Issues of cracks in fresh concrete and importance of curing concrete structure

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Site engineers may often observe cracks appearing after casting of concrete, Figure 1. Issues of such cracks formation on the surface of fresh concrete, more particularly on the horizontal surfaces, are essentially due to the high evaporation rates causing surface to dry out fast. This is called as 'Plastic Shrinkage cracks', which are generally parallel to each other and shallow in its depth. Mostly plastic shrinkage cracks, does not impair the strength of concrete member, however it can act as access point for movement of aggressive chemicals into concrete and steel and impact the durability of the reinforced concrete structures. Such cracks can be minimized by taking proper precautionary measures during placing and finishing operations in the concrete.

Normally the cement in concrete reacts when it comes into contact with water and the process of setting and strength gain in concrete takes place by chemical reaction. During this process of chemical reaction, the cement liberates heat which will convert the mix water into water vapour if the outside air temperature is high. This liberation of heat is predominantly observed to be more in case of OPC cements than any blended cements. In addition to this, during summer, the intensity of solar radiation and wind velocity particularly in coastal areas further aggravates the evaporation of water in concrete. If such evaporation of water in concrete is more than the bleeding rate on the surface of concrete, then the chances of formation of plastic shrinkage cracks is more.

Various research articles reveal that the bleeding rate for normal grade concrete is 1.0 kg(m^2/hr) (ACI 305). If evaporation rate in the concrete exceeds this bleeding rate, then plastic shrinkage cracks tend to form on the surface of concrete members. This issue of plastic shrinkage cracks is predominantly observed in slab members, which is due to higher surface area to thickness.

Traditionally for site-mixed concrete mostly nominal mix proportions are adopted. For buildings up to G+2 storeys, for structural work, nominal mix proportion of 1:1.5:3 or 1:2:3 are adopted at the site. If one calculates the cement

Figure 1. Cracks after concrete casting

content per cubic meter for the nominal mix proportion, it is more than 400 kg/m^3, which is much on the higher side. Moreover, now-a-days, due to non availability of river sand, mostly M. Sand or CRF are also being extensively used for site-mixed concrete work. Also, M. Sand or CRF which is available in the market, mostly have fines particle of less than 150 micron, more than 30% and sometimes upto 45%. Presence of such finer particle further demands more water for a given workability and also reduces the bleeding rate in the concrete. Usage of M. Sand or CRF in nominal mix concrete at site, tends to reduce the bleeding rate in concrete drastically.

In addition to these factors, during summer, the outside temperature increases significantly, i.e., up to 40°C and RH value in inland area are also less than 50%, which will further aggravate the rate of evaporation of water in concrete. Also during night time, the wind velocity was observed to be more than 15 km/hr, which is also factor for increase in evaporation of moisture from surface of the concrete (this is like drying clothes under the fan). This is the most important issue for structures built in coastal environment.

We shall understand and arrive the rate of water evaporation using the nomogram given in Figure 2. With the help of

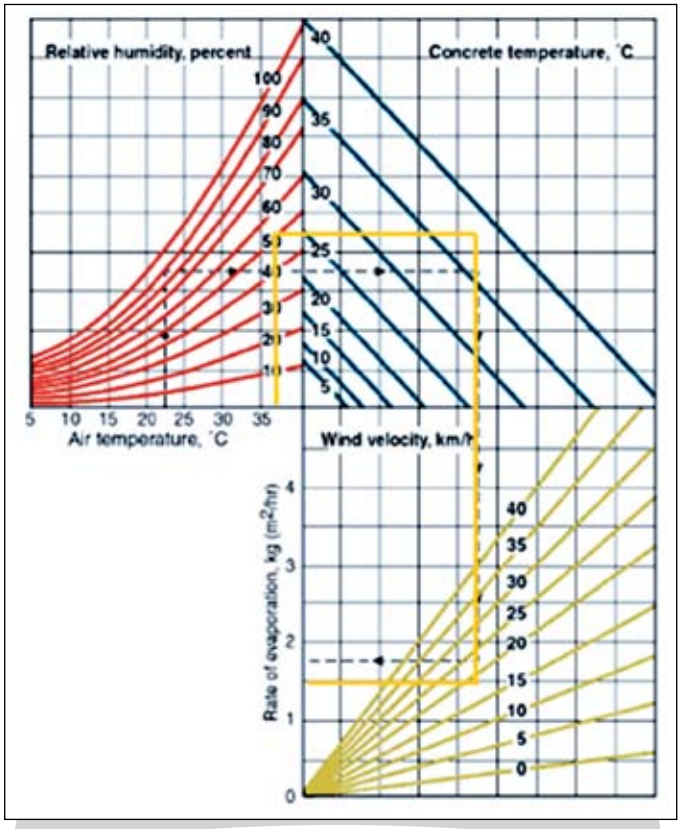

Figure 2. Nomogram for estimation of rate of evaporation
Source: Portland Cement Association

weather application (cellphone App. in a smart phone), one can easily measure the outside air temperature, wind velocity and Relative Humidity (RH) of the given site location. Normally the temperature of fresh concrete after five hours of casting would be 36 to 39°C which again depends on grade of concrete, cement content, cement type, water-cement ratio and ambient temperature.

Case – 1: Suppose if air temperature is 36°C, Relative Humidity at 50%, concrete temperature 38°C and wind velocity at 20 km/hr, then the rate of evaporation is 1.5 kg (m^2/hr). This is a typical situation in inland areas. This combination of high solar radiation, wind velocity and lower RH, increases the rate of hydration of cement and rate of evaporation on the concrete surface.

Case – 2: Suppose if the air temperature is 23°C, Relative Humidity at 95%, concrete temperature 35.5°C and wind velocity at 22 km/hr, then the rate of evaporation is 1.8 kg (m^2/hr). This is a typical situation during winters in coastal areas. Wind velocity plays a major role on rate of evaporation.

When the evaporation rate exceeds 1 kg(m^2/hr), then plastic shrinkage cracks starts appearing on the concrete surface if the proper curing methods are not adopted.

Plastic shrinkage cracks in concrete are essentially due to these following reasons

1. Increase in air temperature and lower relative humidity – Ideal temperature to avoid cracks in concrete is 27 ± 2 °C
2. Wind velocity
3. High fines content in the fine aggregate (M. Sand) or more clay substances in river sand
4. High cement content in concrete using volume batch at site
5. Excessive vibration in concrete elements, which leads to accumulation of more cement paste on the top surface of concrete elements
6. Fineness of cement.

CURING

Curing is the process of protecting the freshly placed concrete, from the loss of moisture and maintain the concrete temperature within the range. Curing not only mitigates the plastic shrinkage cracks but also greatly helps concrete to

gain the strength by continued hydration of cement and also reduces the permeability in concrete.

One would like to refer the strength development chart, Figure 3. Suppose if the concrete is allowed to dry in air without any curing, it will attain only 50% of strength of moist cured concrete. In fact the rate of strength development is almost stopped for air cured concrete after 7 days. However, if the moist curing period extended to more than 7 days, the rate of strength development increased significantly.

Hence, for better strength development and durability, curing of concrete elements should be for at least 14 days and it can be extended up to 28 days to attain maximum benefit if blended cements are used in concrete.

HOW TO PREVENT PLASTIC SHRINKAGE CRACKS?

The formation of plastic shrinkage cracks in concrete can be prevented by adopting the following proper curing methods.

1. Preventing the loss of moisture by sealing the surface during curing, including (i) applying membrane forming curing compounds (Figure 4), (ii) plastic sheet or tarpaulin covering (Figure 5) (iii) leaving the formwork in place and (iv) saturated jute bags covering (Figure 6)

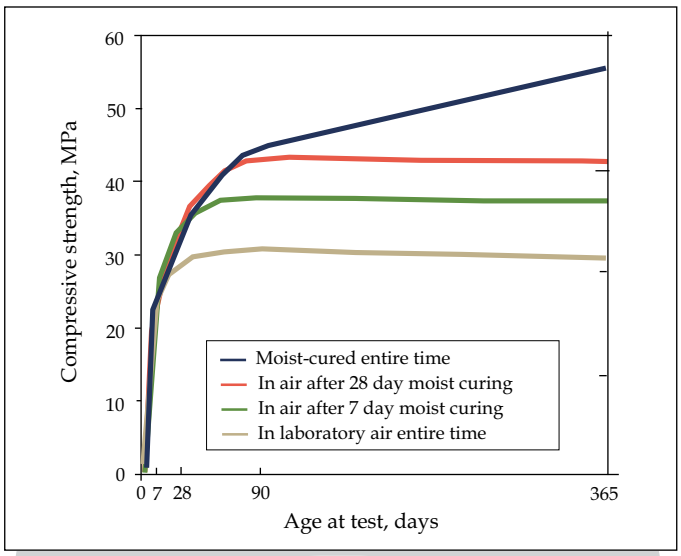

Figure 3. Rate of strength development with various curing methods

Figure 4. Membrane curing

Figure 5. Curing using plastic sheet or tarpaulin

Figure 6. Curing using Jute bags covering

Figure 7. Water pond curing

2. Maintaining mix water during early stage of concrete curing including (i) water ponding or immersion (Figure 7), (ii) spraying (Figure 8) and (iii) fogging. These method of curing in fact cools the concrete.

CURING UNDER DIFFERENT WEATHER CONDITIONS

For normal weather condition, variation of temperature is not a major problem. However, the key challenges will be the influence of wind speed. Suppose if the wind speed is more than 10 km/hr, it may be a cause of concern for rapid drying of concrete surface. This may be prevented by adopting appropriate methods such as installing wind barriers or sealing of concrete surface using curing compounds.

For extreme climate such as hot weather conditions, the rate of evaporation of moisture is significant due to higher air temperature and rapid reaction of cement compounds. Keeping surface of concrete under damp conditions continuously by water ponding or covering with wet gunny bags, will prevent rapid loss of moisture.

Figure 8. Water spraying curing method

If air temperature is below 5°C, the rate of cement hydration will be slower which impairs the strength gain in concrete. This is a matter of concern for large surface area structural members like slabs. However, for massive members like deep beams, the heat generated from cement hydration is sufficient for continuing the hydration process in concrete. For non-massive members, best method of curing would be steam curing or installing heating coil or insulating the members. The favourable temperature to maintain the hydration process active is in the range of 10 to 21°C with the extended period of curing.

CURING PERIOD

The period of curing concrete members are essentially depends on grade of concrete, mix proportion, type of cement, ambient conditions, member shape and curing methods. As mentioned above, the properties of concrete, particularly the strength of concrete, enhances over period of time under normal temperature. IS 456:2000 states in clause 13.5.1, that the concrete made with OPC should be kept wet/ damp for at least 7 days in case of normal weather and 10 days for hot weather condition. However, in case of blended cements (PPC and PSC) moist curing should be employed continuously at least for 14 days.

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