 % of liquid nitrogen is added and increase compressive strength up to 16% as compared to conventional concrete.
ii. After 28 day concrete attaining highest Split Tensile strength when 12.5% of liquid nitrogen is added and increase Split Tensile strength upto 5% as compared to conventional concrete.
iii. After 28 day concrete attaining highest Flexural strength when 12.5 % of liquid nitrogen is added and increase Flexural strength upto 5%` 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 34.6^{o} C as compared to normal concrete this was 4.1^{o} C low temperature which is 10% low temperature.

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