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Experimental Analysis of Light Weight Thermal Resistant Concrete

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Abstract: Growth in civil construction has increased the consumption of raw materials by the construction sector, resulting in chronic shortage of building materials and the associated environmental damage. In the last decade, construction industry has been conducting various researches on the utilization of easily available raw materials and use of plastic waste with concrete in construction since plastic waste is a waste which takes millions of years to decompose while its generation is increasing day by day.

In this experimental research, light weight thermal resistant concrete block is developed using polyurethane plastic waste in concrete as it is one of the materials which can scope up with the shortage of building raw materials and can produce a light weight, thermal resistant, energy efficient and environmentally friendly concrete block.

This study deals with the introduction to the polyurethane in concrete block and its experimental advantages compared to the normal concrete block.

Keywords: Plastic waste, polyurethane, concrete blocks, thermal resistant concrete block, light weight concrete.

I. INTRODUCTION

A. Plastic Waste Problem

The plastic industry is one of the largest industries worldwide. Globally, in 2013, over 299 million tons of plastic were produced. Plastic has replaced paper, cardboard, metal and glass (Andrady, 2015). This displacement is a result of several advantages that plastic has over these other materials. Plastic is lowcost, lightweight and easy to handle, it also has relatively high strength and corrosion resistance (Andradi, 2015; Ferreira et al., 2012). Because plastic products have a large presence in a variety of markets (e.g. packaging, automotive, healthcare), these markets are directly contributing to increase the volumes of plastic in the waste stream (Silva, de Brito, and Saikia, 2013).

Plastic consumption has increased dramatically worldwide. This is in contrast to the recycling rate, which has remained low (Gu and Ozbakkaloglu, 2016). In USA, the contribution of plastic to the waste stream has increased from an average of 0.39 million tons in the 1960s to 31.75 million tons in 2012. Over the span of 50 years, the recycling rate has increased only 8.8%, which makes 2 plastic waste volume a serious issue for solid waste management (Gu and Ozbakkaloglu, 2016). Every year in the Canadian province of Newfoundland and Labrador, approximately 4-thousand tons of plastic are consumed, which is approximately 8% of the solid waste generated in the province. This plastic waste is collected, compacted and sent to other provinces. Because of the option of sending plastic waste to other provinces, Newfoundland has not yet developed any long-term strategy for the management of this solid waste. This has drastic economic and environmental impacts (Government of Newfoundland, 2002).

B. Lightweight Concrete

Lightweight concrete is a specialized type of concrete that is known for its significantly reduced weight in comparison to traditional concrete.

It is designed to have a lower density by incorporating lightweight aggregates or by introducing air voids into the mixture. This unique composition results in a concrete that is lighter, making it an ideal choice for various construction applications where weight reduction is desired. The production of lightweight concrete involves the replacement of traditional coarse aggregates, such as gravel or crushed stone, with lightweight materials. These lightweight aggregates can include expanded clay, shale, slate, perlite, vermiculite, or pumice. These materials are chosen for their inherent lightweight properties while still providing adequate structural strength.

C. Polyurethane

Polyurethane (PUR and PU) is a polymer composed of organic units joined by carbamate (urethane) links.

While most polyurethanes are thermosetting polymers that do not melt when heated, thermoplastic polyurethanes are also available. Polyurethane is a polymer formed by reaction of isocyanate with a polyol.

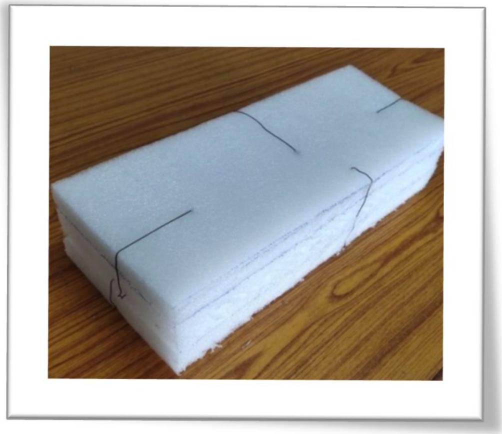

Figure1 Polyurethane

D. Chemical Structure And Reaction Mechanism Of Polyurethane

Polyurethane is a general term for polymers containing urethane groups formed by chemical reactions between isocyanate and hydroxyl groups. Polyurethane is a block copolymer with multiple carbamate (R-NH-CO-OR1) chain segments made by the polymerization of isocyanate (OCN-R-NCO) and polyol (HO-R1-OH), whose structure is shown in Figure

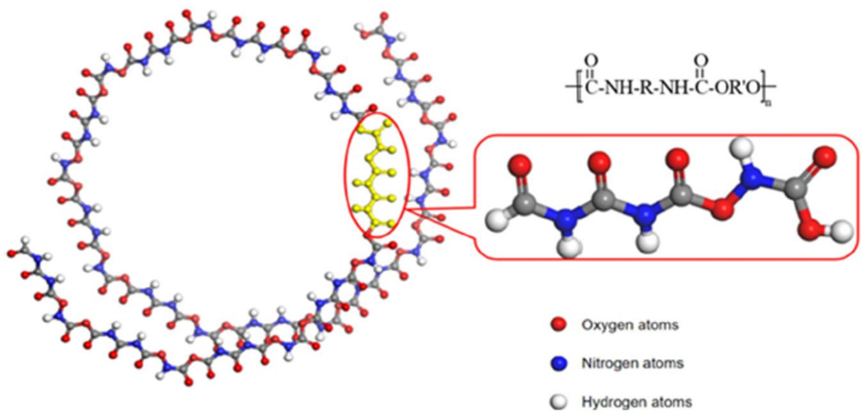

Figure 2 Molecular structure of polyurethane.

E. Properties Of Polyurethane

1) Wide Range of Hardness
2) High Load Bearing Capacity
3) Flexibility
4) Abrasion & Impact Resistance
5) Tear Resistance
6) Resistance to Water, Oil & Grease
7) Electrical Properties
8) Wide Resiliency Range
9) Strong Bonding Properties
10) Performance in Harsh Environments
11) Mould, Mildew & Fungus Resistance
12) Colour Ranges
13) Economical Manufacturing Process
14) Short Production Lead Times

F. Objective

The specific objectives are to:

1) Identify an affordable and suitable waste material for the production of lightweight concrete.
2) Compare the strength and density of lightweight concrete with normal concrete.
3) Compare the heat transfer of lightweight concrete with normal concrete

II. METHODOLOGY

A. Summary Of Mixture Design Approach

Figure 3: Mixture design process, adapted from Anderson and Whitcomb (2005) and Kharazi (2013).

The first stage involves: Goals of optimization, ranges of variation (constraints) Determination of number of experiments Execution of experiments Selection of the model -Analysis of variance ANOVA Adequacy of the models and predictions -Lack of fit test -Residuals OPTIMIZATION Verification in the lab of the predicted values Comparison between predicted and real values

1) determination of optimization goals, selection of the components and their ranges of variation and additional constraints;
2) identification of the responses and the number of experiments; and
3) execution of the experiments and measurement of the responses.

The second stage involves

a) selection of the model through the analysis of variance (ANOVA);
b) analysis of adequacy, through lack of fit test, R-squared adjusted and predicted, and graphical analysis of residuals; and
c) optimization through graphical and numerical optimization using the desirable function approach.

B. Selection of materials

1) Cement
2) Water
3) Aggregates
4) Waste Polyurethane

C. Test Performed

Compressive strength

Figure 4: Shows the Concrete Cubes

Figure 5: Shows the compressive strength test on Cubes

III. RESULT AND DISCUSSION

A. Compressive Strength Test Results

Table 1 Compressive strength of cubes without polyurethane after 7 days

Serial No.	Age of Cube	Cross sectional area (mm2)	Load (N)	Compressive strength (N/mm2)	Average Compressive strength (N/mm2)
N1			4614	20.507	
N2	7 Days	150*150	4907	21.809	20.64
N3			3525	19.678	

Table 2 Compressive strength of cubes with polyurethane after 7 days

Serial No.	Age of Cube	Cross sectional area (mm2)	Load (N)	Compressive strength (N/mm2)	Average Compressive strength (N/mm2)
P1	7 Days	150*150	2972	13.208	13.497
P2			3019	13.418	
P3			3120	13.867	

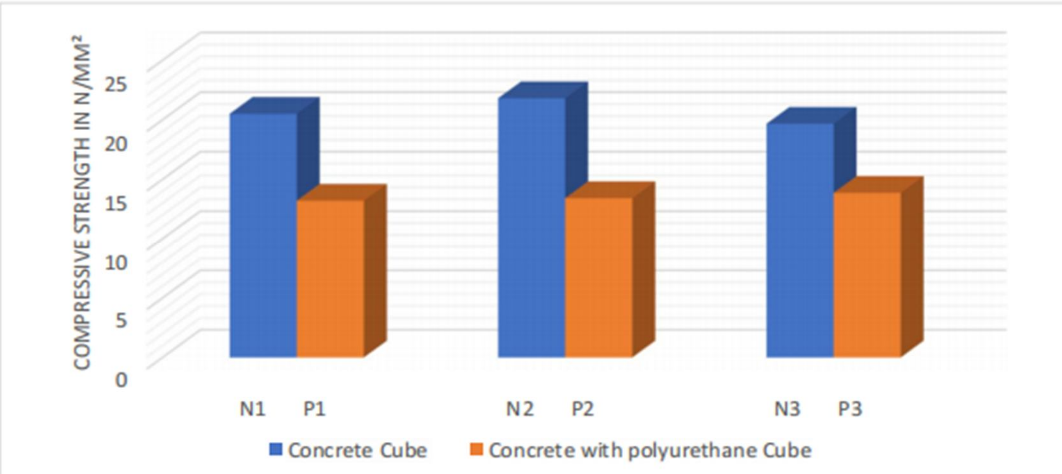

Figure 6 Comparison of compressive strength of cubes with and without polyurethane after 7 days

Table 3 Compressive strength of cubes without polyurethane after 28 days

Serial No.	Age of Cube	Cross sectional area (mm2)	Load (N)	Compressive strength (N/mm2)	Average Compressive strength (N/mm2)
N4	28 Days	150*150	6201	27.56	25.86
N5			5760	25.6	
N6			7489	24.42	

Table 4 Compressive strength of cubes with polyurethane after 28 days

Serial No.	Age of Cube	Cross sectional area (mm2)	Load (N)	Compressive strength (N/mm2)	Average Compressive strength (N/mm2)
P4	28 Days	150*150	5600	24.89	23.08
P5			5320	23.64	
P6			4664	20.3	

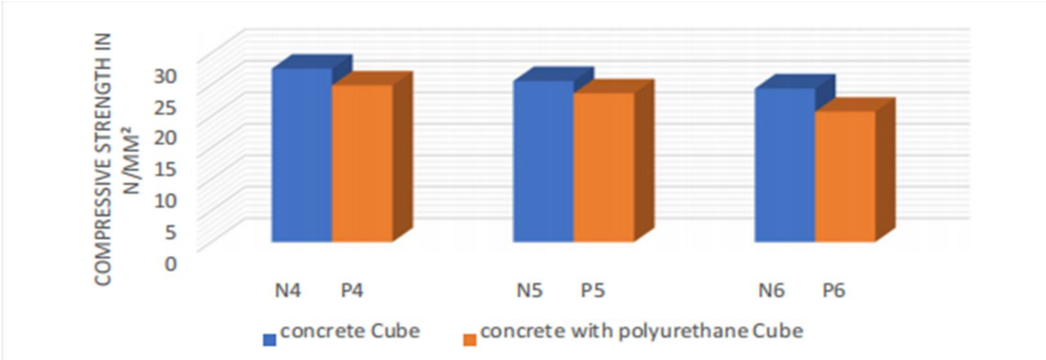

Figure 7 Comparison of compressive strength of cubes with and without polyurethane after 28 days

B. *Results Of Weight Of Concrete Cubes*

Table 5 Weight of cubes without polyurethane after 7 days

Serial No.	Age of Cube	Weight of Cube (grams)	Cross sectional area (mm2)	Average weight (grams)
N1	7 Days	9060	150*150	8953
N2		8950		
N3		8850		

Table 6 Weight of cubes with polyurethane after 7 days

Serial No.	Age of Cube	Weight of Cube (grams)	Cross sectional area (mm2)	Average weight (grams)
P1	7 Days	8420	150*150	8380
P2		8370		
P3		8350		

Table 7 Weight of cubes without polyurethane after 28 days

Serial No.	Age of Cube	Weight of Cube (grams)	Cross sectional area (mm2)	Average weight (grams)
N4	28 Days	8950	150*150	8853
N5		8800		
N6		8810		

Table 8 Weight of cubes with polyurethane after 28 days

Serial No.	Age of Cube	Weight of Cube (grams)	Cross sectional area (mm2)	Average weight (grams)
P4	28 Days	8460	150*150	8467
P5		8450		
P6		8490		

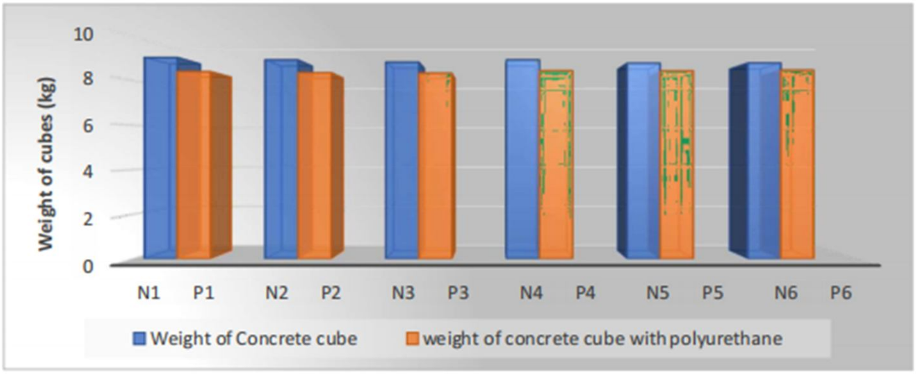

Figure 8 Comparison of weight of cubes with and without polyurethane

C. Heat Transfer Results

The heat transfer through concrete by thermal conductivity measurement is based on Fourier's law of heat conduction. Fourier's law states that the rate of heat transfer through a material is proportional to the temperature gradient across it and the thermal conductivity of the material.

Figure 9 Thermal conductivity measurement

Mathematically, the formula can be expressed as :

$Q = (k * A * \Delta T) / L$

Where:

Q = heat transfer rate (in watts),
k = thermal conductivity of concrete (in watts per meter per Kelvin),
A = cross-sectional area of the concrete sample (in square meters),
ΔT = temperature difference across the concrete sample (in Kelvin),
L = thickness of the concrete sample (in meters).

Table 9 Heat transfer rate of cubes with and without polyurethane

Block Material	K(W/mK)	A(m^2)	T_{hot}(°C)	T_{cold}(°C)	D (m)	Q(W)
Concrete	1.4	0.125	223°C	33°C	0.20	**166.25**
Concrete & polyurethane	1.0	0.125	223°C	33°C	0.20	**118.75**

IV. CONCLUSIONS & SCOPE FOR FUTURE STUDIES

1) The findings demonstrated the feasibility of using the waste material as a lightweight concrete and highlighted the potential benefits in terms of reduced density, satisfactory mechanical properties, improved thermal insulation, and sustainable construction practices.
2) Based on the provided results, it can be observed that the inclusion of polyurethane in the concrete mixture had an effect on the weight of the concrete cubes after curing. The concrete cubes containing polyurethane exhibited lower weights compared to the cubes without polyurethane, both at the 7-day and 28-day curing periods.
3) The compressive strength of the concrete cubes with polyurethane after 7 days of curing was measured to be 20.64 N/mm2, while the cubes without polyurethane had a compressive strength of 13.497 N/mm2. After 28 days of curing, the compressive strength of the cubes with polyurethane increased to 25.86 N/mm2, while the cubes without polyurethane reached a compressive strength of 23.08 N/mm2.
4) Based on the provided results concrete and polyurethane, the measured thermal conductivity values of 166.25W and 118.75W respectively indicate that polyurethane has a lower thermal conductivity compared to concrete. This suggests that polyurethane exhibits better insulation properties and reduces heat transfer more effectively than concrete.

The involvement of polyurethane opens up the possibility of further research in specific areas. IT IS:

a) Ratio of the contents can be varied and tested to further reduce the weight and cost of the block.
b) Sound test will be conducted.
c) A cost analysis is to be done.

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