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EFFECT OF HOT-WEATHER ON CONCRETE

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Definition of Hot-Weather

Hot weather is expressed as an average of 3 consecutive days of air temperature above 30 °C according to the EN 206 Standard. Average temperature at the concrete casting site; It is the arithmetic mean of the air temperatures measured at 07:00, 10:00, 13:00, 16:00 and 19:00.

It is necessary to evaluate hot weather conditions not only as air temperature, but as a combination of the following conditions:

- Ambient temperature
- Concrete temperature
- Relative humidity
- Wind speed
- Effect of sun rays

LOWEST CONCRETE TEMPERATURE
5 °C

HIGHEST CONCRETE TEMPERATURE
32 °C

OPTIMUM CONCRETE TEMPERATURE
15-20 °C

Effects of Hot-Weather on Concrete

Hot air adversely affects the quality and properties of concrete and causes problems in mixing, placing and curing processes. The majority of these problems result in increased hydration rate and evaporation rate of water in the fresh concrete mixing.

As the air temperature increases;

- Concrete temperature rises,
- The need for water increases,
- Loss of consistency increases,
- Setting time is shortened,
- Cracking due to plastic and drying shrinkage tends to increase,
- The risk of cold joint formation increases,
- Air content becomes difficult to control.

All these factors adversely affect the strength and durability properties of concrete. Therefore, the negative effects of hot weather conditions on concrete should be monitored and necessary precautions should be taken.

Evaporation and Transpiration in Concrete

Water loss in concrete occurs by evaporation. This loss can be compensated either by measures to prevent evaporation or by returning the lost water to the concrete. There are 3 main factors affecting evaporation:

1. Ambient temperature
2. Relative humidity
3. Wind speed

Transpiration rate and duration; It varies according to the method of compaction of the concrete, the thickness of the concrete section and the content of the concrete. The water/cement ratio is the most important factor in transpiration. Things to know about transpiration:

- With the excessive vibration process, the transpiration rate increases.
- Condensation is higher in thick-section elements.
- In concretes with less perspiration, the surface dries earlier.
- Since the fine material content is higher in high-strength concrete, transpiration is less.
- In concrete placed on dry ground, transpiration is less.
- As the cement specific surface (cement fineness) increases, transpiration becomes less.

It is an ideal situation that the rate of evaporation and the rate of transpiration are in balance [Figure 1]. However, if the evaporation rate is above the critical level, plastic shrinkage occurs on the concrete surface as seen in Figure 2. Cracks on the surface will increase the permeability of the concrete as well as spoil the aesthetic appearance.

Unhumid and windy Weather combined with high air temperature is the most unfavorable environment for concrete pouring.

IMPORTANT NOTE

As a result of surface screeding and surface finishing processes to be carried out before transpiration is completed, a layer with a high W/C ratio is formed on the concrete surface and undesirable situations such as dusting and crusting may occur.

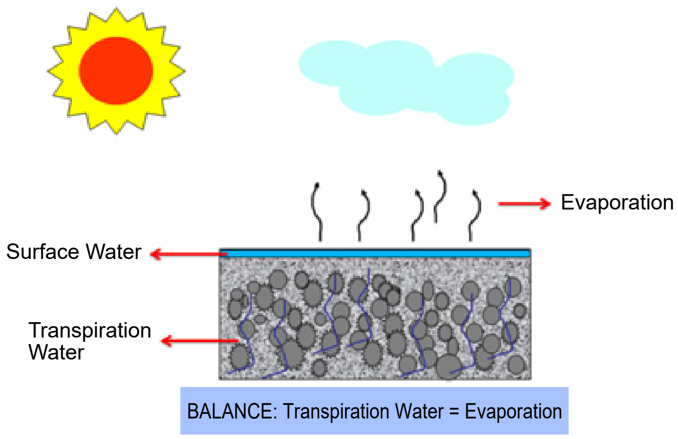

Figure 1. Equilibrium state of evaporation and transpiration

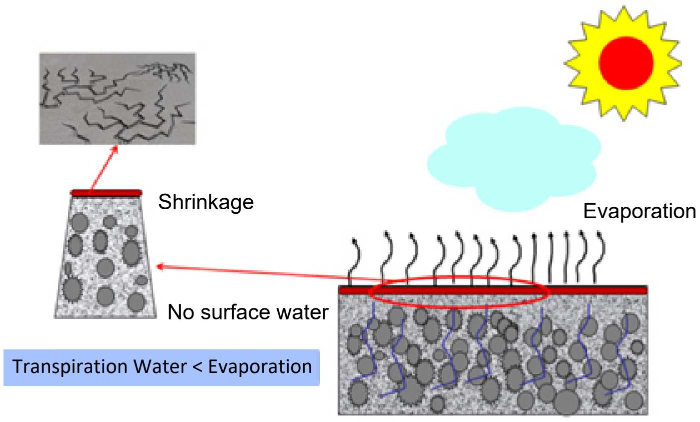

Figure 2. Situation in which evaporation is greater than perspiration

IMPORTANT NOTE

- ***The highest allowable evaporation rate E_{max} = 1.0 kg/m²/h***
- ***Precautions should be taken at 0.5 kg/m²/hour and above.***
- ***E_{max} value should be even lower for high strength concretes.***

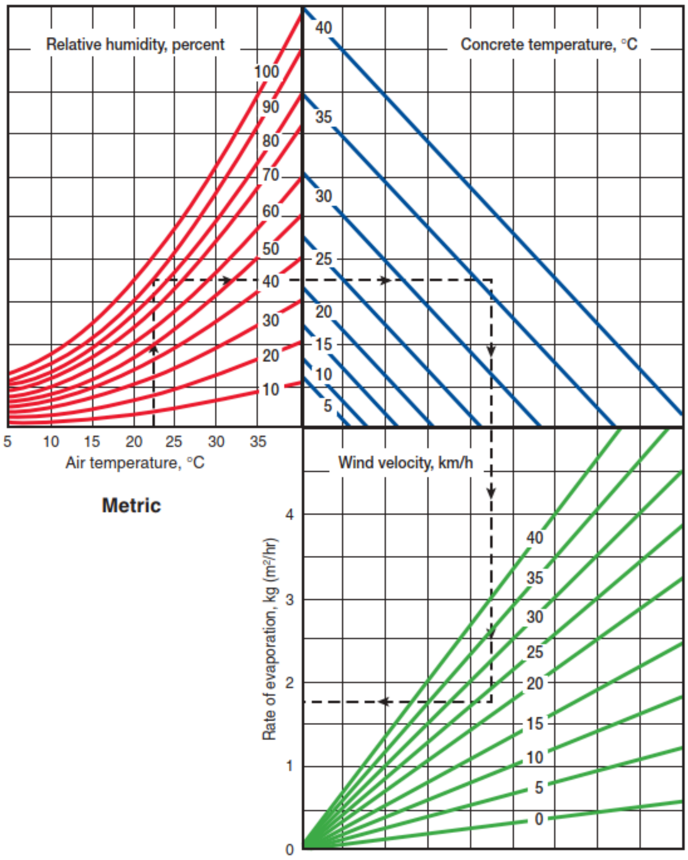

Figure 3. The effects of concrete temperature, air temperature, relative humidity and wind speed on the evaporation rate on the concrete surface.

The graph above shows the rate of evaporation that will occur in one hour on one square meter of concrete surface. Also, the evaporation rate can be calculated by the following formula. In the absence of wind or very low wind speed and high relative humidity, the air temperature being higher than the concrete temperature causes the evaporation rate to be negative. In this case, condensation occurs on the concrete surface.

$$B = 5 \times ([T_c + 18]^{2.5} - r[T_a + 18]^{2.5}) \times (V + 4) \times 10^{-6}$$

⇒ B = The rate of water evaporated from 1 m² per hour
⇒ r = Relative humidity, %
⇒ T_a = Air temperature, °C
⇒ T_c = Concrete temperature °C
⇒ V = Wind speed, km/hr

Air Temp. - Water Requirement Relationship

As seen in Figure 4, the water requirement of the concrete increases as the air temperature increases. When the cement dosage is kept constant, the water/cement ratio, which is the most critical value for strength and durability, increases. In this case, a significant decrease in concrete strength is observed.

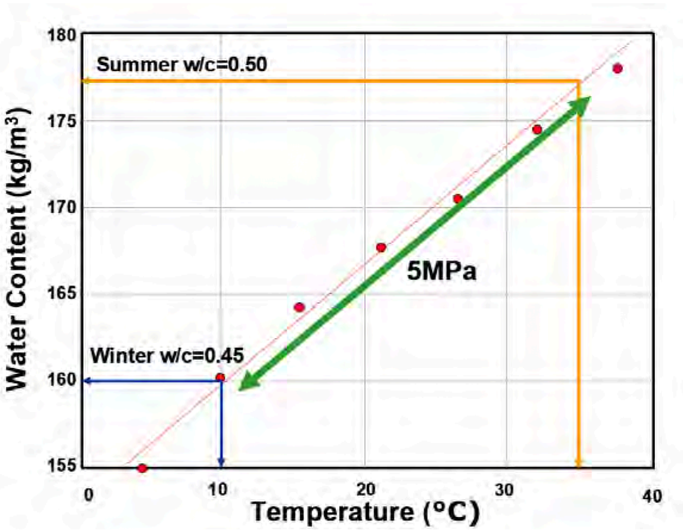

Figure 4. Relationship between temperature and water content

Concrete Temperature - Workability Relationship

An increase in concrete temperature causes a loss of consistency in concrete (Figure 5). For this reason, it is beneficial to use chemical additives that retard setting, reduce water and maintain consistency.

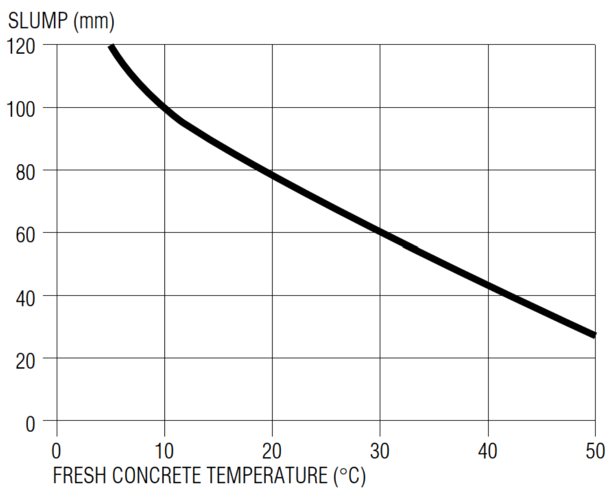

Figure 5. Decrease in workability of fresh concrete (as measured by slump), made with constant water content, as temperature increases.

Air Temperature - Setting Time Relationship

Figure 6 shows the relationship between air temperature and setting time. It is seen that an increase in air temperature of 5°C reduces the setting time by 20-25%.

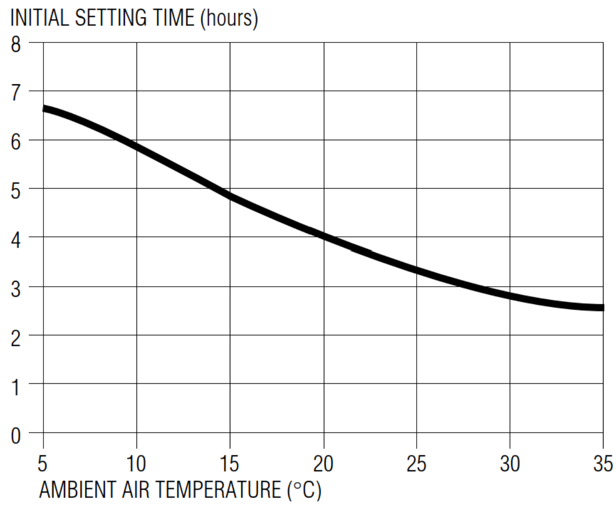

Figure 6. Influence of air temperature on setting times of concrete made with Type GP cement.

Concrete Temperature - Setting Time Relationship

As seen in Figure 7, the increase in concrete temperature decreases the time taken for the beginning and end of the setting. However, this situation can be avoided with the use of blended cement. In addition, setting times can be extended with the use of set retarding additives.

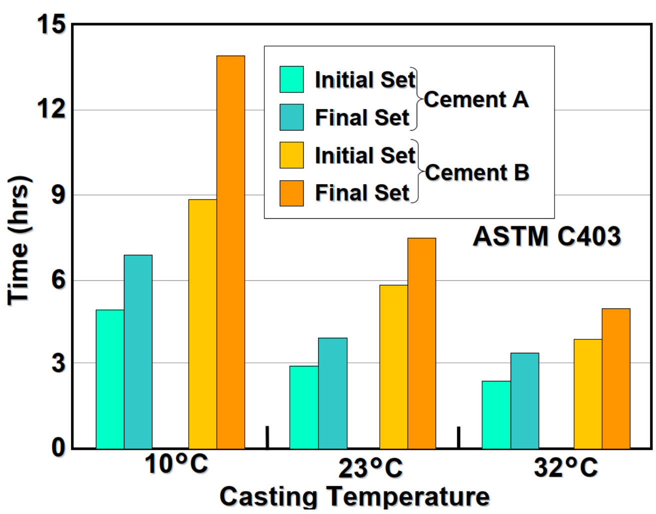

Figure 7. Effect of temperature on setting time.

Concrete Temp. - Compressive Strenght Relationship

Increasing the concrete temperature increases the early age strength of concrete. The main reason for this is that the hydration reaction accelerates with temperature and more hydration products are formed. Increasing the concrete temperature causes the final strength to be lower than the normal conditions, contrary to the early wet strength. The reason for this is that the products formed due to heat at an early age form a very dense and low permeability layer around the cement particles. The products formed are not uniformly dispersed and prevent water from reaching the unhydrated cement. As a result, the development of strength slows down.

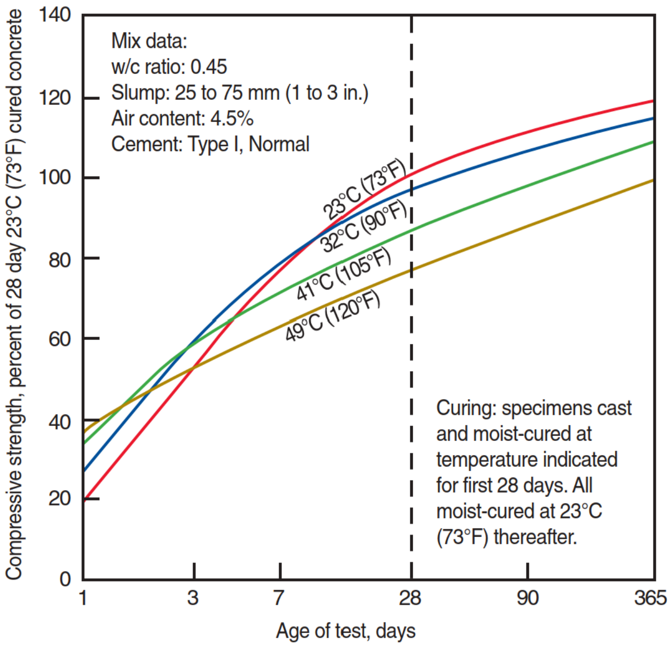

Figure 8. Effect of high concrete temperatures on compressive strength at various ages (Klieger 1958).

Figure 8 shows the strength development of the samples of the same concrete cured at different temperatures. Considering the one-day strength values, the highest strength was seen in the sample cured at 49°C, and the lowest strength was seen in the sample cured at 23°C.

Considering the seven-day strength, the sample cured at 49°C gave the lowest strength, while the sample cured at 32°C gave the highest strength. In 28 days, on the contrary to the 1-day strength, the highest strength was observed in the sample that was cured at 23°C and the lowest temperature. Strength development after 28 days continued in a similar way.

IMPORTANT NOTE

If the layer thickness is more than 1 m in mass concrete castings in summer, pouring should not be done in one go. The material temperature should be lowered and proper care should be taken after concrete pouring. Temperature values should be measured at the bottom, middle and top of the concrete layer. The two most important issues to be considered in mass concrete casting are the highest temperature value and temperature difference in the concrete. It is undesirable for the internal temperature of the concrete to be above 70°C. There should be no more than 20°C difference between the internal temperature of the concrete and the surface temperature. Otherwise, thermal crack formation may occur.

Concrete samples taken in hot weather conditions should be stored in an environment between 15°C and 25°C between 16-72 hours. After being removed from the mold, it should be preserved in water between 18°C - 22°C. Especially in the summer season, samples that are not kept in suitable conditions give misleading values. In Figure 9, it is seen that the 28-day strength value of the concrete, which was exposed to higher temperatures for the first two hours, decreased. An important conclusion to be drawn from Figure 8 is that the results of the concrete producer and the building inspection laboratory may differ significantly as a result of sample storage at different temperatures. Especially, considering the difficult sampling and storage conditions in the construction site environment, the strength of the samples taken at the facility may be higher. Authorities should be warned in case of misapplication.

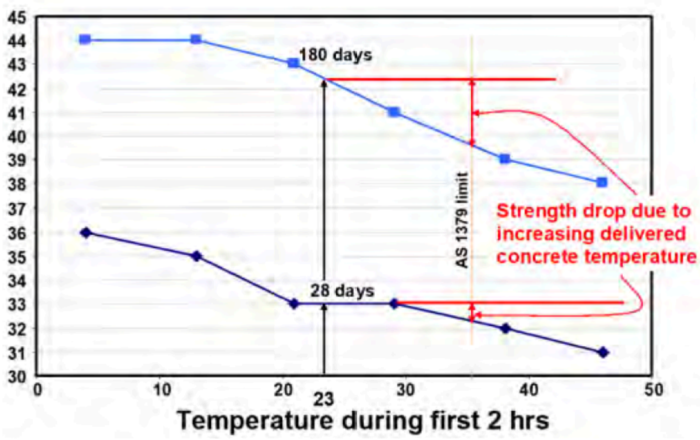

Figure 9. Strength of concrete exposed to different temperatures for two hours at the construction site.

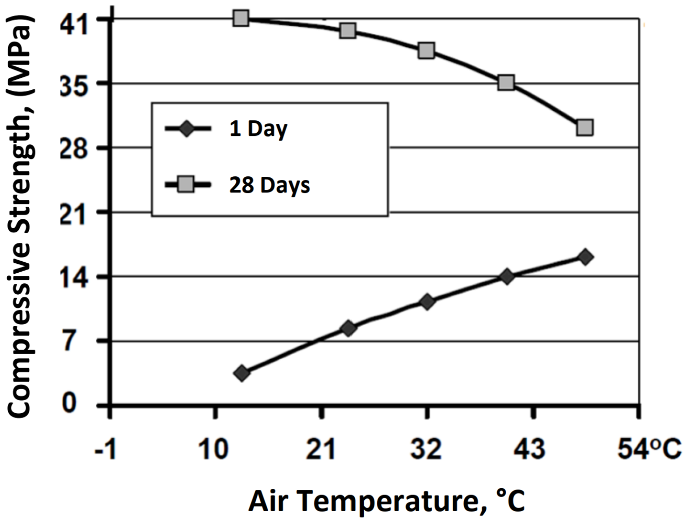

Figure 10. Air temperature - compressive strength relationship.

IMPORTANT NOTE

As a result of the researches, it was determined that the 28-day strength of the concrete samples cured at 38°C for the first 24 hours was 10-15% lower than the normal situation.

IMPORTANT NOTE

Concrete temperature between 15°C - 20°C is ideal; Concrete temperature should be minimum 5°C and maximum 35°C according to EN 206 standard.

Effect of Concrete Components on Concrete Temperature

The temperatures of the concrete components affect the average concrete temperature at different rates. The specific heat values and weight ratios of the components are the determining factors. Concrete components' Controlling the temperature is very useful, especially in hot weather conditions.

Concrete temperature can be easily calculated with the following formula.

$$T = \frac{0{,}22(T_a W_a + T_c W_c) + T_w W_w + T_a W_{wa}}{0{,}22(W_a + W_c) + W_w + W_{wa}}$$

T_a: Aggregate temperature (°C)
T_c: Cement temperature (°C)
T_w: Water temperature (°C)
W_a: Dry weight of aggregate (kg)
W_c: Cement weight (kg)
W_w: Water weight (kg)
W_{wa}: Mass of free water on the aggregate at Ta temperature and the water absorbed by the aggregate (kg)

Precautions to be Taken in Concrete Production

- Aggregate should be stored in the shade.
- Ice can be added to the mixing water.
- Additive cement can be preferred.
- Plasticizer and setting retarder chemical additives should be used.
- The ground to be poured concrete is wetted and saturated with water.
- Molds and reinforcements are wetted.
- Concrete should be poured during the day when the temperature is low.
- Fresh concrete temperature should be controlled.
- Excessive vibration should not be done.
- Casting should be carried out as soon as possible.
- Finishing should be done as soon as the sweating water is finished on the surface.
- Concrete should be cured with water or chemical additives.
- Evaporation can be prevented by covering the concrete surface with a membrane. Formwork of vertical elements can be wetted with water.
- It is recommended that the floors be cured for at least one week and the vertical elements for 3-4 days.

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