Curing BarChip Fibre Reinforced Concrete

BarChip Inc.
The Synthetic Fibre Experts

The final process in concrete placement.

Good concrete is concrete that has been placed, compacted, and cured properly. In simple terms, poor compaction, and poor curing - singly or together - produce poor concrete with lower strength and lower durability. (The Concrete Society, 2010).

Background

In any concrete slab, pavement or floor, the integrity of the uppermost surfaces is critical, from both a functional and aesthetic point of view. The external surfaces bear the brunt of the wear and tear, and importantly these same surfaces are required to provide the abrasion resistance and overall exposure protection of the concrete structure to achieve its design life. However, without curing, the all-important uppermost or external surfaces of the concrete structure can potentially become the weakest link.

Curing as stated by the Concrete Society "Is the last and most important stage of concrete construction. No matter how thorough you have been up to this point with your mix design, placing and compacting. If curing is not done properly, the concrete will not develop its full potential". (The Concrete Society, 2010).

The ultimate strength of concrete is based on the water-cement ratio with the specified amount of water necessary for hydration to attain the desired strength being added in the mixing stage. Hydration is a very complex chemical reaction between cement powder and water which continues for an extended time, but essentially after 28 days normal concrete would have attained approximately 98% of its ultimate strength. Excessive moisture loss from evaporation, or substrate absorption, during placing, compacting, and finishing processes will result in insufficient volumes of total available water essentially required in achieving full hydration. Incomplete hydration reduces capacity in achieving concrete's designed and desired hardened properties.

Understanding the hydration process is key to understanding the importance of curing. Simply explained, cement clinker contains or is made up four principal minerals or "phases". Each mineral or phase reacts at a different rate producing different hydration products. Simplistically, if you consider a cement grain to be like an onion, then over time, the water in the mix slowly dissolves the cement grain layer by layer.

The dissolved cement "phases" and water chemically produce four reactions concurrently, each "phase" forming different products of hydration "resulting in the formation of a solid mass composed of gel and crystalline material which binds together the constituents of a concrete mix." (Winter, 2009). While as mentioned previously this process takes in the region of 28 days, the most critical time in the development of the young concrete is during the first 3 days starting immediately after it has achieved its initial set and up to 7 days.

"Curing according to the British Ready-mix Concrete Association is important to prevent the newly placed concrete from drying out too soon, well cured concrete is stronger, more resistant to chemical attack and traffic wear, and more watertight, it also withstands freezing and abrasion better" (British Readymix Concrete Association, 2008).

Curing is defined by the American Concrete Institute (ACI) as the "action taken to maintain moisture and temperature conditions in a freshly placed cementitious mixture to allow hydraulic cement hydration and (if applicable) pozzolanic reactions to occur so that the potential properties of the mixture may develop." (American Concrete Institute, 2016).

When to start curing?

Traditionally under normal conditions curing has been seen as a single step process that is initiated soon after the concrete has been placed and finished but the definition of normal conditions is indeed a grey area because what one person might consider normal, concrete might not.

The speed of the hydration of concrete, while impacted by the cementitious composition and admixtures, is very dependent on the prevailing weather conditions. Under certain weather conditions, especially hot and windy conditions, the concrete could be compromised by early moisture loss and curing may have to start after placing but before finishing is completed. This is generally done by use of fog sprays or evaporation reducers, while in cooler conditions curing can start on completion of finishing. The all-important decision of when to start curing is essentially left to the personnel on site based on prevailing conditions. While field experience with the prevailing weather conditions and concrete mix being placed is used, this is at times insufficient. Therefore, it is better to do some pre-planning to ensure that dry surfaces or even alternating wet and dry surfaces before the concrete has hardened sufficiently are totally avoided.

Drying out or excessive moisture loss in the early life of young concrete, even sometimes before it is finished, can result in surface cracking, usually referred to as plastic shrinkage cracks.

Plastic shrinkage cracks form while the concrete is still plastic (soft), usually soon after it has been placed. They are a result of the slab surface drying at a faster rate than what the bleed water can rise to the surface, causing the surface to shrink and crack. The CCAA notes that "Plastic shrinkage cracks are not always evident during finishing operations and may not be discovered until the next day" and describes them as "forming either in a random manner or being roughly parallel to each other and ranging in length from 25mm to 2 m, but usually in the region of 300-600mm long." (Cement Concrete Aggregates Australia, 2005).

The rate of evaporation from the concrete surface is not simply caused by hot weather but often by a combination of several environmental factors such as wind speed, relative humidity, and temperature. The rate of bleed water leaving the newly placed concrete is mix design dependant with bleed being slowed down by a high proportion of fine material. While slower screeding rates and delayed finishing has been known to reduce the extent of plastic cracking, the best way to avoid plastic cracking is to determine the potential evaporation rate on the day of placement.

The recommendation by the CCAA is to take precautions when the anticipated evaporation rate will exceed 0.5 kg/m^2/h while the ACI suggests that accepted evaporation control measures capable of preventing rapid evaporation are in place for the duration of an evaporation rate equal to or greater than 1kg/m^2/h.

The easiest way to calculate the evaporation rate is to use what is known within the ready-mix concrete industry and specified by the ACI as the "Uno Evaporation Rate Equation" (Uno P. , 1998). Alternatively, the ACI nomograph (American Concrete Institute, 2010) can be used as shown below.
The ACI states that the instruments or equipment used to measure the prevailing weather conditions to be used in the Uno evaporation rate equation or ACI nomograph are to be certified by the manufacturer to within 1 (°C), 5% relative humidity and 1.6km/h wind speed. Furthermore, site conditions including air temperature, relative humidity and wind speed should be monitored from 1 hour before placing concrete and at 30-minute intervals thereafter to assess the need for evaporation control measures and this monitoring should continue until acceptable curing procedures have been applied. (American Concrete Institute, 2015).

The Uno Evaporation Rate Equation

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

Where E = evaporation rate (kg/m^2/h)

R = relative humidity/100

T_a = air temperature (°C)

T_c = concrete (water surface) temperature (°C)

V = wind velocity (km/h) (Uno P. , 1998)

Uno suggests that "It is imperative that the user of the formulae, be it in their own calculation or using an App developed by the various authorities, quantifies the air temperature, wind velocity, humidity etc on the site itself and do not rely on automated weather information downloaded from a local weather station. This is simply because weather stations do not necessarily reflect site conditions and this could leave the contractor open to litigation if it came to that." (Uno P. , 2022).

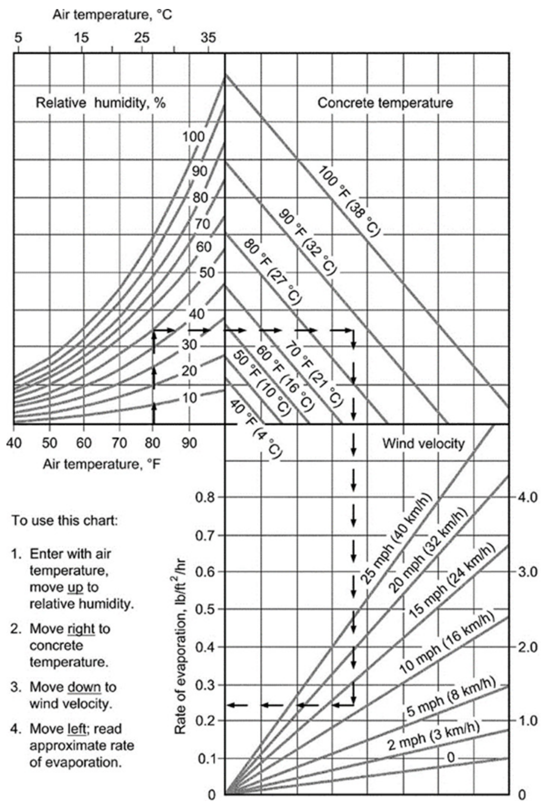

Figure 1: ACI Nomograph to determine evaporation rate (American Concrete Institute, 2010).

Initial Curing Methods

Initial curing refers to procedures implemented any time after placement and before the concrete has been finished to reduce moisture loss from the concrete surface. The most common procedure used at this point is fogging using a specially designed nozzle that atomizes the water into a fog like mist. It is important that the fog spray is directed above and not at the concrete surface, as its primary function is to reduce the rate of evaporation by increasing the humidity of the air just above the concrete. The effect only lasts if the mist is suspended in the air over the slab making continuous or frequent fogging necessary. An alternative to fogging is the application of liquid applied evaporation reducers. These are solutions of organic chemicals in water that can produce a monomolecular film over the bleed water and, when applied in sufficient concentration, the film reduces the evaporation rate. Evaporation reducers can be sprayed onto freshly placed concrete to reduce the risk of shrinkage when the evaporation rate exceeds the bleed rate. (American Concrete Institute , 2008).

Final Curing Measures

Final curing methods refer to curing that is implemented once finishing is completed and the concrete has reached its final set. To be effective, curing should commence as early as possible after the final finish and continue for a minimum period of three days, and where possible as long as seven days. The various methods of curing are categorised by the CCAA as:

- Those that minimise moisture loss from the concrete, for example by covering it with a relatively impermeable membrane.
- Those that prevent moisture loss by continuously wetting the exposed surface of the concrete.
- Those that keep the surface moist and, at the same time raise the temperature of the concrete, thereby increasing the rate of strength gain. This method is typically used for precast concrete products. (Cement Concrete Aggregates Australia, 2006).

Final Curing Methods

Ponding: Probably the most thorough method of water curing, ponding is a method where a “dam” is created around the slab using a clay type material and this “dam” is filled with water, noting that joints can cause the water to drain prematurely. Care also needs to be taken that ponding does not cause the base of the slab to flood so the sand ridge should ideally be at the edge of the slab.

Ponding method of concrete curing.

Burlap and other absorbent materials: Burlap, cotton mats and other absorbent materials can hold water on both vertical and horizontal surfaces. These coverings should be free of any deleterious materials such as sugar, fertiliser or substances that might discolour the concrete. The thicker the material the more water it will hold and the less frequently it will require wetting. During the curing period, it should not be allowed to dry out and when stored it should be completely dried to prevent mildew.

Sand Curing: Wet clean sand can be used provided it is kept wet throughout the curing period. It should be thick enough to hold water uniformly over the entire surface to be cured.

Burlap material for concrete curing.

Plastic film for concrete curing.

Application of curing compounds.

Plastic Film: This is available in black, white and clear and according to ASTM C171 it should have a minimum thickness of 0.10mm. White plastic minimizes heat gain while black or clear plastic is advantageous in cold weather. Care needs to be taken to avoid any tearing of the plastic and it should be noted that plastic can cause temperature variations which can result in a mottled appearance to the surface of the concrete. The mottled appearance can however be minimized or prevented by occasional flooding under the plastic. A combination of plastic film bonded to an absorbent material helps to retain and more evenly distribute the moisture and have been effective in reducing mottling. Plastic film needs to be weighted to ensure it maintains contact with the surface and wrinkles in the plastic need to be avoided.

Liquid membrane-forming compounds: There are several liquid membrane-forming compounds specially formulated for curing concrete and can be clear or pigmented. Their suitability should be investigated taking into consideration their moisture-retention capability. Curing compounds should conform to AS3799- Liquid membrane-forming curing compounds for concrete, and particular care should be taken in the selection of any compound taking into consideration its compatibility with any intended subsequent applied finish or covering. (Australian Standard, 1998 / 2018).

This is by no means an exhaustive guide to curing or a list of curing methods and there is a lot of additional information available from various sources and industry bodies. However, it must be remembered if concrete has been placed, compacted, and cured properly these aspects will contribute greatly to the satisfactory development of overall strength and durability of the finished product.

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BarChip macro synthetic fibre.

BarChip Inc.

OUR VISION

BarChip has a simple vision - revolutionise the world of concrete reinforcement. For over 100 years the technology of concrete reinforcement has barely changed. We set out to create a new reinforcement for the 21st century. We created BarChip synthetic fibre reinforcement.

OUR PROCESS

We believe that long term business relationships can only be sustained by a commitment to provide the highest quality products and services. We make sure to understand your concrete, know the performance requirements and work with you to get the right design and the right performance outcomes.

YOUR PRODUCT

When you work with BarChip you know that your concrete asset has been reinforced to the latest engineering standards. It will never suffer from corrosion. It will be cheaper and quicker to build. It will be safer and it will keep performing throughout its entire design life.

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