# Effect of Polyurethane Foam addition on Thermal Conductivity of Concrete

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***Abstract*—To improve thermal comfort in building and save energy, it is important to use high performance materials with good thermal insulation. The major objective of this study is to determine effect of Polyurethane Foam addition on thermal conductivity and compressive Strength of concrete. Polyurethane is an insulating material having thermal conductivity 0.018W/mk. The mix Design of M20 grade concrete was prepared by adding 0%, 0.1%, 0.25%, 0.5% liquid polyurethane foam by total weight of concrete and followed by curing in water for 7, 14, 28 days. The test results shows that there was decrease in thermal conductivity from 0.993W/mk to 0.842W/mk due to insulating effect of polyurethane foam. Decrease in density due to porosity and air pores present in concrete results in reduction in thermal conductivity. Also compressive strength decreases with addition of polyurethane foam. M20 grade concrete with 0.25% addition of polyurethane foam having 0.89W/mk thermal conductivity and 20.31N/mm$^2$ compressive strength shows good results from thermal and design point of view.**

***Keywords*—Polyurethane Foam, Thermal Conductivity, Compressive strength, Insulation, Concrete.**

## I. INTRODUCTION

Energy saving is important issue in the world because of both economical and environmental concern. Consumption of energy from the buildings constitutes about 33% of total consumption with about half of this lost through the walls [5]. Insulation in buildings is an important factor to achieve thermal comfort for its occupants for cold winters and warm summers in a composite climate. Insulation reduces unwanted heat loss or gain and decreases the energy demands of heating and cooling systems. The thermal insulation in walls and roofs not only contributes in reducing the required air-conditioning system size but also in reducing the annual energy cost in buildings. Thermal conductivity of concrete range from 2.15 to 2.51 kcal/mh0c according to different aggregates used. Thermal conductivity of concrete greatly affected by Mix design, aggregate types, as well as moisture status and unit weight in dry state [12]. If the thermal conductivity of concrete is further reduced heat loss will be decreases and hence many researchers are seeking to produce such materials.

Various types of lightweight materials like wood sawdust, polymers, leather residues, mineral additives, waste Polyurethane foam, polystyrene, kraft pulps from sisal and banana waste, waste rubber, recycle paper are added to form light weight cement bricks and concrete [1], [3]-[10], [22]. Addition of these materials lowers Thermal conductivity of concrete and bricks.

Mounanga [1] used rigid polyurethane foam waste as aggregate for preparation of light weight concrete. They observed that thermal conductivity in hardened state ranges between 0.22 - 0.67 W/mk for dry specimen and 0.6 - 1.33 W/mk for the specimen cured under the water. Gutierrez [14] used to polyurethane waste for light weight plaster material. They observed that thermal conductivity falls by up to 66% relative to the reference material, without polyurethane foam waste. Increase in proportion polyurethane foam for making cement mortar and concrete shows that decrease in compressive strength. Compressive strength will increased according to age of concrete [11], [13]. Johnson [2] studied the effect of oil palm shell and foaming agent on various properties of foamed concrete. They concluded that thermal conductivity decreases with decrease in density as a result of air pores formed inside. Drifa [3] observed that inclusion of olive pomace fibre decreases density but at expense of its compressive strength. They concluded that compressive strength decreases with addition of insulating materials. Ashwin [4] prepared low density bricks by using locally available waste materials. They observed that increase in porosity results lower heat transfer rate [4], [7], [8]. Mucahit [5] concluded that use of recycled paper for making porous bricks decreases compressive strength and thermal conductivity and thermal conductivity was closely related to density and porosity. According to test results addition of 30% paper residue shows 52% apparent porosity and 0.42 W/mk thermal conductivity with 51 Kg/cm2 compressive strength.

Benazzouk [6] concluded that addition of waste rubber particles helps in reducing thermal conductivity of concrete. They observed that thermal conductivity decreases from 1.16 W/mk for cement paste to 0.47 W/mk for specimen containing 50% rubber particles. The reduction in thermal conductivity due to insulating effect of rubber particle, porosity and entrapped air. However compressive strength found to be decreases (from 82Mpa to 10.5Mpa) with addition of 50% rubber particles. Ramazan [7] reported that fly ash is more effective than silica fumes in decreasing thermal conductivity of expanded perlite aggregate concrete. According to test result 30% replacement of Portland cement with fly ash decreases the thermal conductivity by 18% and reduction in compressive strength by 27%.

Liquid Polyurethane foam is another material widely used in sound and thermal insulation in refrigerator, insulated buildings, thermosets etc. Thermal conductivity of Polyurethane foam is generally 0.018W/mk [24], [15], [16]. Polyurethane foam in liquid form will used for producing thermal insulating concrete which reduce thermal conductivity and helps to reduce heat transfer rate and consumption of energy.

In the present paper, we focused on study of thermal conductivity of concrete by polyurethane foam mixing so as to reduce heat transfer rate through concrete and its effect on compressive strength of M-20 Grade concrete, also the effect of curing on thermal conductivity and compressive strength.

## II. MATERIAL MIX DESIGN AND SPECIMEN PREPARATION

### *A. Materials*

#### *1) Cement*

43 Grade Ordinary Portland cement manufactured by Ultratech Company in India was used in concrete as the primary binding agent.

#### *2) Aggregates*

River sand produced at the Sindhudurg was used as fine aggregate and crushed stone used as a coarse aggregate.

#### *3) Water*

Potable water is used for mixing of concrete. Water used in manufacture of concrete shall be free from matter harmful to concrete.

#### *4) Polyurethane foam*

The production of rigid polyurethane foam requires two main liquid components polyol with R141b blowing agent and polyisocyanate. Thermal conductivity of polyurethane foam material is 0.018 W/mk.

### *B. Mix design*

Mix Design was prepared according to Concrete Mix Proportioning - Guidelines IS 10262: 2009[23]. This standard provides the guidelines for proportioning concrete mixes as per the requirements using the concrete making materials including other supplementary materials identified for this purpose. The total quantities of ingredients for M20 grade concrete are as follows

TABLE I

MIXDESIGN

| Water (kg/m3) | Cement (kg/m3) | Fine aggregate (kg/m3) | Coarse aggregate (kg/m3) |
|---|---|---|---|
| 0.5 | 1 | 1.5 | 3.3 |

### *C. Specimens preparation*

Initially all raw materials were batched and dry mixing was done. All the mixing procedure was followed by mechanically operated concrete mixer. Dry mixing was followed by wet mixing which was done over a time span of 2 to 3 minutes [4]. Then polyol and polyisocyanate was stirrer together to form polyurethane foam gel. This polyurethane gel added in to wet mixture in proportion of 0%, 0.1%, 0.25%, and 0.5% by weight of concrete to produce different proportion samples. The material was filled up in mould and material was compacted using vibration machine.

For compressive strength test three 150 x 150 x 150 mm concrete cubes were prepared for each sample mix. After 24 h the specimen removed from the moulds and were cured in laboratory water curing tank for 7, 14, 28 days respectively. After 7, 14, 8 days curing specimens were tested for compressive strength.

For thermal conductivity test, six square slab samples of 200mm x 200 mm and depth 30mm were prepared and cured in laboratory water curing tank and tested at age of 7, 14, 28 days in dry state. All the specimens were dried in drying oven at 500c.

## III. EXPERIMENTAL SETUP

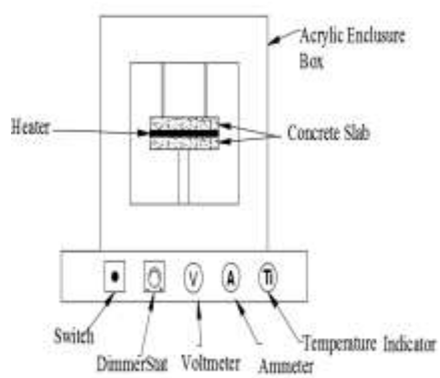


Fig. 1. Composite wall apparatus

For thermal conductivity measurement Composite wall apparatus was used in this study. The apparatus consists of central heater sandwiched between heater the two concrete slabs. Heater is provided to supply heat input across the concrete slab.

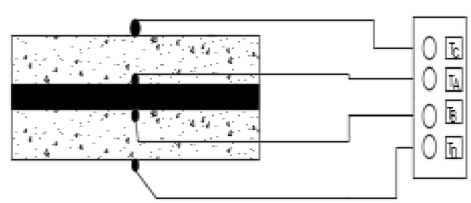

Fig. 2. Arrangement of thermocouples on Concrete slabs

Thermocouples are provided at center of slab to record inside temperature and outside temperature of slab. Multi-channel temperature indicator is used to measure this temperature. Small hand press is provided to ensure there is no air gap between the slab and heater. The heat input to heater is given through dimmer stat and measured by voltmeter and Ammeter. Consider one dimensional heat transfer through the concrete slabs as thickness was small as compared to width and length. Note down the temperature every 10 minutes till a steady state condition is reached.

Specifications of apparatus

Thickness of concrete slab = 30mm

Heater = 300 W Mica heater

Dimmer stat = open type, 230V, 0.2A, single phase

Enclosure size = 600 x 360 x 370 mm

For compression strength test compression testing machine was used. The concrete cube specimen was placed on the table and hydraulic force was applied by selecting the suitable loading intensity. Note down the ultimate load to calculate the compressive strength.

Maximum loading capacity = 2000 kN

Least count = 2kN

Cross section area of cube = 150 mm x 150 mm

## IV. Results and Discussion

### *A. Relationship between thermal conductivity and age of curing*

To understand effect of age of curing on thermal conductivity a series of specimens was tested at 7, 14, 28 days after mixing. As indicated in figure thermal conductivity of concrete mixture was approximately same for all curing age i.e. thermal conductivity was independent of curing age, although these values were remarkably changed with respect to different mixtures. Lower thermal conductivity 0.823 W/mk was found for 0.5% Polyurethane foam concrete sample during 14 days curing. The highest value of thermal conductivity 1.01 W/mk was found for 0% concrete during 14 days curing.

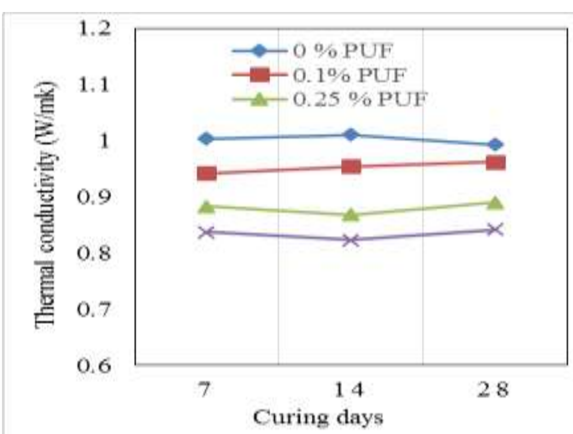


Fig. 3 Relationship between thermal conductivity and age of curing

### *B. Relationship between thermal conductivity and density*

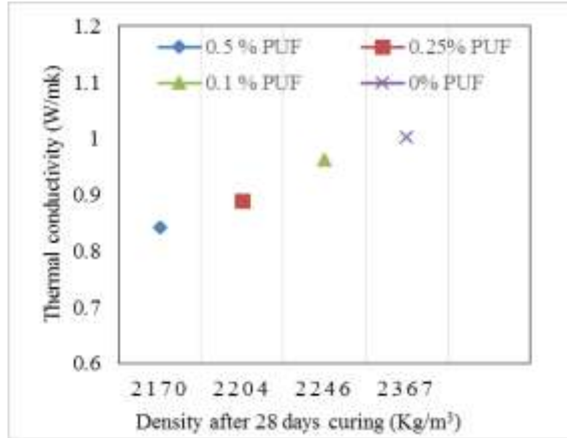


Fig. 4 Relationship between thermal conductivity and density

Figure 4 shows that thermal conductivity increases with increase in density of concrete. The highest thermal conductivity was observed for 0% polyurethane foam addition having 0.993 W/mk value. The lowest thermal conductivity 0.842 W/mk was observed for 0.5% polyurethane foam addition. Whereas the most efficient concrete from M20 grade from design and thermal consideration was 0.25% addition of Polyurethane foam having thermal conductivity 0.89 W/mk and compressive strength greater than 20 N/mm2. The addition of polyurethane foam increases the porosity and decreases the density of concrete and consequently thermal conductivity. Also air pores were formed inside the structure. As the air is good insulator thermal conductivity value was further decreases.

### *C. Relationship between compressive strength and age of curing*

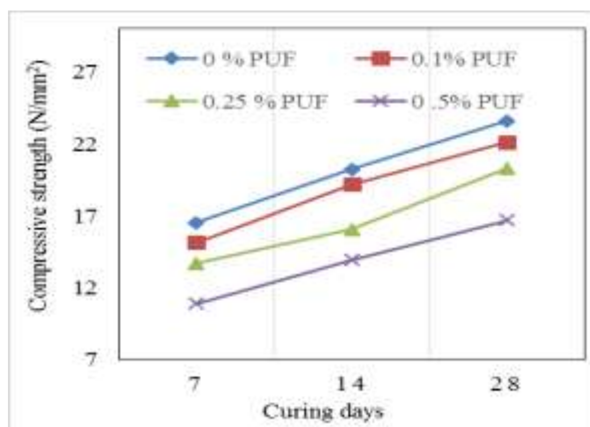


Fig. 5 Development in compressive strength with curing days

Figure 5shows that compressive strength increases with curing days. The highest value of compressive strength 23.46 N/mm2 was observed during addition of 0% polyurethane foam in concrete and lower compressive strength was 16.71 N/mm$^2$ during 0.5% addition of polyurethane foam for 28 days of curing. Addition of polyurethane foam in concrete decreases compressive strength because it increases porosity in concrete structure.

## V. Conclusions

The work presented herein has focused on the effect of addition of polyurethane foam on the thermal conductivity of concrete. According to test results Thermal conductivity was approximately constant for all curing days.

It was also found that reduction in thermal conductivity of concrete with addition of polyurethane foam due to insulating effect of polyurethane foam. Addition of polyurethane foam by 0.5% in concrete was decreases thermal conductivity by 17.93% for 28 days of curing.

Densities decreases from 2367.9 Kg/m3 to 2170.8 Kg/m3 with addition of 0.5% polyurethane foam. Decrease in density due to porosity and air pores formed inside concrete structure results in reduction in thermal conductivity.

Compressive strength decreases by 40.39% due to 0.5% addition of polyurethane foam for 28 days of curing also compressive strength increases with increase in curing days.

Addition of 0.25% polyurethane foam for 28 days of curing shows thermal conductivity and compressive strength of 0.89 W/mk and 20.31N/mm2 respectively can be considered as structural and insulating concrete.

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