Research Paper Engineering

Thermal Properties of Concrete

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ABSTRACT

The paper describes the various thermal properties of concrete. The thermal properties like coefficient of thermal expansion, thermal conductivity of concrete, thermal diffusivity and specific heat are important for evaluation of the performance concrete over the period of time. Thermal expansion properties are important to the fire performance of concrete structures in two ways: The conductivity of concrete is determined by the conductivities of its constituents. The major factors influencing the conductivity are the moisture content of concrete, the type of aggregate, the mix proportions, the type of cement and the temperature of the concrete. The value of thermal diffusivity is dependent on the aggregate type, moisture content, degree of hydration of the cement paste, and exposure to drying . Specific heat represents the heat capacity of concrete. It increases with the moisture content of concrete and is affected by the mineralogical character of the aggregate, specific heat increases with an increase in temperature and also increases with a decrease in the density of concrete.

KEYWORDS Thermal expansion, thermal conductivity, thermal diffusivity and Specific heat.

Introduction

Thermal properties :

The thermal properties like coefficient of thermal expansion, specific heat, density and thermal conductivity of concrete are important for evaluation of the performance concrete over the period of time.

Coefficient of thermal expansion

Thermal expansion is a physical phenomenon common to all materials. It is however, complicated in concrete due to the differential expansion of its components producing high internal stresses. Thermal expansion has a significant effect on all types of concrete structures.

Concrete has a positive coefficient of thermal expansion and it depends on the compositions of mix and on the value of the coefficient of expansion of cement paste and aggregate and they have dissimilar thermal coefficients. The coefficient of thermal expansion of cement paste varies between about 11 x 10^{-6} and 20 x 10^{-6} per °C and is higher than the coefficient of aggregate. An average value of coefficient thermal expansion of normal weight concrete varied from 7 x 10^{-6} to 14 x 10^{-6} per °C depending on the type of aggregates used.

Thermal expansion properties are important to the fire performance of concrete structures in two ways:

(i) The expansion of individual and adjacent members can induce stresses capable of buckling reinforced members while at high temperatures.
(ii) Differences in thermal expansion potential of the cement paste and the aggregate may produce stresses in the concrete. At sufficiently high temperatures these stresses can induce cracking within the paste and around aggregate margins. This cracking further accentuates the refractory effect of the damage surface layers, since air held in the crack voids is of lower thermal conductivity than the concrete.

It can be appreciated that the response of concrete to fire attack is such that heat penetration is reduced by the production of low thermally conductive surface layers. A consequence of low conductivity at the surface is the creation of high temperature gradients between the exposed surface and the concrete interior [1],[2],[3]

For ordinary concrete the value of coefficient of thermal expansion varies from 9 x 10^{-6} per °C to 12 x 10^{-6} per °C. (Fig. 1)

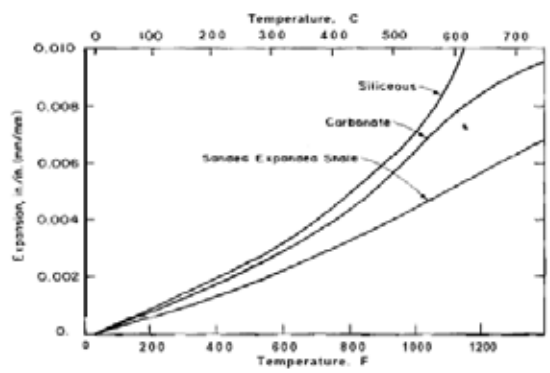

Fig. 6.2-Thermal expansion of concrete at high temperatures

Fig. 1 Thermal expansion of concrete at high temperature

The thermal expansion increases with increase in temperature. Fig. 1 shows the linear thermal expansion of different types of aggregates. The thermal expansion of concrete is influenced by, aggregate type, cement content, water content and age of concrete. [3]

Thermal conductivity

The thermal conductivity of concrete is one of the key parameters needed to predict temperature variation during hydration. This measures the ability of the material to conduct heat and is defined as the ratio of the flux of heat to temperature gradient. It is measured in joules per second per square meter of area of body when the temperature difference is 1°C per meter of thickness of the body. [3]

The conductivity of concrete is determined by the conductivities of its constituents. The major factors influencing the conductivity are the moisture content of concrete, the type of aggregate, the mix proportions, the type of cement and the temperature of the concrete.

The conductivity of concrete is highly affected by its moisture content, as water has a higher conductivity than air. Though the effects a variation in the moisture content are not as large as those caused by the aggregate type for normal weight concrete, in light weight concrete the affects can be quite pro-

nounced. The thermal conductivity varies with the density of concrete, with heavier aggregates resulting in higher thermal conductivity. The conductivity of concrete is known generally to decrease with increased temperature, through the loss of pore water and the dehydration of cement paste. A concrete surface exposed to sufficiently high temperature will undergo these changes and effectively produce an insulating layer of lower thermal conductivity, which acts as a refractory material and reduces the ingress of heat. The mineralogical character of the aggregate greatly affects the conductivity of concrete.

Both light-weight and calcareous aggregate concrete possess low thermal conductivity (and hence low thermal diffusivity), which results in less temperature rise in light weight or calcareous aggregate concrete than in one with siliceous aggregate, after equal exposure to fire.

Thermal diffusivity

Thermal diffusivity is a measure of the rate at which temperature change within the mass take place. The larger the value of thermal diffusivity of a mass the faster the changes will occur. The value of thermal diffusivity is dependent on the aggregate type, moisture content, degree of hydration of the cement paste, and exposure to drying. [3]

Diffusivity can be determined by:

$$D = \frac{K}{Sd}$$

D = Thermal diffusivity (m^2/s)
K = Thermal conductivity (J/s m K)
S = Specific heat (J/kg K)
d = Density of concrete (kg/m^3)

Specific heat

Specific heat represents the heat capacity of concrete. It increases with the moisture content of concrete and is affected by the mineralogical character of the aggregate, specific heat increases with an increase in temperature and also increases with a decrease in the density of concrete. (3)

Conclusion

Thus it is concluded that since these thermal properties play important role in the behavior of concrete at elevated temperature. These properties must be studied.

REFERENCES

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