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Review on Thermal Insulation Performance in Various Type of Concrete

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Abstract. Thermal insulation concrete building plays an important role in environment sustainability especially energy saving buildings. Buildings are one of the largest consumers of energy worldwide. Therefore, significant energy saving can be realized by buildings with proper materials, design and operation. Thermal insulation systems are nowadays mostly applied for such building envelopes where the materials of load bearing structure such as concrete do not have a substantial thermal insulation capability. Thermal insulation in concrete are materials or combinations of materials that are used to provide resistance to heat flow, should have low conductivity for building application in order to represence of a temperature gradient, has an important effect on the heat exchange between the building interior and the ambiance.The aim of this paper is to review the thermal properties include thermal conductivity and specific heat on various types of concrete.

INTRODUCTION

The utilization thermal insulation of building becomes a great potential to reduce the building thermal load and consequently its energy consumption especially in hash weather [1]. Thus, thermal insulation systems lead to improvement of economical aspects of buildings due to increased awareness and increased electric energy tax. Insulation materials can be made in different forms including loose-fill form, block form, board form,blanket form, pipe form, rigid form, foamed in place, or reflective form [2]. The choice of the proper insulation material form and type depends on the type of application as well as the desired material physical, thermal and other properties. Thermal insulation materials, like other natural or synthetic materials which exhibit temperature dependence properties that vary with their characteristics and the influencing temperature range [3]. Thermal insulation are very important in a wide variety of scientific and industrial applications especially building construction where a number of different experimental techniques have been developed to measure the thermal conductivity for different experimental conditions and for different materials in concrete.

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Concrete generally exhibits good fire resistance properties and thus finds wide applications in buildings and other built infrastructures, where fire safety is one of the primary considerations.The properties of concrete that are needed for fire-resistanceanalysis are thermal, mechanical, deformation, and special properties. Thermal properties are mainly determined by thermal conductivity, specific heat, thermal diffusivity, thermal expansion, and mass loss.Thermal conductivity is defined as the ratio of heat flow rate to the temperature gradient, and represents the uniform flow of heat through concrete of unit thickness over a unit area subjected to a unit temperature difference between the two opposite faces.The thermal conductivity value of normal concrete ranges from 0.62 to 3.3 W/m/K across more than five folds of magnitude depending on the types of coarse aggregate, moisture condition and temperature [4-7]. However, the lightweight insulating concrete with polystyrene bead or cellular lightweight concrete even exhibits the thermal conductivity of 0.07 to 0.33 W/m/K[8]. Specific heat is the amount of heat per unit mass required to change the temperature of a material by 1°, and is generally expressed in terms of thermal (heat) capacity, which is the product of specific heat and density. Specific heat is highly influenced by moisture content, aggregate type, and density of concrete [9-11]. This aim of this paper is to review significant research in thermal insulation performance in concrete application.

RESEARCH SIGNIFICANCE

The thermal properties determine the amount of heat transfer inside the materials. These properties vary as a function of temperature and depend on the composition and characteristics of concrete.The thermal properties of the normal concrete [7], fly ash concrete [12], high strength concrete [12] and Eurocode concrete model [13] concrete were measured at high temperatures condition in the range of 20–800°C for both specific heat and thermal conductivity test.

THERMAL PROPERTIES

Specific Heat

The specific heat for all the concrete types as shown in FIGURE 1 remains almost constant up to 300°C, and then increases between 650°C and 800°Cindicates the specific heat has linear relationship with the temperature. Fly ash concrete exhibit slightly highest values of specific heat throughout the temperature compare to others type of concrete. This could be attributed to varying permeability characteristics of concrete. This result refer to the permeability of fly ash concrete are less permeable compare to the others concrete [11, 12]. Hence, extra heat is absorbed for releasing bound water in less permeable concretes, whichexhibit fly ash concrete to thehigher specific heat values. The specific heat for all concrete decreases from 700°C to 800°Cexplains that beyond higher temperature the concrete itself decomposition from solid to liquid. Previous research has also observed that the specific heat of concrete is affected by physiochemical processes that occur in the cement paste and aggregate above 600°C [12].

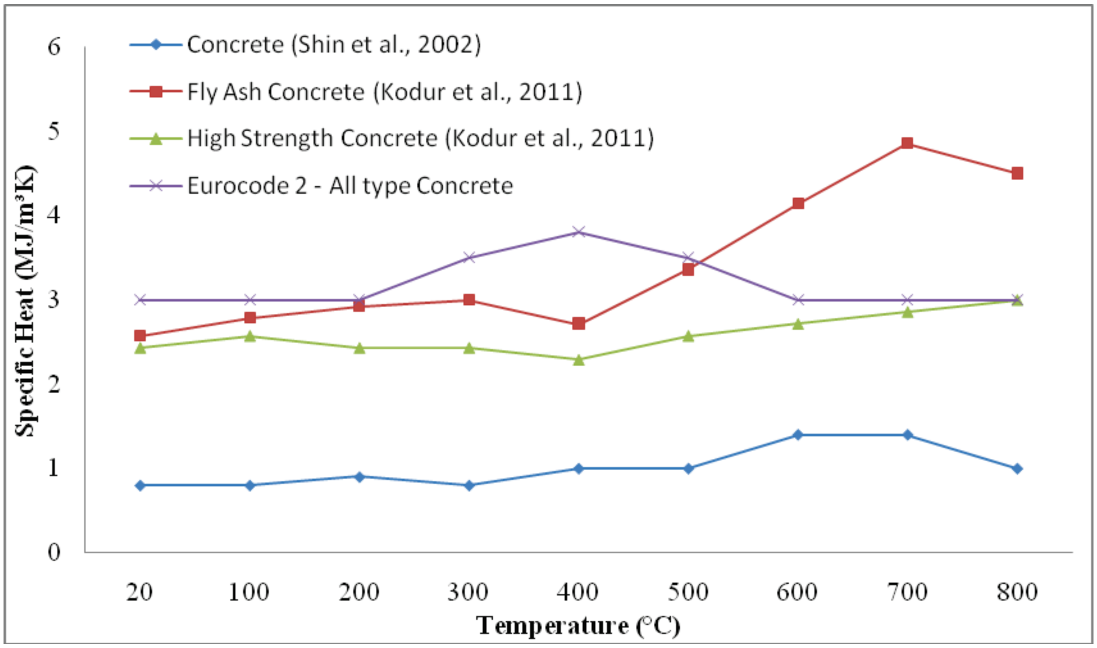

FIGURE 1. Specific heat at elevated temperature of various type of concrete.

Thermal Conductivity

Thermal conductivity all type of concrete is decreases with the increases of temperature as shown in FIGURE 2. There are approximately 50% of the thermal conductivity reduce at 800°C compare at normal temperature. The result of thermal conductivity decreases with temperature, and this decrease is dependent on the concrete mix properties, specifically moisture content and permeability. Subsequently, thermal conductivity for fly ash concrete follows a similar trend to the high strength concrete. The result of thermal conductivity smoothly decreases can be attributed to the moisture loss anddissociation of small amounts of physically bound water present in concrete due to the increases of the temperature [12]. These properties are strongly dependent on temperature.In general, the density, the conductivity and the diffusivity decrease with an increase in temperature [12, 14, 15]. Eurocode provides two limits for the thermal conductivity of concrete but with no reference to concrete type. The thermal conductivity in Eurocode 2 lower and upper limit based on predictions for the fire resistance show that the constitutive property models in the Eurocode manual of practice.

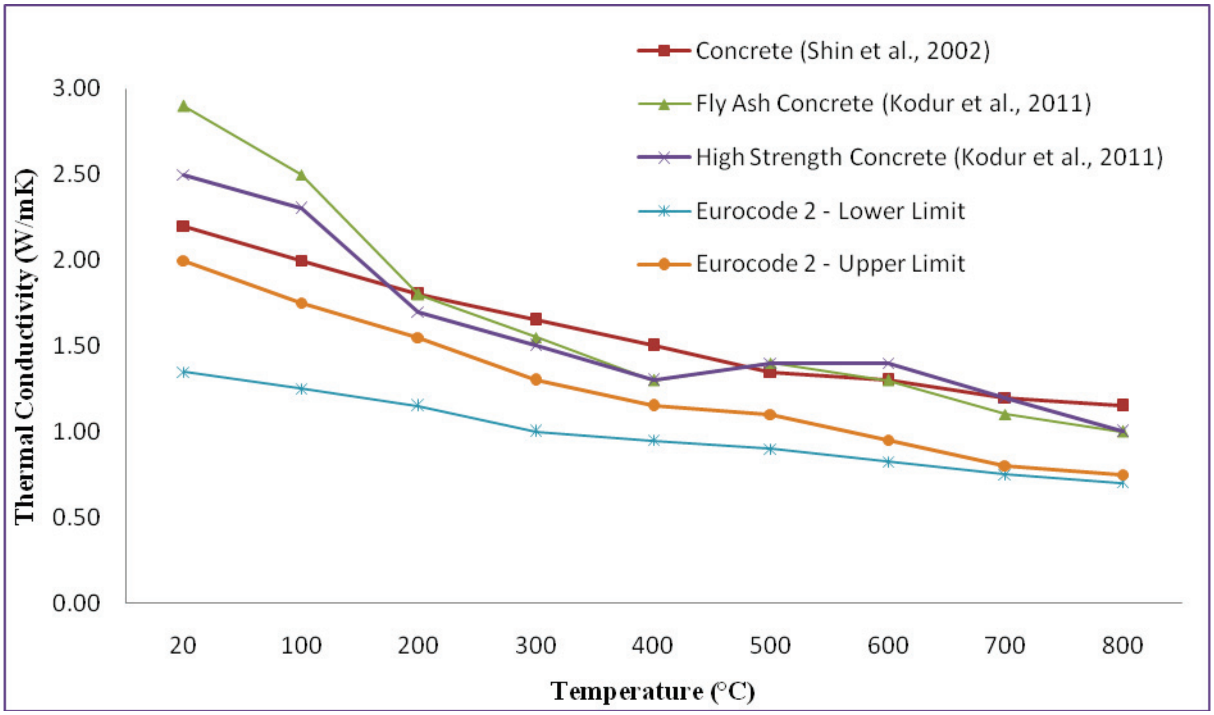

FIGURE 2. Thermal conductivity at elevated temperature of various type of concrete.

Thermal Diffusivity

For concrete application, thermal diffusivity is also one of the thermal properties. High thermal diffusivity in concrete will ensure its temperature to equivalent with the surroundings. Thus, concrete with thermal insulation behaviour require low thermal diffusivity to lead concrete can drop the temperature or barrier temperature extremes happened during a harsh weather. Thermal diffusivity is defined as the ratio of thermal conductivity to volumetric heat capacity:

$$\alpha = \frac{k}{\rho C} \quad (1)$$

where α is the thermal diffusivity, *k*thermal conductivity, ρ density and *C* specific heat capacity.According to previous research, the thermal diffusivity of concrete has decreased with an increase intemperature except for the specific heat [7, 15, 16]. FIGURE 3 shows other studies on thermal diffusivity on various type of concrete. A reduced of thermal diffusivity will reduce thermal conductivity, which may due to the reduction in density as described in formula 1.

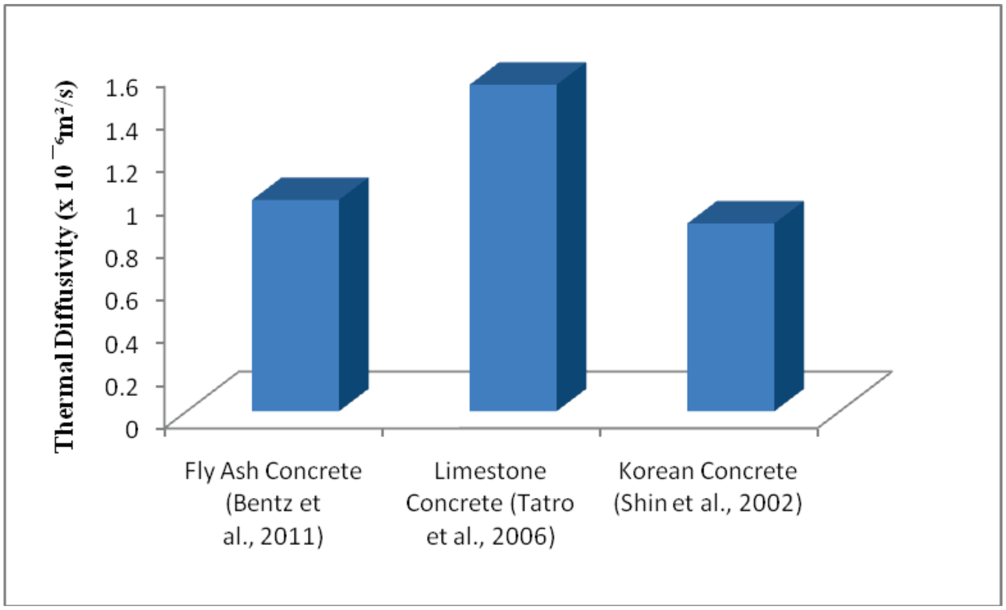

FIGURE 3. Thermal diffusivity of various type of concrete

CONCLUSION

The thermal properties that influence the temperature rise and distribution in a concrete are thermal conductivity, specific heat, and mass loss. A good insulator has a higher specific heat capacity because it takes time to absorb more heat before it actually heats up (temperature rising) to transfer the heat. A low thermal conductivity and thermal diffusivity results in a good thermal performance which can reduce energy losses and drop the temperature equivalent with the surroundings through the concrete of a building.

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