INDUSTRY RECOMMENDATIONS

for

EXTERIOR CONCRETE FLATWORK

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Revise d 09 2018

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FORWARD

The industry recommendation has been assembled for reference by builders and contractors of exterior concrete flatwork.

Concrete is the world's most versatile building material. Concrete is man made and consists of Portland cement, coarse aggregate, fine aggregate and water. Admixtures and additives are usually added to impart various properties to the concrete. Concrete that is carefully proportioned, mixed, delivered, placed, finished, cured and jointed will provide the greatest quality for the owner. Once the concrete is constructed and accepted, the owner should provide routine maintenance to assure long term satisfactory performance.

Sidewalks, driveways and patios are usually constructed with a minimum thickness of 3 ½ inches (the normal depth of 2 x 4 lumber commonly used for forms) of air entrained concrete. They should support the loads created by automobiles and foot traffic provided the subgrade support is adequate.

By far the two most critical aspects of sidewalk, driveway and patio concrete performance are surface durability and absence of random cracking. Excessive water additions to concrete mixes will adversely affect the performance of concrete. Proper and adequate curing immediately after the finishing operation is an essential component in flatwork surface durability.

Concrete is proportioned with an air entrained admixture to provide microscopic voids within the concrete to relieve the expansion of water in the hardened concrete pores when it freezes and changes to ice (water increases 9 percent in volume when it is transformed into ice). Concrete containing an adequate entrained air void system is capable of withstanding severe exposure conditions. Critical periods of exposure occur when freezing takes place following saturation of the concrete by rain or by melting of snow. This same critical condition may also occur when snow and ice is changed to water by deicing agents and the temperature is below freezing.

Proper construction procedures are vitally important to producing durable concrete flatwork. Since the surfaces of concrete are subject to deterioration first as discussed earlier, they need to be properly finished to assure durability. Air entrainment must be maintained at the surface to provide voids necessary to relieve the expansion stresses of water freezing and changing to ice. Therefore, the surface must be brought to specified grade and finished with the least amount of manipulation. Every movement of the strike-off, the bull float, the straightedge and all hand tools can remove some of the surface entrained air simply by rupturing the air bubbles. The most durable surface results when these finishing operations are minimized. For best results, concrete surfaces should be struck off, bull floated, and textured with the minimum number of applications for each operation. Power floats should never be used on concrete that will be exposed to water and freezing as they tend to remove the surface air voids and thereby reduce the durability of the surface.

Joints are constructed in slabs on grade to control the location of cracking due to normal drying shrinkage. In order to achieve the intended objectives of joints it is important to plan their locations prior to placement of concrete and to create the joints with the proper timing and sufficient depth. Proper location, timing and depth of joint construction should assure satisfactory performance without the occurrence of unsightly and unwanted random cracks. Joint should be placed 24-36 times the thickness of the slab (10' to 18' normally) and at a 1/4" to 1/3" of the slab depth. Saw cuts should be done within 4 to 12 hours of final setting of the concrete.

Exterior concrete, mainly sidewalks, driveways and patios, is exposed to loading and weathering. Normally, concrete in this environment as described herein will perform satisfactorily with minimal care. However, conditions can occur which may affect the concrete's performance and life expectancy. Flatwork constructed with properly designed concrete with a water-cementitious ratio of 0.45 or less, 4500 PSI design strength, having an air content of 6 (± 2) percent entrained air, properly constructed and cured has provided years of durable performance under the most adverse exposure conditions.

There are several things the owner can do to avoid these critical conditions which affect the durability of concrete. Anything that will limit the amount of water on the concrete will enhance its durability. Something as simple as eaves, troughs and downspouts or sloping landscape away from the installation is effective. In addition, surface sealing compounds (sealers) applied to the concrete will limit the amount of liquid penetration into the concrete. Sealers are recommended for new concrete before the initial exposure to freezing to provide additional assurance of adequate performance. Application of the sealer should not occur until after the 7 days of water or membrane curing and additional 30 days of air dry curing the concrete. Flatwork placement and the coverage will vary based on the material; follow the manufacturer's instructions. Accelerators do not speed up the curing process they only speed up the compressive strengths of the concrete. 37 days of overall curing is still needed before the first freeze-thaw cycle and concrete may need to be protected until that is achieved.

The recommendation presented here is based upon current national standards for materials and construction of exterior concrete flatwork. Further discussion and reference to industry recommendations on exterior concrete flatwork can be found at American Concrete Institute (ACI), Portland Cement Association (PCA) and National Ready Mixed Concrete Association (NRMCA) research, reports and commentary. Adherence to local, state and national code standards is the responsibility of the user of this document.

Description. This work shall consist of flatwork composed of plain Portland cement concrete constructed on a prepared subgrade in accordance with these specifications and in reasonably close conformity with the lines, grades, thicknesses and typical sections shown on the plans or established by the Architect or Engineer.

Material. Material shall be:

Concrete:	Air entrained concrete at 6% (±2%) with a minimum compressive strength of 4,500 psi (at 28 days) and a maximum water-cementitious material (w/cm) ratio of 0.45 proportioned in accordance with ACI 318-08 and produced in accordance with ASTM C 94. If supplementary cementitious materials are used (fly ash or ground granulated blast furnace slag), the maximum percentage of cement replacement by weight shall be limited to 50% for slag and 25% for fly ash. Use of chemical admixture additives per manufacturer's recommendations under ASTM C 494 is permitted to achieve desired properties for fresh and hardened concrete. A water reducing admixture is typically necessary to achieve the desired workability. Aggregates used in the concrete mixture shall be approved for use by the New York Department of Transportation (NYSDOT) for use in Portland cement concrete and shall conform to the requirements of ASTM C33.
Curing Material	Liquid Membrane-Forming Curing Compounds - ASTM C 309, Type 1, Class A having a minimum solids content of 25% or Sheet Materials for Curing Concrete - ASTM C 171, 4 or 6 mil polyethylene sheeting, waterproof paper, wet burlap with plastic backing.
Isolation/Expansion Joint Material	ASTM D 994, ASTM D 1751, ASTM D 1752 – Bituminous type rubber, cork or recycled PVC boards
Sealer	Good commercial sealers are available from various concrete material suppliers. Always apply the sealer according to the manufacturer's recommendations. Application of most Penetrating sealers should not occur until after the 7 days of water or membrane curing and additional 30 days of air dry curing the concrete.

Equipment. Equipment shall be as follows: Equipment for finishing concrete shall be capable of consolidating and finishing the concrete. A vibratory screed or a hand strike-off screed may be used. Side forms shall be straight and of a depth equal or greater than the specified thickness of the flatwork. Wood forms are permissible and generally may consist of commercially available 2 x 4's, where 3 ½ inch thickness is permitted.

Finegrading of Subgrade. After the subgrade has been shaped to drain and compacted, the areas on which the flatwork is to be constructed including the areas that will support the side forms shall be cut to the plan elevation and shaped to drain. Standing water should be removed from the placement and concrete no placed-on water, concrete should be placed on clean well compacted coarse aggregates.

Ordering. To avoid yield discrepancies, the user needs to understand that the volume of hardened concrete may be, or appears to be, less than expected due to waste and spillage, over- excavation, spreading forms, some loss of entrained air, or settlement of wet mixtures, none of which are the responsibility of the producer. The volume of the concrete, expressed in cubic yards, should be calculated by the contractor and provided to the concrete producer. The strength of the concrete, type of cement, desired slump, maximum size of coarse aggregate, and the use of chemical admixtures and supplementary cementitious materials, or both, should be stated. The order should give the time of the first load and, if required, the time between loads. Any special requirements for the concrete, such as chemical admixtures or fiber reinforcement, should be noted when the order is placed. Day-to-day variations in materials; placing, finishing, and curing techniques; and weather conditions can produce4variations in the color of the finished concrete. Although these variations may not affect the performance of the concrete, they may be aesthetically undesirable.

Thickness. Thicknesses of driveways, patios and walks shall be in compliance with the local building codes. If there is not a thickness required by code, the minimum thickness shall be 3 ½ inches, the nominal width dimension of a 2 x 4 standard size wood board generally used for forms. Between the street pavement and the sidewalk, codes usually specify a minimum thickness of 6 inches for residential driveway approach flatwork. Most codes require 4 inches of thickness for public sidewalks with an additional 2 inches (a total of 6 inches) across driveways.

Contractor. The contractor responsible for performing the work shall be an American Concrete Institute (ACI) Certified Concrete Flatwork Finisher or an National Ready Mix Concrete Association (NRMCA) Residential Concrete Flatwork Finisher for residential applications and licensed by the locality where the work is being performed. The size of the crew shall be sufficient to perform all installation steps in a timely manner and not jeopardize the integrity of the material as intended.

Placing Concrete. Within 90 minutes after cement and water are thoroughly combined (minimum 70 revolutions for truck mixed concrete), deliver and completely discharge concrete. In hot weather, or under conditions contributing to rapid stiffening of the concrete a set-retarding or water-reducing and set-retarding admixture could be used, or a time less than 90 minutes may be needed for complete discharge. The concrete shall have a slump between 3 to 5 inches and shall be deposited on the grade in a manner that requires as little rehandling as possible. The slump of the concrete can be increased with the use of chemical admixtures. It is strongly recommended that water is not added to the concrete on-site. If water is added on-site, the amount of added water should not exceed 1 gallon per cubic yard of concrete and shall not exceed the maximum water-cementitious ratio (0.45). A one time addition of water is permitted at the beginning of the placement and no water should be added after the initial adjustment within the specified water-cement ratio. Any added water should be measured by the truck water meter. The concrete must be sufficiently mixed after the addition of water or admixtures. Water added at the jobsite in excess of the maximum water-cementitious ratio (0.45) to ease placement may result in long-term durability problems. The subgrade shall be free from frost when concrete is deposited.

Consolidating and Finishing. The flatwork shall be screeded, or struck off, by an approved vibratory or hand operated wood or metal strike-off screed. Level the concrete using a bull float to embed large aggregate and smooth the surface prior to any presence of bleed water (upward migration of water to the surface caused by settlement of aggregates and cementitious ingredients). Bleed water must then be given time to disappear before any further finishing operations. Finishing any water back into the concrete may result in surface durability problems.
Before the concrete has taken its initial set, the edges of the flatwork along each side shall be worked with an approved tool and rounded to a radius of one-fourth inch, or greater.

The flatwork shall be textured to provide a satisfactory surface. A medium to fine transverse broom texture generally will provide a uniform slip-resistant texture; swirl finishes are not recommended due to the additional surface manipulation required. Air entrained concrete may be floated & not troweled. Troweling reduces traction and results in poor durability under freezing & thawing exposure due to reduced air content at the surface

Never sprinkle water or cement on concrete flatwork while finishing it including the application of water on the broom surface. This will create a weakened surface and reduce the durability and wear-resistance of the surface.

Joints. Joints shall be constructed of the type, dimensions, and at locations specified. Joints shall be continuous for the full width or length of the flatwork without offsets. Joints may be constructed by sawing or they may be hand formed. Joints shall be created as soon as possible.

(a) Contraction Joints - Longitudinal. If the 3 ½ inch thick driveway or patio flatwork exceeds 10 feet in width, a longitudinal joint shall be constructed along the flatwork centerline. Jointing shall be done as soon as possible, but not later than the following day. Longitudinal jointing shall be a minimum depth of one-third of the specified flatwork thickness.

(b) Contraction Joints - Transverse. Transverse joints shall be constructed to a minimum depth of one- fourth of the specified flatwork thickness. Unless otherwise shown on the plans, joints shall be constructed at a spacing in feet at two (2) to three (3) times the inches of slab thickness (10.5 feet maximum for a 3 ½ inch slab). The long dimension of the resultant flatwork slab should not exceed .5 times the short dimension. This will govern the maximum spacing of transverse joints in narrow walks.

(c) Construction Joints. Construction joints shall be constructed at the end of each day's work and whenever necessary to suspend work for more than 30 minutes. Construction joints shall be plain butt joints without load transfer devices or keyways.

(d) Isolation Joints. When the new concrete placement will be placed adjacent to existing concrete or other existing construction, an isolation joint should be used to permit horizontal and vertical movement between the new concrete and any surface that it abuts.

Curing. ***Immediately*** after the finishing operations have been completed, the concrete shall be cured by spraying a uniform application of curing membrane compound in such a manner as to provide a continuous uniform film without marring the texture of the surface. This membrane is intended to keep moisture in the concrete so that it can develop properties necessary for long-term durability and strength. The curing material shall be applied in accordance with the manufacturer's coverage rate. To ensure adequate coverage the curing material shall be applied in two directions at right angles. White pigmented curing materials should be used in the summer months for heat reflectance. Pigmented curing compounds are also recommended so the applicator can visually see that complete coverage is being obtained. Curing material shall be thoroughly agitated immediately prior to use.

Curing may also be accomplished by means of water curing with wet burlap cloth, waterproof paper and polyethylene sheeting as well as insulated blankets during cold weather. Curing shall be applied as soon after the finishing operations as possible without marring the surface texture. Curing shall be continued for a minimum of seven days**.** Poor and inadequate curing practice is one of the primary contributing factors to surface durability failures. With proper curing, concrete becomes stronger more impermeable, and more resistant to abrasion and freezing and thawing stresses.

The need for adequate curing of the concrete cannot be overemphasized. Curing has a strong influence on the properties of hardened concrete such as durability, strength, watertightness, abrasion resistance, volume stability, resistance to freezing and thawing, and resistance to deicer salts.

Concrete slabs should receive at least 30 days of air-drying time after the 7 day moist-curing period and before exposure to deicing chemicals. Non-chloride accelerators speed up compressive strength gains but not cure time. The exact length of time for air drying will vary with climate and weather conditions. The application of deicing chemicals should be avoided during the first winter following placement.

Placing and Curing Concrete During Hot Weather.
During hot weather, most frequently encountered in the summer, additional precautions need to be taken to ensure proper placing, finishing and curing of the concrete. High temperatures will accelerate the setting time, requiring more rapid finishing. Use of chemical agents and/or supplementary cementitious materials will aid in extending the set time. Advance timing and scheduling to avoid delays in delivery, placement and finishing is essential.

During sunny, windy, low humidity weather conditions, the concrete surface can rapidly lose moisture rapidly and crack prior to hardening. This type of cracking is referred to as plastic shrinkage cracking. When weather conditions occur that can cause plastic shrinkage cracking, the surface must be kept moist either by a fog spray of water or the application of a monomolecular film per manufacturer’s instructions to retard the moisture evaporation until the curing is applied. This water or film is not to be worked into the concrete but simply rest on the surface until it has evaporated. Use of synthetic fibers in the concrete mixture also reduces the formation of plastic shrinkage cracks.

Rapid curing and protection is critical in hot weather conditions. Do not allow the surface to dry out by delaying this crucial step. The Contractor shall be responsible for protecting the concrete. The above requirements are minimum requirements only.

Placing and Curing Concrete During Cold Weather.

Concrete must be properly protected when the air temperature is 40°F or below. The concrete should be protected immediately after placing in the forms and the protection shall provide a concrete temperature between 50°F and 80°F. The subgrade or subbase upon which concrete is to be placed shall be entirely free from frost when the concrete is deposited.

The concrete shall be cured by maintaining the surface temperature between 50°F and 100°F for a period of not less than seven days. Insulating blankets are readily available to maintain this temperature range. To prevent thermal cracking at the end of this curing period, the temperature shall be reduced at a rate not to exceed 20°F in 24 hours until it is within 20°F of atmospheric temperature. If the surface temperature drops below 50°F, the protection period shall be extended. Sufficient high-low thermometers shall be furnished and installed by the Contractor in such a manner that the surface
temperature of the concrete may be readily determined.

For slabs placed in the fall in cold weather areas, curing blankets or plastic sheeting shall be used instead of curing compound. Curing compounds may trap excess water in the slab after the initial curing period. To prevent surface scaling, 30 days of air-drying shall be provided after the cure period before subjecting new concrete to deicing salts and freeze-thaw cycling. ACI 322 states that application of deicing chemicals should be avoided during the first winter following placement.

Inspection. When inspection of the concrete mixture and/or installation operations is to be conducted, the individual and firm shall be qualified by either a local or national organization (American Concrete Institute certifications, CCRL approved test facility) specific to those services conducted. ACI318-11 Section 5.6.1 requires the testing agency performing acceptance testing of concrete to have minimum proficiency in compliance with ASTM C1077 Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory inspection. All reports of acceptance tests are required to be provided to the licensed design professional, contractor, concrete producer, and when requested, to the owner and the building official. Testing must be performed in accordance with ASTM C-31 maintaining test cylinders at 60 to 80 degrees in a moist condition. Cylinders that are not fabricated and tested in strict conformance to the specification shall not be used for evaluation of strength and acceptance.