Concrete Placements Exposed to Rain

Damage types, protection options, and repair methods

by Ronald L. Kozikowski, Scott M. Tarr, Kevin Rowswell, and Bruce A. Suprenant

Concrete contractors in some parts of the country are adept at placing concrete in rainy weather. Those in the Pacific Northwest must deal with an extended wet season. Contractors in Miami must be prepared for short bursts of intense rain with little to no notice. Flatwork placements are driven by the construction schedule, so concrete contractors don't have the luxury of waiting for a 100% probability of clear skies. That's why experienced contractors have developed means and methods for dealing with concrete placements that occur during a rain event.

With rain comes risk, but having a sound awareness of situational options, having established protection plans, and ensuring that the right supplies are ready for use allow risk to be managed effectively. This article discusses the properties of rainstorms and potential types of damage that can occur. It also provides situational protection options for managing placements exposed to rain. Further, it discusses repair methods that can be used if superficial damage occurs despite protective actions. The content of this article can be used as a guide to help contractors establish a rain protection plan that prepares finishers to take actions that minimize the potential need for repair.

Rainwater and Bleed Water

Addressing rainwater concerns can be complicated, but contractors, designers, and owners should recognize that in many ways, **rainwater is similar to bleed water**. Neither should be intermixed into the body of the concrete or worked into the surface of the concrete.

Other than air, water is the lightest component of the mixture and is forced to the top of the slab during the bleeding process. Rainwater has a different source, but water standing on top of plastic concrete that has already been placed and floated will not harm the concrete if the water can be effectively removed prior to final finishing.

ACI's "Concrete Craftsman Series: Slabs on Ground"[1] has a "Rained-on surfaces" section that helps finishers prepare for rain. The section makes the same comparison to bleed water and rainwater: "Freshly placed concrete that has been struck off and bull floated is not very permeable. Note, for instance, that bleed water collects on the surface instead of soaking back into the concrete. As long as no attempt is made to further finish the concrete while there is free water on the surface, the strength and durability are unlikely to be affected…"[1]

Properties of Rainstorms

Timing, duration, intensity, and volume are the potentially harmful properties of rainstorms. Timing is the most influential factor. If rain falls on a slab during the placement stage, damage is likely because excess water may be intermixed with concrete as workers walk through, consolidate, and strike off the plastic concrete. If rain falls on a slab after the concrete is placed and floated, there should be no damage if the rain stops in time for the contractor to remove the excess surface water prior to final finishing. The shorter the storm's duration, the better chance that excess water can be removed prior to finishing. Lastly, if rain falls on a slab shortly after finishing operations are complete, then the slab has likely stiffened enough to resist damage. In this case, rain may be beneficial because it will contribute to curing.

Intense rain has the potential to wash away surface paste. Some contractors choose to place plastic sheets on sloped surfaces to minimize loss of paste. However, many contractors allow water to collect and pond on horizontal surfaces as the standing water cushions the blows from rain droplets. As noted previously, both excess bleed water and rainwater must be removed prior to final finishing operations.

The volume of rainwater falling on a slab is the least of the four concerns; however, large volumes can pose issues from a labor standpoint, and large volumes of flowing water can wash away excess surface paste if not handled properly.

Potential Damage Types

Loss of surface paste

A highly intense storm or a high volume of rainwater passing over the surface of a slab can remove an excessive amount of paste. A substantial amount of surface aggregate is thus exposed (Fig. 1), and it will be difficult to rework enough paste to the surface to provide an acceptable finish.

Low compressive strength

Low compressive strength may result if rain occurs during concrete placement and workers intermix the rainwater with the fresh concrete, thus increasing the water-cement ratio (*w/c*). However, we are not aware of any low-strength issues as the result of rain collecting on the surface of plastic concrete that has already been placed and vibrated.

Weakened or marred surface

If the timing and duration of a rainstorm permits finishers to remove standing water prior to final finishing, a weakened surface should not be a concern. However, if the conditions prevent removal of standing water before final finishing operations, the surface could be weakened as shown in Fig. 2(a). Fortunately, as shown in Fig. 2(b), this type of damage is very shallow (typically 1/8 in. [3 mm] or less) and can often be addressed by repair options discussed later in this article. Slab surfaces may also be marred by protective covers, as shown in Fig. 2(c), or impacts of rain droplets, as shown in Fig. 2(d). However, in both cases, the damage is generally very shallow and repair is possible.

Fig. 1: An intense rainstorm can cause excessive loss of surface paste

Protection Options

Planning is a critical part of providing protection against damage during a rain event. To simplify planning, we have broken the placement and finishing operations into four stages: placement, waiting/dormancy, final finishing, and curing (shown in Fig. 3). The situational protection options for a rain event vary with these stages.

Stage 1: Concrete placement

Stage 1 involves the placement, screeding, and floating of concrete. This is the only stage of the placement where rainwater may get intermixed into the body of the slab. Mixing water into the body of the slab may create strength concerns due to localized increases in *w/c*. Figure 4 shows an example from a placement where a rain event occurred during Stage 1. In this case, the most viable protection plan is to stop placement, install an emergency bulkhead (Fig. 5), and evaluate the affected concrete.

(a) (b) (c) (d)

Fig. 2: Examples of concrete exposed to rainwater after it has been placed and floated: (a) a weakened surface; (b) shallow depth of the weakened surface; (c) surface marring caused by a protective cover; and (d) pockmarks caused by rain droplets

Stage 2: Waiting period/dormancy

A rain event occurring during Stage 2 is much more favorable than one occurring during Stages 1 or 3. As discussed previously, once concrete is placed and floated, it is not very permeable. Rainwater will not be absorbed into the slab. A protection plan for Stage 2 will include considerations for protecting washout of surface paste, removal of excess water, and maintaining a dry slab. There is always a chance that the duration of the storm may extend beyond the dormancy period and impact the slab's finish. However, the dormancy period typically extends several hours, allowing time for the rain to stop and finishers to remove excess water prior to finishing.

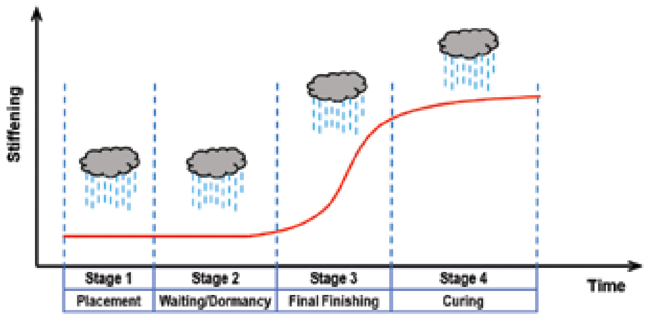

Fig. 3: The stages of concrete placement and finishing are correlated with concrete stiffening

Fig. 4: Freshly placed concrete with rainwater puddles

Fig. 5: Installation of an emergency bulkhead

Covering the slab may not be the best option. In cases of intense rain or on sloped surfaces, covering the slab with plastic sheeting can help prevent the loss of excess surface paste from the surface of the slab. In other cases, covering a slab can be problematic. The concrete may be too plastic to walk on without damaging the surface; and items projecting from the slab such as anchor bolts, reinforcing bars, and plumbing often create punctures in the plastic and make it difficult to spread.

Sheets of plastic are rarely large enough to cover an entire placement, so it is likely that water will find its way onto the concrete surface at the seams between sheets. Further, water will shift to the concrete during the removal of the plastic sheets, and this water must be removed from the concrete prior to finishing.

Most importantly, we have found that plastic sheeting traps heat and limits the cooling effect of exposed pools of water. As a result, the setting time of a covered slab will be about 10 to 20% faster than the setting time of an exposed slab, reducing the time available for removing water prior to final finishing.

Removing water from the surface is critical. Timely removel of water from the surface of the slab is critical to success of the placement. The goal is to remove rainwater as quickly as possible without removing excess surface paste. A loss of some surface paste is expected, however, and removal of the uppermost paste layer that was in contact with standing water may be beneficial.

We have observed several different methods of water removal. Finishers may find the following summary of alternatives helpful when preparing for future projects or developing a rain protection plan.

Water removal tools include:

- Squeegees;
- Polystyrene foam insulation boards;
- Garden hose;
- Old compressor hose; and
- Leaf blowers.

If a garden hose is used, it should be filled with water to make it heavier and able to maintain better contact with the slab surface. Old compressor hoses offer the benefits of being more flexible and heavier than garden hoses. Based on the number of slab projections and the placement layout, a combination of these tools may be needed. For example, dragging a hose over the slab will cover the widest amount of area at once; however, in congested areas containing projecting obstructions, squeegees or foam boards will be easier to maneuver over the surface (Fig. 6).

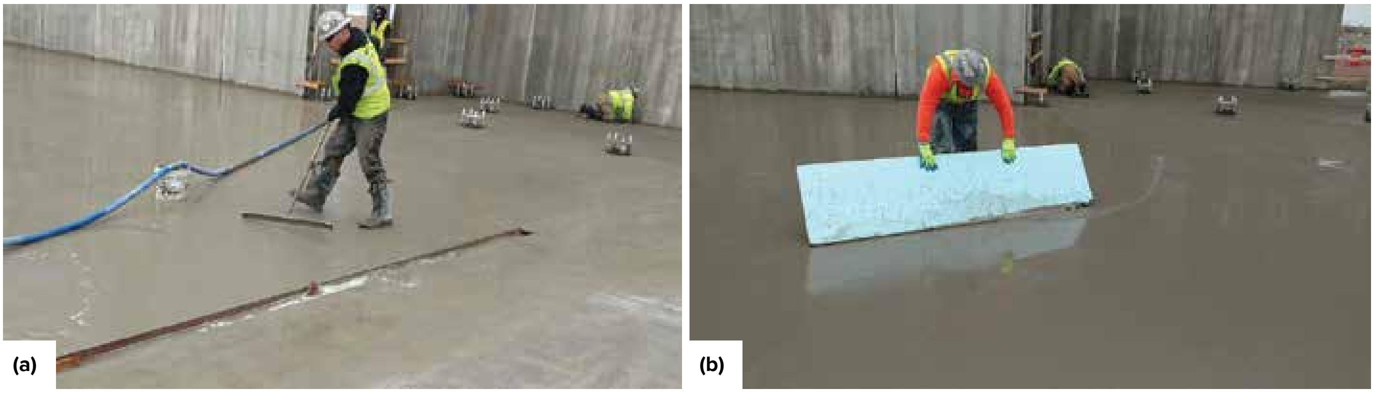

Fig. 6: Removal of rainwater from concrete surface: (a) using a squeegee and hose; and (b) using a foam insulation board

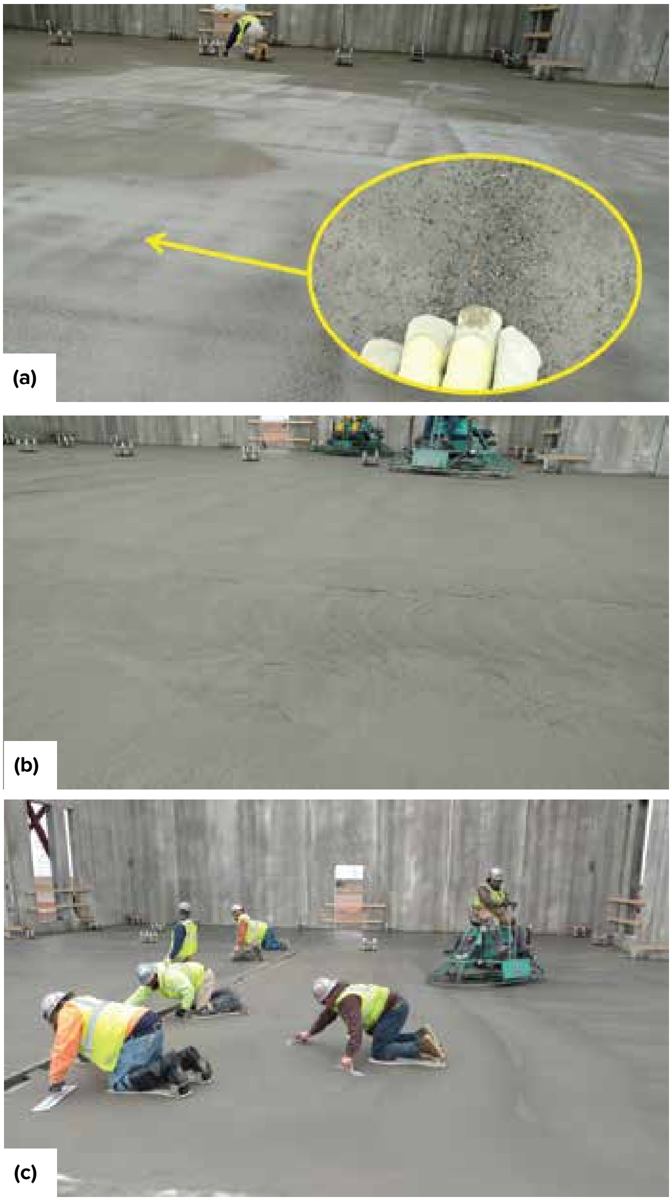

Fig. 7: Concrete slab surface: (a) after removal of rainwater, with a close-up showing the sandy appearance of the surface; (b) after the first pass of a ride-on trowel; and (c) during final finishing

In our experience, we have found that a foam board (Fig. 6(b)) is often the best tool, as it covers more area than a squeegee and can be more easily worked around penetrations than a hose. The smooth texture and relatively soft material in the board also help minimize the amount of surface paste lost during water removal.

Typically, after water removal, the slab surface may appear slightly sandy, as shown in Fig. 7(a). Figure 7(b) is a view taken at the same location after the first pass of a ride-on trowel machine and shows how additional paste is easily worked into the surface. Figure 7(c) shows progression of the finishing process and how a hard/dense finish was created on the previously rain-covered slab. Note the drying surface of the slab (Fig. 7(a)) prior to final finishing.

As mentioned previously, working with rainwater on a slab is no different than finishing a slab with excess bleed water. An important consideration is that the ambient humidity after a rain event is often high and does not support quick water removal and stiffening of the slab surface. If additional rain is forecast, finishers may find it helpful to use portable leaf blowers to help remove excess water and stiffen the surface more rapidly in preparation for final finishing and to beat an incoming storm.

Be prepared to keep water off the surface. While it is desirable to drag water off the edge of a slab to completely remove it, this is not always possible. Finishers should have pumps ready to remove water as it is directed away from the placement. Figure 8 shows a unique solution that finishers might apply when they are in a bind: using dry cement or sand to create a dam around the perimeter of the placement to prevent previously removed rainwater from flowing back onto the working area. Note, however, that dry cement should never be added to fresh concrete. The dam must be placed outside of the fresh concrete and removed shortly after final finishing.

Stage 3: Final finishing

Unfortunately, if rain occurs or continues into Stage 3, only a few protection options are available to finishers. During this stage, the slab surface is rapidly stiffening and finishing operations are being conducted to flatten and densify the surface. If a light rain occurs between finishing passes, it may still be possible to rapidly remove water and air-dry the surface with blowers as discussed in Stage 2. However, if water is worked into the surface during finishing operations, it will create a weaker surface layer[2] that may require repair.

Stage 4: Curing

The most ideal timing for a rain event is during the curing stage. Generally, slabs have achieved final set after hard-troweling passes are complete. If the surface has sufficiently hardened and the rain is not intense enough to remove paste, rain will be beneficial to the curing process. While it is unlikely that washout of the surface paste would occur at this point, finishers could be prepared in the event of a very intense rain by having plastic sheets ready to cover a freshly finished surface.

Rain Slab Repair Options

Unfortunately, not all rained-on slabs are successfully finished. If substantial intermixing of water occurs and the damage impacts the concrete full-depth, slab removal may be necessary. If the timing, duration, or intensity of the rain event results only in damage to the concrete surface, it may be possible to repair the surface. The affected layer is very superficial in most cases and several repair options are available. The solution should be developed based on the depth of the damage and the acceptance criteria for the final surface appearance.

In addition, if repair is necessary, the contractor needs to consider what is going on top of the slab. Review Division 9 (floor coverings) in specifications and identify what level of repair is needed for the type of floor covering applied. For example, carpet or thickset tile will require less remediation than thinset tile or a polished floor application.

Common repair approaches follow.

Fig. 8: Finishers used dry cement to create a dam outside of the fresh concrete placement and prevent previously removed rainwater from flowing back onto the working area. The dry cement was removed shortly after final finishing

Application of surface hardener/densifier

Application of a penetrating reactive silicate-based hardener/densifier is an economical remediation approach if a rain event resulted in a surface that is less wear-resistant than adjacent areas that weren't affected by rain. The effectiveness of a reactive silicate treatment depends on the amount of calcium hydroxide available for the reaction. When portland cement concrete cures, two basic compounds are formed: calcium silicate hydrate (CSH) and calcium hydroxide. The formation of these compounds depends on the effectiveness of the curing (retention of moisture within the concrete as well as at the exposed surface of the concrete). While a hard-trowel densified surface will help retain moisture within the concrete, for example, it does very little to retain moisture and "cure" the exposed surface. In general, when effective curing is provided, CSH is the compound that provides the strength and hardness of the concrete, while calcium hydroxide is a benign by-product. Whether sodium, potassium, lithium, or any other type of silicate-based treatment is used, it is the silicate portion of the product that reacts with available calcium hydroxide in the presence of moisture. The reaction forms additional CSH, thus "hardening" and "densifying" the concrete surface (Fig. 9). The depth of the reaction depends

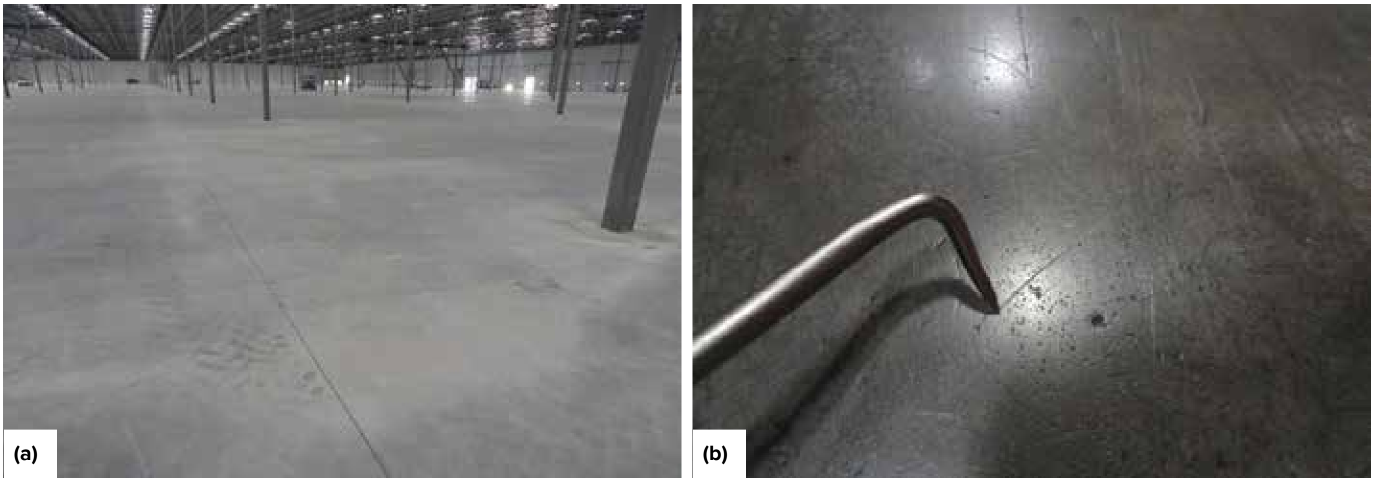

Fig. 9: Discolored (whitish) concrete slab (on the left) and the same slab after an application of a silicate hardener (on the right)

on the depth of penetration of the silicate product. Typically, silicates penetrate less than 1/2 in. (13 mm), but this is enough to repair weakened rain-affected surfaces that are superficial in nature.

Application of a penetrating reactive hardener can be an economical and effective repair approach if the surface was well-cured and sufficient calcium hydroxide is present. For a rained-on slab repair, the recommended approach is to conduct a series of small 4 x 4 ft (1.2 x 1.2 m) mockups using various surface-hardener products. Based on the performance of the mockups, the best product can be selected and applied to the entire rain-affected area.

Surface grinding

Grinding is a long-accepted approach for repairing concrete surfaces. The American Concrete Pavement Association (ACPA)[3] and others[2,4] recommend grinding as an acceptable means for repairing rain-damaged slabs. While some engineers and owners may question the durability of slabs that have been repaired by removing a thin layer of paste, ACPA indicates that diamond grinding has been successfully used to repair rain-damaged surfaces exposed to winter conditions and many years of truck traffic.[3] Compared to exterior pavements, the exposure conditions and traffic on interior floors is typically less harsh. In cases where slabs are exposed to hard-wheeled forklift traffic, mockup sections can be used to evaluate the repaired surface. Abrasively removing the weakened layer of paste will result in a surface that is as hard and wear-resistant as adjacent surfaces that did not experience the rain event. Further, equipment and technologies have been developed over the past decade to provide a "diamond-polished" slab surface that is attractive and durable. However, we recommend that a small area is initially treated for owner approval prior to grinding an entire slab. Figure 10 shows a mockup section where the superficial weak layer was removed, exposing the hard and dense concrete layer below.

Fig. 10: An example of a ground mockup section where a superficial weak area was removed, exposing dense concrete layer below

The surface can be subjected to successive passes of grinding equipment. Each pass or operation can be performed with progressively higher "grit" of diamond-impregnated pads. Like sandpaper designations, the higher the grit, the less material is removed and the finer and more polished the surface becomes. If the depth of the weakened surface is very minimal, grinding can start with 200-grit pads to restore the surface hardness and wear resistance. If the weakened layer is deeper, the initial grinding passes should be made using 100-grit (or lower) pads, so that more material is removed. Later passes can use 200- and 400-grit pads. It is important to determine the grit that will result in a surface smoothness and shine equal to the surrounding surface not exposed to rain. Typically, a hard-troweled surface is equal to about a 400-grit grind. Grinding passes made with higher-grit pads can result in a surface that stands out from the rest of the floor.

Topping slab

Rain-affected surfaces are superficial and application of a thin bonded topping or overlay is another way to restore a slab surface damaged by rain. For a detailed discussion of topping slab options and design, refer to References 5 and 6.

Proprietary products are available for bonded overlays where the top 1/2 in. or less of the surface is being restored. The manufacturer's installation instructions should be followed carefully. It is recommended that small 4 x 4 ft mockup sections using different products be evaluated prior to full-scale repairs. Mockup sections are helpful for investigating surface preparation, bond strength, and appearance of the final product.

Final Thoughts on Mitigating Risks

As this article discusses, concrete contractors need to be aware of the risks of rain events. Being proactive, understanding the options based on the timing and duration of a rain event, and developing a wet weather plan are keys to success. When preparing for placements in adverse weather conditions, we recommend that contractors:

- Use the preplacement meeting to discuss how the construction team will handle a rain event;
- Work with the project's design professionals to develop an approved bulkhead plan, along with doweling requirements and options;
- For elevated flatwork projects, develop a plan for removal of surface water and controlling splatter to avoid damage to the finishes on nearby vehicles, equipment, and building elements;
- If possible, ensure that finishers have at least 3 ft (1 m) of work space adjacent to placements;
- When placing under a metal deck, be prepared for rainwater to leak through the decking and onto the placement. Preparation should include access to a means for diverting or removing rainwater from the decking above;
- Recognize that a very narrow window of time may be available for removing rainwater and completing finishing operations. When there is a chance of rain, contractors may need to consider having additional finishing equipment available to complete final finishing operations as quickly as possible; and
- When trying to complete a placement prior to a rain event, clearly communicate with the concrete supplier and verify that required delivery rate can be achieved to finish the placement on time.

There is very little standardized information available on preparing for wet weather concreting or how to address rain-damaged slabs. We hope that the situational considerations discussed in this article will enable construction teams to develop their wet weather plans and help them understand practical repair options if damage does occur.

Acknowledgments

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Selected for reader interest by the editors.

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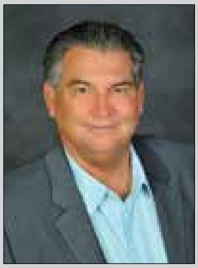

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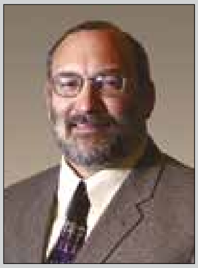

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