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Effect of Temperature on Concrete

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Abstract—*Concrete is the most widely used material in the construction industry and it will retain its importance in near future due to demand of construction of various types of structures. Since the Industrial Revolution human activities have significantly enhanced the global warming. Due to global warming there has been a rapid change in temperature, which has a negative effect on the properties of concrete. Thermal properties are important for structures in which temperature differentials occur.*

The thermal properties of concrete are more complex than most of other materials because they are affected by moisture content and porosity. Concrete expands as temperature rises and contracts as temperature falls. The size of concrete structure whether it is large or small does not make it immune to the effect of the temperature. The expansion and contraction with change in temperature occur regardless of the cross-sectional area. Change in temperature also affects the workability of concrete.

Different types of aggregate have great influence on the expansion and contraction, while the moisture content plays a significant role in reducing strength.

An average value for the coefficient of thermal expansion of concrete is about 10 millionths per degree Celsius (10x10-6/C), although values ranging from 7 to 12 millionths per degree Celsius have been observed.

Unstressed tests, stressed tests, residual unstressed test are the three types of test commonly used to study the effect of transient high temperature on the stress-strain properties of concrete under compression. For a normal strength concrete, when the exposure temperature is greater than 450°C the residual unstressed strength decreases.

To avoid the environmental effects on concrete, application of smart technology along with the use of hybrid materials to enhance the concrete behaviour in terms of strength, ductility and durability is being done to make the concrete behave well under adverse conditions.

Keywords: *Concrete, Expansion, Contraction, Ductility, Coefficient of thermal expansion, Transient.*

1. INTRODUCTION

Concrete is versatile in nature, has desirable engineering properties. Concrete is most widely used building material. It is strong, brittle and tough material. It can be made on site using easily available materials. It can be molded into any shape and surface can be textured for aesthetic purpose. Most importantly, it is produced with cost–effective materials and it will retain its importance in near future due to demand of construction of various types of structure. Since the Industrial Revolution human activities have significant enhanced the Global Warming. Due to Global Warming there has been a rapid change in temperature. The effect of temperature on different properties of concrete is considerable. It has been found that high early temperature has negative impacts on later strength of concrete. The adverse effect on long term strength of concrete is due to high initial temperature. High initial rate of hydration due to increased temperature retards the subsequent hydration and produces a non-uniform distribution of the products of hydration

So that much of the basic information about the properties of both fresh and hardened concrete is based on the behavior of concrete at these temperatures. In practice however the concrete is mixed and remains in service at a variety of temperature. Indeed, the actual change of temperature has widened up considerably with much modern construction taking place in countries which have a hot climate. Also, new developments, mainly offshore, take place in very cold regions.

2. THERMAL PROPERTIES OF CONCRETE THERMAL EXPANSION AND CONTRACTION

Thermal properties are important in structures in which temperature differentials occur including those due to solar radiation during casting and the inherent heat of hydration. the thermal properties of concrete are more complex than those of most other material because these are affected by moisture content and porosity.

Three types of test are commonly used to study the effect of temperature on stress strain properties of concrete under compression. These are the following

(a) Unstressed tests, where specimens are heated under no initial stress and then loaded until the point of failure.

(b) Stressed test, where a fraction of the compressive strength capacity at room temperature is applied and sustained during heating. When the target temperature is reached; the load is increased until the point of failure.

(c) Residual unstressed test, where the specimens are heated without any load, cooled to room temperature, and then loaded until the point of failure.

For normal strength concrete, when the exposure is greater than 450°C, the residual unstressed strength decreases. When tested under precompressedload, the loss in strength is less, as compressive load helps to delay the spread of crack. The moisture content plays a significant role in reducing the strength due to increase in temperature. The variation of the modulus of elasticity of normal and high strength concrete with temperature. The modulus decreases by about 5-15% when exposed to the temperature in the range of 100-300°C. At 800°C, the value of E reduces to 20-25% of its value at room temperature. Dimensional stability is an important property of the hardening concrete mass.

3. THERMAL EXPANSION AND CONTRACTION IN CONCRETE

Most materials expand when they are heated, and contract when they are cooled. When free to deform, concrete will expand or contract due to fluctuations in temperature. The size of the concrete structure whether it is a bridge, a highway, or a building does not make it immune to the effects of temperature. The expansion and contraction with changes in temperature occur regardless of the structure's cross-sectional area.

Concrete expands slightly as temperature rises and contracts as temperature falls. Temperature changes may be caused by environmental conditions or by cement hydration (the exothermic chemical process in which the cement reacts with the water in a mixture of concrete to create the calcium silicate hydrate binder and other compounds). An average value for the coefficient of thermal expansion of concrete is about 10 millionths per degree Celsius ($10x10^{-6}/C$), although values ranging from 7 to 12 millionths per degree Celsius have been observed. This amounts to a length change of 1. 7 centimeters for every 30. 5 meters of concrete subjected to a rise or fall of 38°C.

Thermal expansion and contraction of concrete varies primarily with aggregate type (shale, limestone, siliceous grave land granite), cementitious material content, water cement ratio, temperature range, concrete age, and ambient relative humidity. Of these factors, aggregate type has the greatest influence on the expansion and contraction of concrete.

Severe problems develop in massive structures where heat cannot be dissipated. Thermal contraction on the concrete's surface without a corresponding change in its interior temperature will cause a thermal differential and potentially lead to cracking. Temperature changes that result in shortening will crack concrete members that are held in place or restrained by another part of the structure, internal reinforcement or by the ground. For example, a long restrained concrete section is allowed to drop in temperature. As the temperature drops, the concrete tends to shorten, but cannot as it is restrained along its base length. This causes the concrete to be stressed, and eventually crack.

4. HOT WEATHER CONCRETE

Concrete placed during the hot months of the year is subject to conditions that can adversely affect the properties and serviceability of the hardened concrete. Some of these conditions are:

Problems:

- Increased water demand
- Increased rate of slump loss
- Increased rate of setting
- Increased tendency for plastic shrinkage cracking and drying shrinkage cracking
- Lower ultimate strengths
- Decreased durability
- Undesirable surface appearance

Hot weather as defined by ACI committee 305 1. 2. 1 is any combination of the following conditions that tend to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration, or otherwise resulting in detrimental results.

Detrimental Conditions

- High ambient temperature
- High concrete temperature
- Low relative humidity
- Wind velocity

The term —hot weather can be misleading, as some of the undesirable effects on concrete can and do occur in the spring and fall seasons and in arid climates any time of the year. The ideal conditions for placing concrete occur when the temperature is

68°F to 72°F, the relative humidity is at 50% or higher, and wind speeds low. As the temperature rises the humidity begins to drop, the wind velocity increases, or any combination of these conditions occur, control procedures are needed to minimize the harmful effects.

Controls for Hot Weather:

1. Using a concrete mixture that is properly proportioned for conditions expected in the field can help to minimize the rate of slump loss, and water demand.

2. Consider the use of a set-retarding admixture to control set times. The use of fly ash can also reduce the effects of fast-setting concrete.

3. Have adequate manpower and equipment available to handle the concrete at the desired rate of placement and to unload the concrete trucks promptly.

4. Drying shrinkage cracking is greatly influenced by the amount of water in the mix. As the temperature rises so does the amount of water needed to maintain the specified slump. Add water only once—adjust the slump when the truck first arrives and follow through with prompt placement.

5. EFFECTS OF LOW TEMPERATURE

At temperature ranging from the freezing point of water down to about -2000C, the strength of concrete is markedly higher than at room temperature. the compressive strength may be 2 to 3 times the strength at room temperature when the concrete is moist while being chilled, but the compressive strength of air-dry concrete increases very much less.

What Happens When Concrete Freezes?

- Pore water in concrete starts to freeze around -1°C (30°F)
- As some water freezes the ion concentration in the unfrozen water goes up, further depressing the freezing point.
- At around -3°C to -4°C (25 to 27°F), enough of the pore water will freeze so that hydration will completely stop, and depending on the extent of hydration, and thus the strength of the concrete, the forces generated by the expansion of ice (ice occupies ~9% more volume than water) may be detrimental to the long term integrity of the concrete.

6. COLD WEATHER CONCRETE

Objectives:

The objectives of cold weather concreting are to:

- Prevent damage to concrete due to freezing at early ages
- Assure that concrete develops the required strength for the safe removal of forms
- Maintain curing conditions that foster normal strength development without using excessive heat
- Limit rapid temperature changes in the concrete to prevent thermal cracking
- Provide protection consistent with the intended serviceability of the structure for every 10°C (18°F) reduction in concrete temperature, the times of setting of the concrete double, thus increasing the amount of time that the concrete is vulnerable to damage due to freezing. It should be noted that warm concrete placed on cold sub-grade will lose heat and its temperature will drop. It is important to understand that having the concrete reach the specified 28-day strength is irrelevant if the structure is damaged by inadequate curing and protection. Concrete that is protected from freezing until it has attained a compressive strength of at least 3. 45 MPa will not be damaged by exposure to a single freezing cycle. Concrete that is protected and properly cured will mature to its potential strength despite subsequent exposure to cold weather. Except in heated, protective enclosures, little or no external supply of moisture is required for curing during cold weather.

Definition:

Cold weather is defined by ACI committee 306 as a period when for more than 3 successive days, the following conditions exist:

1. The average daily air temperature is less than 40°F, and

2. The air temperature is not greater than 50°F for not more than one half of any 24 hour period.

The average daily air temperature is the average of the highest and lowest temperatures occurring between the periods from midnight to midnight. Normal concrete practices can resume once the ambient temperature is above 50°F for more than half the day. Concrete can be placed safely throughout the winter months if certain precautions are met. During cold weather, preparations should be made to protect the concrete; enclosures, windbreaks, portable heaters, insulated forms and blankets should be ready to maintain the concrete temperature.

Effects of cold weather on concrete:

Effects of cold weather on concrete, in the absence of special precautions, may be as follows:

a) Delayed Setting - When the temperature is falling to about 5°C or below, the development of concrete strength is retarded compared with the strength development at normal temperatures. The hardening period, necessary before the removal of forms is thus increased and the experience from concreting at normal temperature cannot be used directly.

b) Freezing of Concrete at Early Ages- When concrete is exposed to freezing temperature, there is the risk of concrete suffering irreparable loss of strength and other qualities, that is, permeability may increase and the durability may be impaired.

c) Repeated Freezing and Thawing of Concrete- If concrete is exposed to repeated freezing and–thawing after final set and during the hardening period, the final qualities of the concrete may also be impaired.

d) Stresses Due to Temperature Differential- It is a general experience that large temperature differentials within the concrete member may promote cracking and have a harmful effect on the durability. Such differentials are likely to occur in cold weather at the time of removal of form insulations.

Recommended Practices and Basic Principles

Planning:

Prior to the pour, clearly define the cold weather concreting methods that will be used. A preplacement meeting with the contractor, specifier, producer, laboratory and other interested parties is highly recommended.

Curing and Protection

Where a specified concrete strength must be attained in a few days or weeks, protection at temperatures above 10°C is required.

Temperature Records

Temperature of the concrete determines the effectiveness of protection, regardless of air temperature. Maintaining temperature records of concrete in place is essential.

Heated Enclosures

Must be strong enough to be windproof and weatherproof. Combustion heaters must be vented to the outside to prevent carbonation.

Exposure to Freezing and Thawing

Concrete should be properly air entrained if it will be saturated and exposed to freezing and thawing cycles during construction.

Slump

All else being equal lower slump and/or lower water/cement ratio mixes are particularly desirable in cold weather for flatwork. This reduces bleeding and decreases setting time.

Truck Travel Time

The distance from the plant to the point of placement can have a severe effect on the temperature of concrete.

Hot Water

While hot water improves setting time of cold weather concrete, after the first few batches of concrete hot water heaters may not be able to maintain hot water temperature. Later in the pour, concrete may be cooler than at the beginning of the pour.

Acceleration of Concrete Hydration in Cold Weather:

The reduction of setting time and the acceleration of strength gain often result in substantial savings due toshorter protection periods; faster form reuse, earlier removal of shores, and less labor in finishing flatwork.

- Setting time is more important in flatwork finishing
- Early strength gain is more important for early form removal
- Acceleration may be encouraged by using: Type III Portland cement
- 20% additional Type I or II cement to provide

Type III response

Calcium chloride is the most cost effective accelerator available, but it causes corrosion of embedded metals in the presence of oxygen and moisture. This is why limits exist on the use of chlorides in concrete. It is important to verify that non-chloride accelerating admixtures are also noncorrosive.

Some accelerating admixtures which are labeled as non-chloride may still contain materials which cause the products to be corrosive to embedded metals. Non-chloride, noncorrosive accelerators are more expensive upfront, but when life-cycle costs and regulations limiting chlorides are considered, they are the most cost effective products. Accelerators have been introduced successfully into concrete both before and after the addition of cement to the mix, but it may be best policy to add the accelerator to the mix the cement has been wetted. On rare occasions, when accelerators are added to the mix prior to the batching of under-sulfated cements, there may be adverse reactions with the tricalcium aluminate (C_3A) in the cement which may result in retardation. Therefore, we recommend that if the accelerator is to be added up-front, before the cement, it should be tested with the intended cement at the intended use temperature, prior to placement. Different mixes and materials will exhibit different setting times. It should not be assumed that two different Portland cements will set at similar rates. If pozzolans are to be used in the concrete, they should also be included in trial mixes prior to placement.

7. FUTURE TENDS IN CONCRETE TECHNOLOGY

Development in concrete industry can be classified into five major focus areas:

a. Application of smart technology

b. Improvement to rebar technology

c. Use of hybrid material in concrete

d. Enhancement of concrete behavior in terms of strength, durability and ductility for making it behave well even under adverse load conditions.

e. Conservation of concrete making materials so that the industry is sustainable.

Recycling of demolition waste, use of industrial wastes such as fly ash, and green building material method are developments that have stemmed from the need to conserve materials and obtain maximum output from concrete.

8. CONCLUSIONS

Concrete is widely used commodity. It is used in a variety of environments. Concreting, though a relatively easy concept is less under stood sometimes and even small factors like temperature can play a big role in the proper and satisfactory performance of concrete. It has seen that the temperature variation results in both positive and negative impacts on different properties of concrete. It also yields good results but keeping in view the demand of concrete's strength the temperature of the environment under which it is mixed, cast, cured and finally tested must be controlled. Increase in temperature increases initial strength while at the same time it reduces the long term strength.

Small or large, all types of construction use concrete. Though conventional concrete is a widely used construction material, there are other tailored forms of concrete that are being increasingly used for special purpose. Depending upon the need, one may employ pre-stressed, self-compacting, and fiber reinforced concrete.

REFERENCES

[1] A. R. Santhakumar concrete technology OXFORD.
[2] The Effect of Elevated Temperature on Concrete Materials and Structures—A Literature Review by D. J. Naus Oak Ridge National Laboratory Managed by UT-Battelle, LLC P. O. Box 2008 Oak Ridge, TN 37831-6283
[3] C. R. Cruz and M. Gillen, Thermal expansion of Portland cement paste, mortar and concrete at high temperature, Fire and Materials, 4, No. 2, (1990).
[4] The Effect of Elevated Temperature on Concrete Materials and Structures—A Literature Review by D. J. Naus Oak Ridge National Laboratory Managed by UT-Battelle, LLC P. O. Box 2008 Oak Ridge, TN 37831-6283