IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

ISSN PRINT 2319 1775 Online 2320 7876

Research paper Journal Volume 11,Iss 10, 2022

FACTORS INFLUENCING THE THERMAL CONDUCTIVITY OF CONCRETE: A REVIEW.

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Abstract:

Concrete is a recognized building material that is utilized extensively in infrastructure projects all around the world. Still, the reduction of natural resources has been obstructed by its extensive use. Researchers have made several attempts to investigate the use of waste materials in concrete as a substitute for natural qualities, in addition to sinking waste disposal difficulties. Essentially, the process of verifying concrete involves determining its strengths, permeability, durability, shrinkage, thermal properties, and other attributes. Of all the thermal qualities of concrete, thermal conductivity (TC) has received the most attention because it depends on the composition of the concrete. Thermal conductivity is a critical metric for assessing a material's capacity to transmit heat in building insulation materials. This paper's goal is to go over the techniques and variables that affect the thermal conductivity (TC) of concrete that contains different kinds of waste materials.

Keywords: Thermal Conductivity, concrete, waste material, heat flow analyzer, building construction.

1. INTRODUCTION

The availability and characteristics of concrete in Indian demonstrate the country's continued reliance on the material for building construction. Nevertheless, despite its need, this will result in a rise in the consumption of natural resources like cement and sand, both of which are connected to global warming. Finding a way to improve concrete's sustainability and performance in terms of its qualities while simultaneously controlling resource consumption and environmental threats is crucial.

The prevalent problem with waste materials that we currently face is the disposal of waste, which has grown to be one of the most important environmental, economic, and social challenges [1, 2]. Owing to this problem, several approaches have been put out recently to address environmental issues facing the construction sector. One such approach is using more waste materials, particularly those that are left over from industrial processes [3].

Concrete is a building material with significant thermal properties; however, studies of the material typically concentrate more on its mechanical and physical characteristics than its thermal qualities [4]. The primary determinants of thermal characteristics are mass loss, thermal diffusivity, specific heat, and thermal expansion [5].

Understanding the TC of construction materials, such as concrete, is crucial. Construction industries place a great deal of importance on thermal conductivity (TC), which is the study of heat transport in a material [5]. Moreover, one of the main elements influencing heat

ISSN PRINT 2319 1775 Online 2320 7876
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transfer in buildings is the TC of the materials employed. The user will feel uncomfortable due to the environmental heat that has been carried into the buildings [7].

There are three ways that heat can be transferred: conduction, convection, and radiation [8]. Watts per meter per degree of infection differential (W/mK) is the unit of measurement for TC. The TC of a standard mass concrete at 20°C has a value between 1.33 and 1.95 W/mK, according to Euro code 2 [9]. High TC materials are typically utilized as heat sinks whereas low TC materials are used for thermal insulation since they transport heat more quickly than low TC materials.

2. Comprehensive review of thermal conductivity with various waste material

2.1. Review on resources and method

2.1.1 Materials:

The main elements of concrete are binders (cement materials), coarse and fine aggregates (or inert mineral fillers) and water [4]. Sand and gravel are examples of natural aggregates comm only used in concrete. Waste materials, sometimes called aggregates, are widely used in const ruction, and include generator explosion slag, fly ash, plastic, etc. Contains. It is often used as a combination or as a combination for a gathering place or gathering fine aggregate. Use recycled materials, fly ash, expanded perlite, palm oil, rubber, husk, palm oil ash, recycled glass, plastic waste, sawmill waste, polyamide, and other waste products. numerous researchers [9, 10–26] have studied the TC of concrete. This paper's primary goal is to provide an overview of how using these waste materials affects the temperature of concrete, a topic that will be covered in more detail later.

2.1.2 Measurement methods:

There are several methods for figuring out TC. The techniques used to analyse a material's thermal behaviour must be well understood and specified [18]. The steady state method and the fleeting method are the two primary approaches used to control the thermal conductivity (TC) of materials. Called as non-steady technique. [15]. A restricted range of materials can be used with this process, depending on the temperature and thermal characteristics.

While the non-steady state or transient approach measures a material while it is heating up, the steady state method measures a material when it is in perfect equilibrium [27]. Though it takes a while to establish the necessary equilibrium, the steady approach simplifies the signals analysis procedure (stationary state implies constant signals). With the non-steady approach, it is possible to measure the parameter quite quickly.

These days, a wide range of experimental techniques have been developed to detect TC using the previously stated techniques. Some examples of steady, state testing methods are the shielded hot plate method, unshielded hot plate, thermometer and cylindrical probe process; Unstable methods include hot metal method, laser flash method, step method, continuous line, Temporary strip. method

and temporary plane method [6,9-11,13-18,20-27]. These devices differ in terms of technique, specimen size, testing duration, capabilities, and measuring approaches. The guarded hot plate and hot-wire technique are commonly utilized in the engineering area due to its connection to the TC measurement of engineering applications. The guarded hot plate apparatus, however, has been found to be the most accurate way to calculate the TC since it

ISSN PRINT 2319 1775 Online 2320 7876

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was adopted by American Society as a Standard Method for testing and Materials (ASTM) [8,27].

The hot-wire method is based on dimensional radial heat flow, and thermocouples are used to detect the temperature on the wire after following the thermal pulse propagation that a heating nickel alloy wire induced in the sample [8]. The hot wire method, which uses surface probes to evaluate the TC coefficient among other thermal parameters, is used to adopt the ISOMET 2114 device [9]. Although the QTM 500 is a fast TC meter that uses a modified hot-wire approach, users can still count on reliable and consistent results [23].

Gandage et al. [15] reported the test technique for determining the steady state heat in a laboratory. A consistent temperature was kept between the specimens in contact with flat, homogenous specimens and solid, parallel borders by using guarded hot plates. A battery, data logger, hot and cold temperature control device, thermocouples to detect the temperature at each specimen face, and the main body or chamber where the specimens were to be held are the key components of the guarded hot plate technique [12, 14, 15, 17, 18].

2.1.3 Specimen preparation for tastings to BS EN 12667 [28], the specimens must be processed in accordance with the applicable product standard. As such, the dimensions of the concrete specimen for the TC test need to be built in line with the standard test specimen for concrete that is suitable for the techniques and instruments that will be used. This section solely covered hot-wire and guarded hot plate approaches because they are strongly related to TC measurement in engineering applications [8].

Demirboga and Kan [23] used a dimension size of 40 x 110 x 160 mm, while Bravo et al. [9] used a specimen size of 100 x 100 x 500 mm to analyse the TC of concrete using the hot-wire technique. Both are in prism dimension. The specimens were analysed in a dry chamber at 20°C and 50% relative humidity, with a measurement range of 0.0116 to 6 W/mK, following a 28-day curing period.

Specimens measuring 150 x 150 x 150 mm were subjected to temperature changes of 20 ± 2°C, 150, 250, 350, 450, and 550°C using the guarded hot plate method to investigate the effects of high fly ash concrete temperatures [10]. However, a lot of research has employed square slab specimens. Sayadi et al. [26], Akcaozoglu et al. [25], Alengaram et al. [14], and Liu et al. [17] created specimens that were 300 x 300 x 50 mm, 300 x 300 x 30 mm, 500 x 500 x 100 mm, and 200 x 200 x 40 mm, respectively. Following 28 days of age and curing at 20 ± 2°C, each specimen was tested in a dry state in accordance with BS EN 12664 [14,18].

2.2 Review for factors of thermal conductivity

The TC value is not variable-continuous. Variations may be caused by a few factors, such as mix proportioning, aggregate kinds and sources, moisture status, and unit weight in the dry state [29]. As temperature, moisture content, and density rise, so does the TC. Several investigations using various types of waste materials have been conducted to assess the TC of concrete. Table 1 summarizes some of the research's conclusions about the factors affecting the TC of concrete, such as various waste material types. Bravo et al. [9] investigated the impact of using recycled aggregate (RA) on the TC of concrete.

These RA were gathered from leftover concrete, ceramics, glass, wood, and other waste products used in building and destruction. Considering that different waste products have different TCs, this could have been caused by the TC of the materials used. Different TC

ISSN PRINT 2319 1775 Online 2320 7876
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concrete compositions were expected [9, 11, 18, 22, 24]. Density has a big impact on the TC of concrete. Gandage et al. [15] state that a lower density in concrete is the reason for its lower TC, which is in line with findings from other studies [9,14,17,20,23, 25]. According to Marie [18], the conductivity of regular concrete is mostly unaffected by density. However, as the temperature rose, the poor conductivity of air trapped on the RA or RCA surface as well as the rubber itself decreased with increase % of RHA.

Authors	Type of waste materials	Influence Factors
9	Aggregates recycled from construction and demolition waste	TC of materials, density
10	Fly ash class F	Micro-environment relative humidity, Temperature, porosity
11	Fibre, Rubber aggregate	TC of materials, amount of aggregate. porosity
13,15	Enlarged perlite	Density, Porosity, Temperature
14	Shell of an oil palm	Density
16,17	Fuel ash from palm oil	Density, aggregate and glass bubble replacement
18	Concrete with hybrid recycled aggregate	TC of materials, Amount of RCA, density, and porosity
6	Recycled glass	W/C ratio, quantity of replacement
20	Expanded polystyrene beads and pumice	Density, porosity
21	Polyethylene, PVC residues on the cable protection sheath	Replacement amount and porosity
22	Wood waste from sawmills	TC of materials, Number of materials, porosity
23	Waste polystyrene	Density, number of materials
25	Polyamide fibres obtained from consumer waste carpets	Temperature and material type
26	Waste polyethylene terephthalate	Bulk density and replacement amount
27	Elongated polystyrene	Volume % of materials

Table 1: Waste materials come in a variety of forms and are influence factors on the TC of concrete.

In the RARC, which is directly related to the density and the TC [18]. This is because it is known that the TC of air is lower than the TC of concrete.

Additionally, it is shown that the water-to-cement ratio of concrete [6], the relative humidity of the microenvironment [10], and the mineralogical properties of aggregates [26, 30] all have a significant impact on the TC of concrete. The findings of Krishna Moorthy and Zujip's experiment [6] demonstrate that the cement's TC coefficient expanded as the w/c increased, demonstrating that the concrete's ingredients have a direct impact on the TC. According to

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Wang et al. [10], an increase in fly ash replacement resulted in a drop in the pore water saturation of concrete, which in turn led to a reduction in the TC of concrete for a given micro-environment relative humidity. The aggregate's mineralogical characteristics have a significant impact on the TC of concrete as well [30]. Concrete's TC can grow by about twice as much depending on the type of aggregate used, and this is also highly dependent on the aggregate's composition and degree of crystallization. It is anticipated that crystalline aggregate will conduct heat more quickly than both amorphous and vitreous aggregates a combination with the same makeup.

3. Conclusion

This investigation helps to mitigate global warming and waste management issues that resulted from improper disposal of waste materials. Since global energy is one of the main concerns facing the globe, this article's goal was to investigate, through a thorough examination, the impact of using waste materials in concrete on its thermal qualities. The review leads to the following findings that can be made:

1. Due to the ongoing production of waste materials, the use of waste elements in concrete, such as plastic waste, building waste, loose ash, etc., can be thoroughly investigated.
2. The most accurate method for measuring the TC of concrete in respect to the TC measurement of engineering applications is the Guarded Hot Plate, even though there are other ways to compute TC.
3. Temperature, density, porosity, volume percentage of materials, type of materials, water cement ratio, relative moisture in the microenvironment, and aggregate mineralogical structures are the primary parameters that affect how the concrete is arranged, which affects TC.

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