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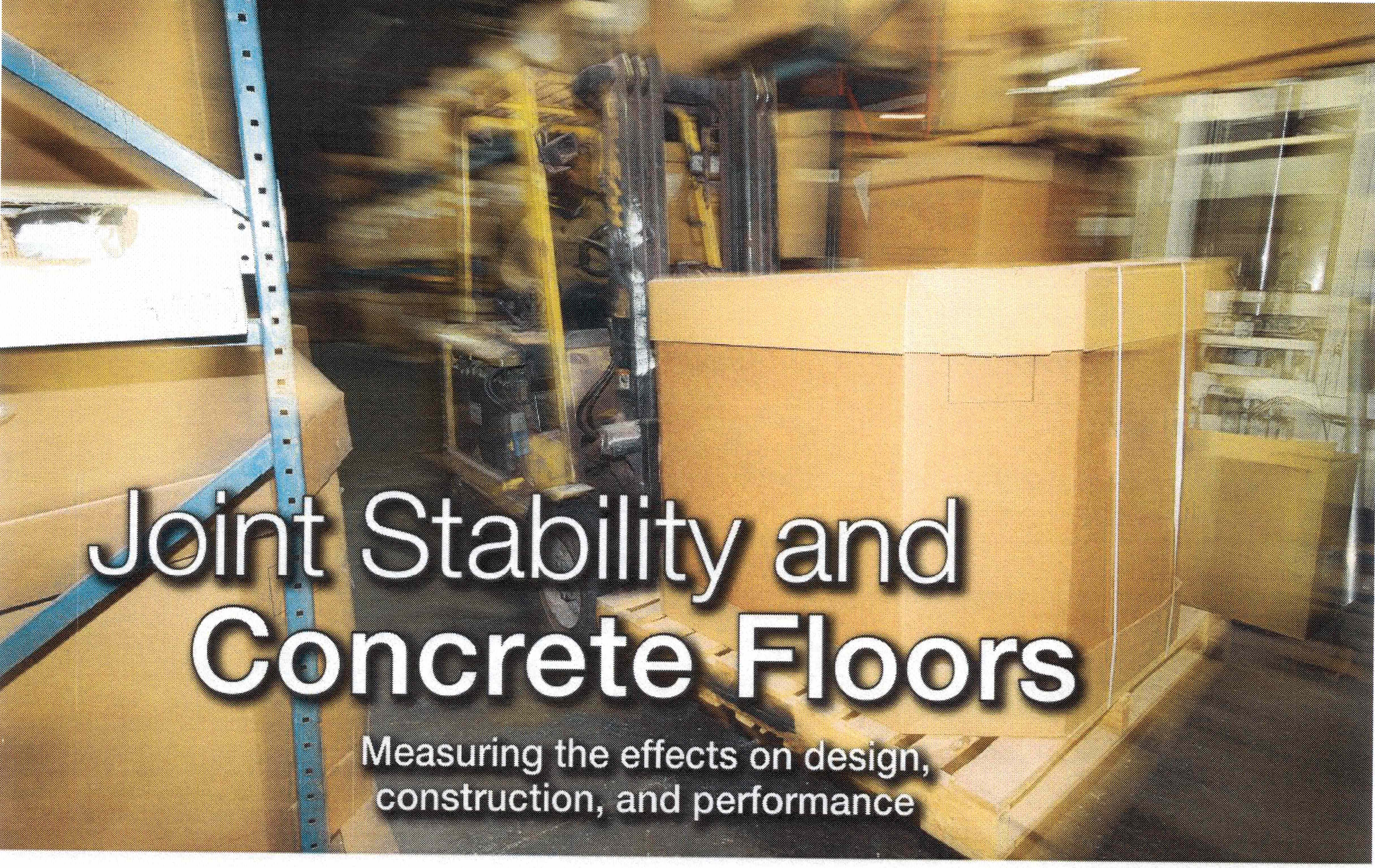

Joint Stability and Concrete Floors

Measuring the effects on design, construction, and performance

by Nigel K. Parkes

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IN CONCRETE SLABS-ON-GROUND, JOINT STABILITY IS THE DESIGN'S CAPACITY TO LIMIT DIFFERENTIAL DEFLECTION OF ADJACENT SLAB PANEL EDGES WHEN A WHEEL LOAD CROSSES THE JOINT. THIS STABILITY IS A MEASURE OF THE LEVEL OF LOAD TRANSFER PROVIDED; SMALLER MEASURED DIFFERENTIAL DEFLECTION NUMBERS INDICATE BETTER JOINT STABILITY.[1]

In industrial and commercial facilities, it is also a critical design component for the long-term serviceability of a concrete slab-on-ground. A design that delivers the appropriate joint stability is key to minimizing spalling and cracking in a slab subjected to lift-truck traffic.

The differential deflection of adjacent slab panels creates an impact point for lift-truck wheels and affects the joint filler's ability to perform its intended function of providing support to the joint wall. As differential deflection increases, so does the likelihood of filler separation and the corresponding potential for spalling.

Spalled joints or cracks can significantly disrupt productivity, require expensive repair, and make facilities less desirable to potential new owners or tenants. Virtually all industry guides recommend the use of load-transfer devices (*i.e.* dowels) in facilities with lift-truck traffic.[2] These guides have historically used slab thickness as the defining criterion when recommending the size and spacing of these devices. Joint stability measurement, however, is a more reliable and definable method of evaluating the performance of a joint design in a given application.

For instance, the 2010 revision of the American Concrete Institute (ACI) 360.R-10, *Design of Slabs-on-ground*, recommends that the total differential deflection across joints should be limited to less than 0.25 mm (0.01 in.) for small, hard-wheeled, lift-truck traffic and 0.51 mm (0.02 in.) for larger, cushioned rubber wheels. The question is, how is the differential deflection best measured?

Testing joint stability

ACI 360.R-10 outlines two types of apparatus for measuring joint stability by testing the differential deflection of adjacent slab panels. In one method, a leveled straightedge and gauge (*e.g.* a tri-square or dial indicator) are used to measure the vertical distance from the upper straightedge to the slab surface at 300 mm (12 in.) spacing (*i.e.* 150 mm [6 in.] on each side of the joint) to determine the amount of vertical movement under the bottom of the straightedge as it occurs. This is known as the 'Type I Apparatus' under ASTM E 1155, *Standard Test Method for Determining* F_F *Floor Flatness and* F_L *Floor Levelness Numbers.*

The other option is the Type II Apparatus, which involves using a device with an inclinometer having 300-mm contact point spacing, located 150 mm on each side of the joint. This gives a visual readout of the vertical movement as it occurs. Generally more practical, the Type II apparatus allows for more tests to be run and data collected within a shorter time.

Three devices similar to those shown in Figure 1 are commercially available, but there is currently no standard ASTM test method for using the devices in this specific application.

George Garber of the international firm, Face Consultants, has proposed recommendations for performing a standardized joint stability test with the devices—as described in "Recommended Joint Stability Test Procedure," page 40.[3]

Designers and builders need to produce the most cost-effective, sustainable, and durable floors to remain competitive in today's market. Designing slabs with an appropriate level of load transfer and measuring the joint stability achieved will provide the best value and performance.

Designing for joint stability

For new construction, the designer must gather data regarding the expected loads and type of wheeled traffic from the owner or tenant up-front. This way, he or she can best determine the level of joint stability required. Once the client's needs are understood, design professionals can provide clear, measurable specifications.

Figure 1

Apparatuses for measuring joint stability. These devices test the differential deflection of adjacent slab panels.

Images courtesy The Face Company, and Allen Face and Company

EFFECTS OF LIFT-TRUCK DESIGN ON FLOOR PERFORMANCE

The rapid change in the logistics industry from using relatively large, cushioned wheels (Figure A) to smaller, harder wheels (Figure B) on lift-trucks, and the increased use of pallet trucks (Figure C), has dramatically increased the problem of joint spalling in warehouse, retail, and manufacturing facilities.

Owners, designers, and contractors can all find themselves in contentious situations and even lawsuits to determine whose responsibility it is to re-establish joint stability and repair spalled joints. The previous lack of a definitive recommendation for the maximum differential deflection (*i.e.* required joint stability) and a readily available test method to determine the level of joint stability achieved has made the resolution of these situations extremely difficult. **CS**

Figure A

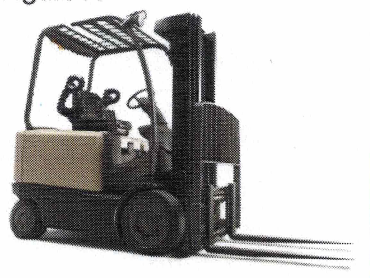
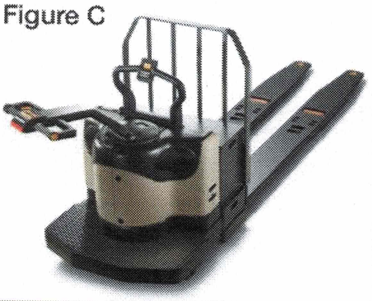


Figure B

Figure C



The introduction of recommended joint stability values, and the departure from dowel recommendations based solely on slab thickness, provides designers with an opportunity to ensure the performance of the joints. It also minimizes material use by optimizing dowel design.

If the slab thickness is controlled by the rack loads and not the lift-truck loads (and this is often the case), less load transfer requirement may be appropriate. This can provide an opportunity to ensure floor performance at a reduced cost.

Engineer and floor consultant Art McKinney suggests that "typically distributed loads do not control slab thickness. Either rack-post loading or lift-truck loading usually control, but the designer should check all three criteria for thickness design and then design the dowels based on the lift-truck loading."

Designers should first determine the minimum level of joint stability required for the expected lift-truck traffic, and then specify the appropriate load-transfer devices required to achieve it.[4] They can also assess the need for further reinforcement. Typically, reinforcement (*e.g.* welded wire, deformed bars, or steel fibers) used to control the width of random cracks is inefficiently located at the slab interior.

On the other hand, there are no cracks with appropriate joint spacing, a well-prepared base, and load-transfer devices engineered to allow for two-directional dowelling. Joints open freely, and slabs are permitted to move laterally, which minimizes restraint. This eliminates mid-panel cracking and provides the required joint stability. Constructed in the most efficient manner, such 'strategically reinforced' floors are often the most cost-effective and sustainable design: steel reinforcement outside the joint is not needed, and slab thicknesses can be decreased due to the reduced edge and corner stresses.[5]

In today's economic environment, contractors often do not have the margins to fix problems caused by the lack of sufficient joint stability. Consequently, more focus is being placed on a designer's responsibility for serviceability issues.

Using joint stability to sell or lease existing facilities

Designers are sometimes pressured by developers or owners to omit dowels from contraction joints in an effort to reduce initial construction costs, even though it is now widely recognized that aggregate interlock is ineffective in providing long-term joint stability.

The readily available testing of joint stability allows owners or tenants to use it as a determining factor when choosing their facility. Realtors can employ joint stability to establish a facility's suitability to their prospective client. This attribute provides an important measure of a slab's quality and its ability to offer clients a low-maintenance, durable floor.

Re-establishing joint stability

Unfortunately, there are many existing facilities that do not have sufficient joint stability for their intended use. In some older facilities, owners have updated their lift-truck fleets from vehicles with large, soft-cushioned rubber wheels to those with smaller, hard wheels. In others, designers relied on aggregate interlock as the only means of providing load transfer at saw-cut contraction joints. In some situations with severe curling and/or heavy loads, the dowel specification may

continued from page 40

6.3 - Inclinometer:

6.3.1 - The inclinometer shall be capable of measuring the elevation difference between two points with resolution of 0.05 mm (0.002 in.) or better.

6.3.2 - The distance between measuring points shall be no less than 250 mm (10 in.) and no more than 350 mm (14 in.).

6.3.3 - Acceptable inclinometer types include, but are not necessarily limited to:

6.3.3.1 - Electronic inclinometer with digital readout designed to measure floor flatness to ASTM E 1155/E 1155M.

6.3.3.2 - Machinist's level with calibrated leveling screw.**

6.3.4 - If desired, the inclinometer can be set out of level so that before and after readings are either both positive or both negative.

7. Procedure

7.1 - Positioning the load vehicle: Orient the load vehicle so its travel path is perpendicular to the joint or crack being tested. Drive the load vehicle toward the joint or crack, stopping when all wheels on the load axle are within 250 mm (10 in.) of the joint or crack but have not yet reached the joint or crack. This is 'Position A.' After recording the elevation difference at Position A, drive the load vehicle ahead so the load axle crosses the joint or crack, stopping after all wheels on the load axle have crossed the joint or crack and are still within 250 mm of the joint or crack. This is Position B.†

7.2 - Positioning the inclinometer: Place the inclinometer on the floor or pavement so its two measuring points meet the following requirements:

7.2.1 - The line connecting the two measuring points shall be perpendicular to the joint or crack.

7.2.2 - The line connecting the two measuring points shall lie at least 250 mm (10 in.) and no more than 350 mm (14 in.) from the outer edge of the load wheel as it passes over the joint or crack.

7.2.3 - The two measuring points shall be equidistant from the joint or crack.

7.2.4 - Do not move the inclinometer between the before and after readings.

7.3 - Taking the readings: Record the inclinometer readings when the load axle is in Positions A and B. A positive inclinometer reading denotes an uphill slope. A negative inclinometer reading denotes a downhill slope.

7.4 - Calculating the test result: Subtract the Position-A reading from the Position-B reading to get the test result.††

8. Reporting

8.1 - Record at least the following information for each test:

8.1.1 - The location of the joint or crack.

8.1.2 - The type of load vehicle and, where practical, the load on its load axle.

8.1.3 - The test result.

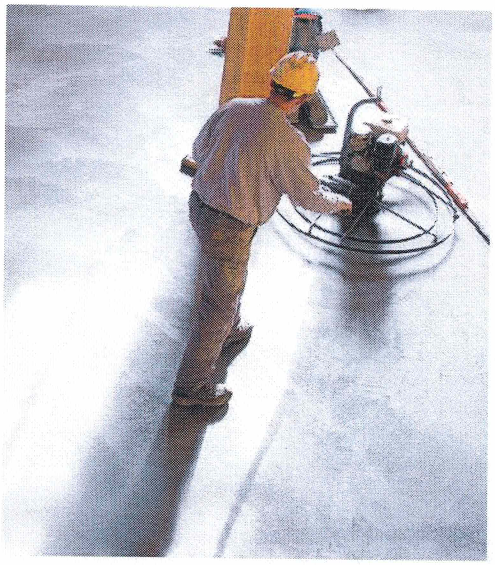
8.1.4 - The date of the test. **CS**

* The smaller the differential deflection number, the better the joint stability.

** Un-leveling the inclinometer by an amount that exceeds the expected inclinometer readings eliminates a potential source of error. When using a leveled inclinometer, the before and after readings can have the same arithmetic sign, or opposite signs. If the operator records a sign wrongly, or errs in comparing values with opposite signs, the test result will be false. Un-leveling the inclinometer eliminates this risk.

† The load axle need not be the first axle to cross the joint or crack. Depending on the type of vehicle and the direction of travel, the load axle may have one or more axles ahead of it.

†† Though inclinometer readings can be negative or positive, the test result is almost always the former. A positive test result would suggest the loaded side of the joint or crack went up, not down, when loaded.



There are few contractors that boast the margins to fix problems caused by the lack of sufficient joint stability. This means that more focus is on a designer's responsibility for serviceability issues.

Photo © BigStockPhoto/Collin Klamper

Full-depth replacement

This is the most widely accepted approach when the joint is already severely spalled. A section of concrete adjacent to each side of the joint is sawn full depth and removed. A marquis-shaped plate dowel,[7] or square dowel and clip,[8] are well-suited to dowel into each new joint face. This allows for new concrete shrinkage without inducing restraint.

Split-cyclinder joint savers

A new system of re-establishing joint stability could potentially result in less downtime and disruption to the facility. Vertical holes are cored into the concrete at the joint intersection. The split-cylinder joint saver device (which resembles a soda can in size and shape) is dropped into the cored hole. A torque wrench is used to tighten an internal screw, which expands the two sides of the device and stabilizes the joint. Internal springs hold the device in contact with the cored-hole walls as the slabs contract due to temperature drops and continued shrinkage.[9] Although this system is relatively new, early uses in industrial facilities seem to be working well and further trials are being conducted.

Conclusion

In summary, joint stability is critical to the long-term serviceability of concrete slabs-on-ground. To improve floor performance and