Point of View

Cost-Effective Slabs-on-Ground

As steel prices soar, plate dowels provide one solution to the material shortage problem

BY GREGORY SCURTO, DAVID SCURTO, WAYNE W. WALKER, AND JERRY A. HOLLAND

In North America, a large portion of the industrial and commercial property development market currently faces a steel shortage crisis. As a result of this shortage, steel prices have dramatically escalated and have become unpredictable, which impacts contractor profit margins, schedules, and project budgets. An economical solution is to provide plate dowels in closely spaced slab-on-ground contraction joints and eliminate inefficient steel reinforcement between the joints.

RE-EVALUATING STEEL USAGE

Many engineers and contractors continue to use traditional design methods for slabs-on-ground, which causes placing of a lot of inefficient and expensive reinforcement. For example, conventional deformed steel reinforcing (bars, bar mats, welded wire, or steel fibers) do not prevent concrete cracking because the reinforcement is "asleep" (has no significant stress) until the concrete cracks. Once a crack occurs, the steel reinforcing "wakes up" (its tensile stress increases substantially) as it tries to hold the crack tight. Many slabs with closely spaced joints are designed as if they had no reinforcing, but then light reinforcement is added throughout the slab as "insurance" to minimize crack widths if any cracks develop away from the joints. In today's volatile steel market, many owners can no longer afford to place steel in their slabs without proper design justification or evaluating other design options that minimize the amount of reinforcement.

OTHER OPTIONS

ACI 302.1R-96, "Guide for Concrete Floor and Slab Construction," states: "In saw-cut contraction joints, aggregate interlock should not be relied upon for effective load transfer for wheeled traffic if the expected crack width exceeds 0.035 in. (0.9 mm)." For aggregate interlock to be effective long-term, and to ensure the crack width does not exceed 0.035 in. (0.9 mm), the theoretical joint spacing should be extremely close. For example, if the well-established shrinkage rate rule-of-thumb of 1/8 in. (3 mm) per 20 ft (6.1 m) is used, the joint spacing would have to be 5.6 ft (1.7 m) to meet ACI 302.1R's recommendations for relying on aggregate interlock. Although slabs with wheeled traffic typically do not have joints this close, we have seen many slabs with 10 to 12 ft (3.0 to 3.6 m) joint spacing that have lost aggregate interlock and experienced distress in less than 1 year.

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Because having joints spaced extremely close together is typically not practical, many slab designers space joints farther apart than required to maintain aggregate interlock and then provide positive load transfer at the contraction joints for slabs exposed to wheeled traffic, heavy loads, or both. ACI 302.1R-96 also states "Doweled joints are recommended when positive load transfer is required." Proper load transfer is highly desirable for slabs exposed to wheeled traffic and/or significant loads. Sharing loads across joints from one slab panel to the next reduces slab stresses and lessens joint damage by minimizing differential deflection across the joint (this is often referred to as "joint stability"). Damage to both lift trucks and joints escalates in a vicious cycle as each individually causes ever-worsening damage to the other. Repairs of joints and lift trucks involve high costs that are often hidden in the maintenance budget of the facility. Having positive load transfer at the contraction joints helps to minimize future joint and lift truck maintenance costs for the owner.

To achieve a low-maintenance slab, many engineers design the slab to be unreinforced with close joint spacing (typically 12 to 15 ft [3.6 to 4.6 m]). They still provide some light amount of reinforcement throughout the slab, but not enough to increase the slab's load capacity, or significantly impact the crack opening width (such as No. 3 bars at

Fig. 1: Light reinforcement continued through contraction joints for load transfer and chaired up just prior to concrete placement and screeding

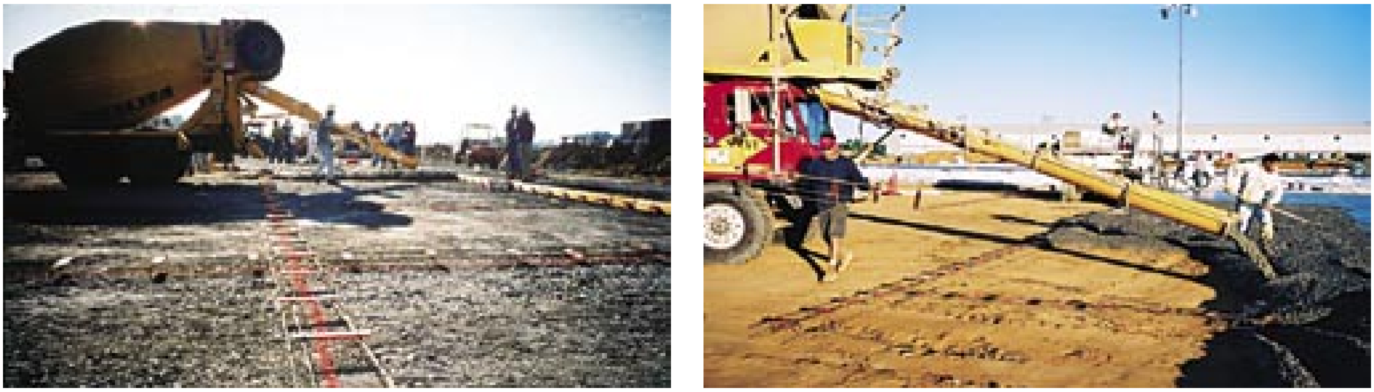

Fig. 2: Plate dowel baskets for contraction joints are installed over painted lines and placed in saw-cut joints just prior to concrete placement and screeding

18 in. [10 mm diameter bars at 460 mm] or steel fibers (40 to 50 lb/yd^3 [24 to 30 kg/m^3]) (Fig. 1). Continuing this light reinforcing through the contraction joints (saw-cut as early as feasible to avoid out-of-joint cracking) enhances and augments the aggregate interlock, while improving joint stability. Eldon Tipping, Past Chair of ACI Committee 302, has coined the term “long dowels” for this design concept, which has proven cost-effective and has worked well in the past. The reinforcement between the joints, however, is not being fully utilized, and with today’s steel prices, this system is no longer affordable for many customers.

A MORE COST-EFFECTIVE SOLUTION

The greatest problem for slabs with exposed joints in industrial and commercial environments is joint deterioration (concrete spalling and joint filler splitting and separation). This deterioration may be due to shrinkage, curling, and/or wheeled traffic crossing joints that have too much differential vertical movement (poor joint stability). The previously described concept of continuous light reinforcing to enhance joint stability makes economic sense only when the cost of continuous reinforcing is less than that of providing other types of load transfer mechanisms. Where this cost advantage is not apparent, reinforcement that was inefficiently located at the slab interior may be relocated to the joints.

Some slab designers and contractors are now turning to this strategic relocation concept (which some have termed “strategic reinforcement”), by using plate dowel baskets at all contraction joints (Fig. 2), and eliminating costly steel reinforcement. This concept saves on steel costs while typically providing the following advantages over one or more of the reinforcement options noted previously:

- Plate dowel baskets can be installed more quickly and easily (while placing and laser screeding the concrete) than having to chair up the reinforcement during concreting;
- Normal concrete mixtures can be used, eliminating the midrange to high-range water-reducing admixtures and time needed for introduction of steel fiber in dosages required for load transfer at the contraction joints;
- Plate dowel baskets may be more safely lifted and will result in a reduced tripping hazard during construction,

compared to bar or wire reinforcement; and

- Rectangular plate dowels with clips, which allow horizontal movement when the slab shrinks, provide the additional advantage of not restraining the slab parallel to the joint. This reduces the possibility of the random cracking sometimes caused by the restraint of bar reinforcement or conventional round dowels.

Walker and Holland gathered recent project pricing data from concrete floor contractors throughout the U.S. Evaluation of this data for a 100,000 ft^2 (9300 m^2) facility with a 6-in.-thick (150 mm) slab and a 15 ft (4.6 m) joint spacing, shows that a savings of 10 to 30% (depending on where the project was located) was achieved by replacing continuous No. 3 bars at 18 in. on center (10 mm diameter bars at 460 mm) with 3/8-in.-thick x 2-in.-wide (10 mm x 50 mm) plate dowels at 24 in. (600 mm) spacing in the contraction joints. These savings are significant and will increase as the price of steel increases.

Some have tried to construct cost-effective floor slabs for wheeled traffic and significant loads by increasing concrete thickness and eliminating reinforcement. These designs depend on aggregate interlock for load transfer at contraction joints. Such slabs are generally not as efficient, serviceable, or cost-effective (especially considering life-cycle costs, which include increased repairs and maintenance for the joints and lift trucks) as a thinner, unreinforced slab with plate dowel baskets at the contraction joints. For example, when comparing a 6-in.-thick (150 mm) slab to a 7-in.-thick (175 mm) slab with the same joint spacing (in the normal 12 to 15 ft [3.6 to 4.6 m] range) and materials, an unreinforced 6 in. (150 mm) slab with plate dowel baskets typically will have the following advantages over an unreinforced 7 in. (175 mm) slab, in which the designer depended on aggregate interlock:

- The use of plate dowels in the 6-in.-thick (150 mm) slab will eliminate the free edge condition that the 7-in.-thick (175 mm) slab will have because of aggregate interlock loss at the contraction joints. Therefore, the 6 in. (150 mm) slab will carry more load based on the loading near joints, which produces the greatest stresses in any slab, but especially when curling is considered;
- The joint edges for the 6 in. (150 mm) slab will experience much less spalling (due to good joint stability with the plate dowels); and
- The joint filler performance will improve with better joint stability.

PLATE DOWEL BASKETS FOR ECONOMY

When today's high cost of steel is considered, the slab designer and contractor can improve the economy and performance of a slab-on-ground by eliminating the interior steel reinforcement and providing plate dowels in the contraction joints (for slabs designed as unreinforced with closely spaced joints). Additional advantages can also be realized by using plate dowels with clips that will allow horizontal shrinkage movement, which will help minimize the possibility of random cracking. The result: engineers and contractors deliver the economical, durable, reduced-maintenance floor their customers expect, while optimizing the amount of steel required.

Selected for reader interest by the editors.

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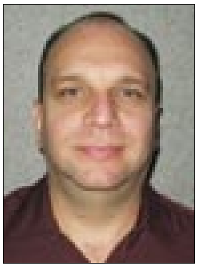

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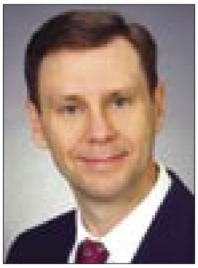

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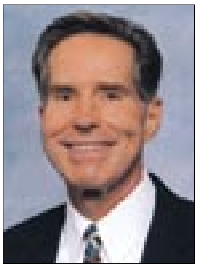

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