Concrete Curing

By Robert E. "Bob" Tobin, FACI

Without a doubt, the most neglected operation in concrete construction today is curing. Inadequate or insufficient curing is all too frequently visible in the form of unwanted or uncontrolled cracks on far too many concrete structures.

In previous issues, From Experience presented the subjects of Concrete Slump and Concrete Shrinkage. In the discussion on shrinkage, it was emphasized that cracking was a failure in the tensile strength of concrete. Therefore, it might be beneficial to devote some thought to this basic property of concrete.

The tensile strength is related to the compressive strength of concrete which is specified for most construction work. The specified compressive strength is generally stipulated to be measured by test at an age of 28 days. It is a well known fact that all concrete increases in compressive strength with age. Its strength at 3 days (see *Table 1*) is approximately 53 percent of its 28-day value. The 7-day strength is approximately 74 percent of the 28-day strength under ideal conditions of moist curing in the laboratory at 73°F. The corresponding tensile strength, according to numerous empirical studies, varies as the square root of the compressive strength. *Table 1* shows the tensile strength which corresponds to these variable compressive strengths. It is interesting to note that the tensile strength at 1 day is only about 48 percent of its 28-day tension.

Curing of concrete consists of retaining all (or as much as possible) of the evaporable water within the mix until the concrete has achieved sufficient strength to resist the tensile forces exerted upon it when it dries. Curing the concrete does not require the addition of more water to the hardened concrete. The amount of water in the original mix is far more than that needed to chemically react with the cement. It is desirable to prevent the loss of the unused evaporable water to delay shrinkage, and to give the concrete an opportunity to achieve as much tensile strength as possible. The longer that this delayed drying can be sustained, the greater will be its tensile strength to withstand restrained shrinkage. Three to seven days are recommended for most jobs.

In order of effectiveness of curing; (1) water (continuous) is best, (2) impervious covers (polyethylene) would rank second, and (3) sprayed membrane would be third. A sprayed membrane is the most popular because it is the easiest, but all too often it may not be applied heavily enough.

It is imperative that a tight seal be applied to the surface immediately after trowelling (but not the next day). The sprayed membrane should be applied to a moist surface to prevent it from being absorbed into the concrete, but the surface should not have any free-water present. The actual film-forming solids in most curing compounds are only a small percentage (around 10%) of the total liquid. If this liquid is not applied in a sufficient amount, or if the coverage is non-uniform, the concrete may not be adequately cured. At least two spray applications at right angles are suggested so that twice as much liquid is applied as the manufacturer recommends. The double application also tends to produce a more uniform membrane thickness. A contractor on a large building job commented that if two coats were better than one, he was willing to try three. The absence of cracks in his building, to this day, still shows the wisdom of his thinking.▪

The author, Bob Tobin, is a retired Structural Engineer in Los Angeles. He has been involved with concrete since graduation in 1938. This now adds up to 65 years of "experience."

Table 1

Approximate Concrete Strengths at Various Ages									
Age	% f'_c	2000 psi		3000 psi		4000 psi		5000 psi	
Days		f_c psi	f_t psi	f_c psi	f_t psi	f_c psi	f_t psi	f_c psi	f_t psi
1	23	460	144	690	176	920	203	1150	227
3	53	1060	218	1590	267	2120	308	2650	345
7	74	1480	258	2220	316	2960	365	3700	408
28	100	2000	300	3000	367	4000	424	5000	474
90	113	2260	319	3390	390	4520	450	5650	504
365	118	2360	325	3540	399	4720	460	5900	515

Specified 28 Day Compressive Strength = f'_c
Compressive strength = f_c
Tensile strength = 6.7 $(f'_c)^{1/2}$ (from ACI 318 Building Code)