Industrial Slab-on-Ground Joint Stability

What It Is, What It Isn't, How Much Is Needed, and How to Get It

By Scott M. Tarr

When problems occur in industrial concrete slabs-on-ground, the weakness is often at the joints. Some experts suggest the way to get a better floor is to design a system without joints. With today's emphasis on value engineering, however, slab designers seldom have a budget that can fund construction of a jointless floor. Frankly, few operations require such specialized floor design and construction techniques, so the additional cost is generally unwarranted. When properly designed, constructed, and maintained, jointed slabs can provide excellent long-term serviceability.

Fig. 1: Joint spalling of an inadequately filled industrial slab joint

Fig. 2: Severe joint spalling due to lack of early repair

Joint Distress

Perhaps the most common slab-on-ground distress is joint spalling. Some degree of joint spalling can be seen on most industrial slabs that support operations using solid-tired lift trucks. As shown in Fig. 1, spalling is the chipping of unsupported vertical joint edges exposed to traffic from lift trucks with hard wheels. A typical contact pressure of 400 psi (2.8 MPa) (from midsized lift trucks with urethane casters or solid rubber tires) can cause joint spalling. If left uncorrected, spalling continues to worsen, as shown in Fig. 2. As a result, vehicle tires can wear rapidly (Fig. 3). In the most severe cases, steel-wheeled carts and vehicles apply a significant load to extremely small areas, resulting in contact pressures that can exceed 1000 psi (6.9 MPa). Under these conditions, the slab surface needs to be hardened for increased wear resistance and joints may need armor, such as steel nosing. If the system is retrofit, however, special attention is needed at the steel/concrete juncture to minimize continued spalling at that location instead of at the joint.

Spalling has also been attributed to hard wheels leaving a deflected panel edge and impacting the adjacent unloaded panel edge. While this may occur under very hard wheels with lower compressive strength concrete, most spalling is not a crushing failure. It typically results in the dislodging of sheared pieces of concrete rather than in the pulverizing or disintegration of the panel edge. Adjacent panels that deflect independently, however, indicate the joint wall is not properly supported, and spalling will occur due to shear, not impact, as the load crosses the joint.

Joint Filler Function

Spalling does not necessarily indicate slab overloading. When a hard wheel approaches the edge of a slab panel where the joint wall is unsupported, the concrete fails in shear and spalling occurs (Fig. 4). A semi-rigid epoxy joint filler provides the compressive resistance or lateral support the joint wall needs to counteract the shearing force and minimize the occurrence of spalling in lift-truck traffic areas. The term semi-rigid is used to describe industrial slab joint fillers because the material needs to be rigid enough to provide edge support yet flexible enough to accommodate some joint movement due to changes in slab temperature and moisture. Neither flexible highway joint sealers nor rigid epoxy repair materials perform effectively under these conditions. To provide proper support, the filler should also be installed to the full depth of the sawed portion of the joint or, as a minimum, extend at least 2 in. (5 cm) deep in construction and isolation joints trafficked by lift trucks.

Ideally, the filler should be installed before hard-wheeled traffic is applied to the floor, but after slabs have completed their drying shrinkage (generally 12 to 18 months). In a realistic construction schedule, this typically is not feasible. Therefore, joint filler installed prematurely will likely separate in adhesion (bond to the concrete joint face) or cohesion (splitting within the material) when the joints inevitably widen due to slab drying. Once this separation has occurred in the filler material, edge support is no longer provided, and the joints are vulnerable to spalling.

The most effective joint fillers are those with the lowest elongation or extensibility. A filler that stretches in tension as the joint widens can actually apply a tensile force to the joint wall, which slightly increases the potential for spalling. Fillers with low tensile elongation separate and, thus, signal the need for proper maintenance to minimize spalling. Additional filler should be installed in accordance with the manufacturers' recommendations.

Joint Stability

Joint stability is the differential deflection of adjacent slab panel edges when a service load crosses the joint, and it is a measure of how the joint functions under current loading conditions. More specifically, the differential deflection of adjacent slab panels affects the ability of the joint filler to perform its intended function of providing support to the joint wall. As differential deflection increases, the likelihood of filler separation and the corresponding potential for spalling increases. Therefore, joint stability can be used to estimate the risk of joint spalling.

The joint stability procedure does not measure the load-transfer efficiency (LTE) of the joint, nor does it indicate the total load-induced slab deflection (LSD). As shown in Fig. 5, LTE and LSD are measured using a device such as a Modified Benkelman Beam, supported outside the deflection basin (area influenced by the load). They can be used to determine the structural load-carrying capacity of the as-built slab, as well as to measure joint stability and the potential for spalling. While limited in its evaluation capability, however, the equipment used to measure joint stability alone is typically easier to transport to the jobsite. Any device that measures the relative change in surface elevation between adjacent panels can be used to determine joint

Fig. 3: Lift truck tire damage due to widespread joint spalling

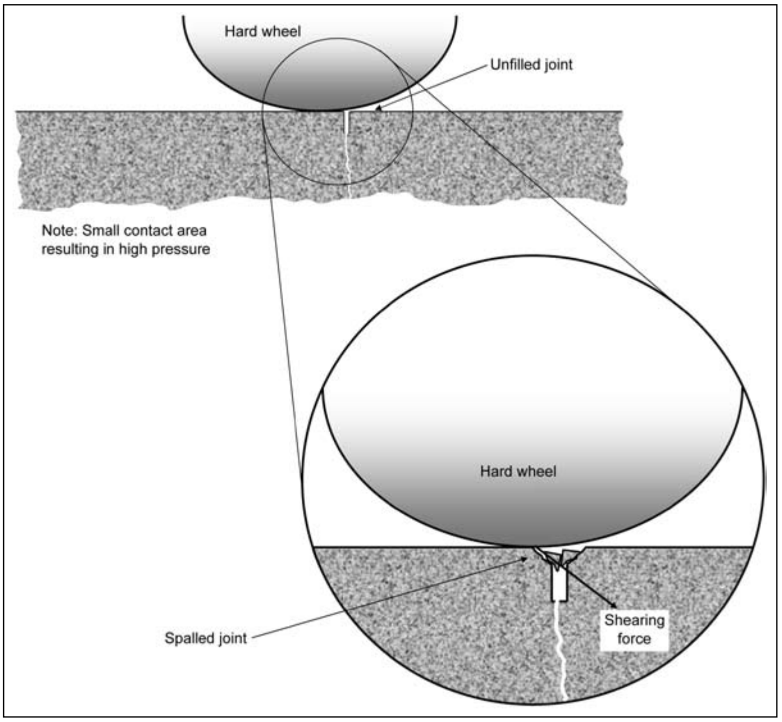


Fig. 4: Illustration of the cause of joint spalling

Fig. 5: A Modified Benkelman Beam is used to determine joint stability and load-carrying capacity of the slab

Fig. 6: A dipstick floor profiler being used to measure joint stability

stability. Instruments developed to measure floor flatness/levelness, such as that shown in Fig. 6, have been used, but these instruments were developed to measure the elevation change at 12 in. (30.5 cm) intervals. Therefore, when straddling a joint, they measure the differential deflection 6 in. (15 cm) away from the joint. This measurement can differ significantly from the actual differential deflection acting on the joint filler within the joint itself. Be sure to consider these limitations when developing acceptable joint stability requirements.

Application of Joint Stability Data

While it's not as comprehensive as measuring the total deflection and LTE caused by loads applied to concrete slabs-on-ground, joint stability data can be used to analyze the cost-effectiveness of repairing spalled joints versus the risk of future deterioration. It can also help determine what type of joint filler material to recommend. Joint spalling is generally repaired by routing or resawing the joint to create a fresh, sharp new edge, cleaning the joint of debris and laitance, and reinstalling joint filler material. For spalling exceeding 1 in. (2.5 cm) in total width, partial-depth repairs should be considered and, if spalling has progressed to half the slab thickness, full-depth local repairs may be required. As these repairs can be costly, it's worth looking at joint stability data to gauge the risk associated with the anticipated repair performance.

For example, suppose a slab has warped upward at the joints due to differential drying between its top and bottom surfaces. Joint stability data may indicate that joint filling alone will not be cost-effective because the filler cannot accommodate such instability and won't provide the support necessary to minimize spalling. Depending on the magnitude of the warping and joint instability, as well as the specific loading conditions, the fillers may not provide long-term serviceability. Although they may function for a short while, these fillers are likely to separate under repetitive traffic and leave the joints at risk of continued spalling.

Another good application of joint stability data is in repairing doweled joints spalled by repetitive traffic. Here again, repairing joint spalling can be costly, so you must be confident in the long-term viability of the repair. In many cases, even when mechanical load transfer is provided in joints, it does not provide the LTE necessary for acceptable joint stability. This can be related to poor consolidation of the concrete below the load transfer device, gaps caused by excessive greasing, over-drilled holes, or deterioration of the dowel slot under heavy repetitive traffic.

Level of Joint Stability Required

Opinions vary regarding the degree of joint stability required for slab serviceability. In general, measurements below 0.010 in. (0.025 cm) are thought to be acceptable, those above 0.060 in. (0.15 cm) are considered unstable, and the range between must be evaluated based on specific conditions.

Required joint stability does not depend on the type of joint, nor on whether the joint transfers loads through mechanical devices or aggregate interlock. It is not even a function of slab thickness, concrete strength, or support conditions. These characteristics relate to the load-carrying capacity of the slab system. For example, loading a 6-in.-thick (15 cm) slab that has snug-fitting dowels in all joints may have 100% joint LTE and excellent filler performance. At the same time, however, depending on the load, the total deflection and corresponding stress may exceed the structural capability of the slab, resulting in fatigue cracking. On the other hand, an 8-in.-thick (20 cm) slab relying on aggregate interlock for load transfer may have less joint stability but an LTE of 50% and a stress well below that necessary to develop fatigue.

Joint stability relates to the joint filler's ability to provide compressive lateral support to the joint wall, and so the level required depends on the properties of the specific joint filler and the type of wheel used in the facility. As discussed previously, a filler material with low tensile elongation properties offers dual benefits by providing good compressive support and by signaling the need for maintenance early, before spalling occurs. For instance, the published data sheet for one repair material shows its tensile elongation as 6%. While deleted from newer revisions, this elongation was once recommended by the American Concrete Institute (ACI) Committee 302, "Guide for Concrete Floor and Slab Construction." Considering a typical joint width of 1/4 in. (0.63 cm), this material can be expected to accommodate a maximum joint movement (joint stability) of 0.015 in. (0.038 cm). Other joint fillers, such as some polyureas and urethanes, can have a tensile elongation of up to 200 or even 500%. These can tolerate a lower joint stability of over 1/2 in. (1.3 cm) but, as discussed, may not provide the needed protection against spalling. Of course, if you measure joint stability before installing a joint filler or repairing joint spalling, the filler may increase the stability somewhat. But again, this is not the purpose of joint fillers and, in unstable joints, may compromise the material's long-term integrity. Consider local conditions, materials, cause for instability, and desired future performance to develop reasonable joint stability limits.

Methods to Improve Joint Stability

When joint instability makes it unwise to proceed with a costly repair, consider ways to improve the stability before making the necessary joint repairs. Joint stability can be increased depending on the specific cause of the instability.

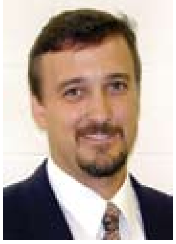
For example, if the edges of the panels are warped upward due to differential drying, the void beneath the warped edges can be injected with a subsealing grout. This will not restore LTE across the joint, but by reducing the total deflection, it potentially increases joint stability.

If the design requires high LTE, and instability is measured at a crack (without dowels), load transfer can be restored by retrofitting with dowel bars. This may also be necessary where mechanical load transfer devices are present but aren't providing sufficient LTE. In other words, if the specified slab thickness was computed based on high LTE, joint stability must be restored by providing the required load transfer. If the design was conservative, the slab thickness may be sufficient to withstand a lower LTE without fatigue. In some cases, the thickness is even adequate to enable free-edge loading of in-service vehicles. Under these circumstances, evaluate the joint stability to determine the type of joint/crack filler material to minimize spalling.

Owners and Maintenance

Serviceable industrial slab-on-ground joints can be achieved if factors that impact the joint stability are correctly identified and addressed. With the correct assessment of conditions, repair and future maintenance costs to the owner can be minimized. Many factors influence the choice of an evaluation technique for a particular slab-on-ground distress investigation. If the concern is limited to joint spalling, measuring joint stability is an effective technique. While it won't indicate the load-carrying capability of the slab, it can help you select proper repair methods, materials, and quantities needed to correct existing and minimize future joint spalling.

Evaluate filler data sheets to select a proper material that will provide the desired level of protection and discuss with the owner the risk and future maintenance cost associated with alternative materials. While some joint maintenance is always advisable for long-term serviceability, the amount of effort required may depend on the type of filler installed and impact future costs to the owner.



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