GATORADE FLOOR:

Quenching Thirst, Joints, Cracks and Curl

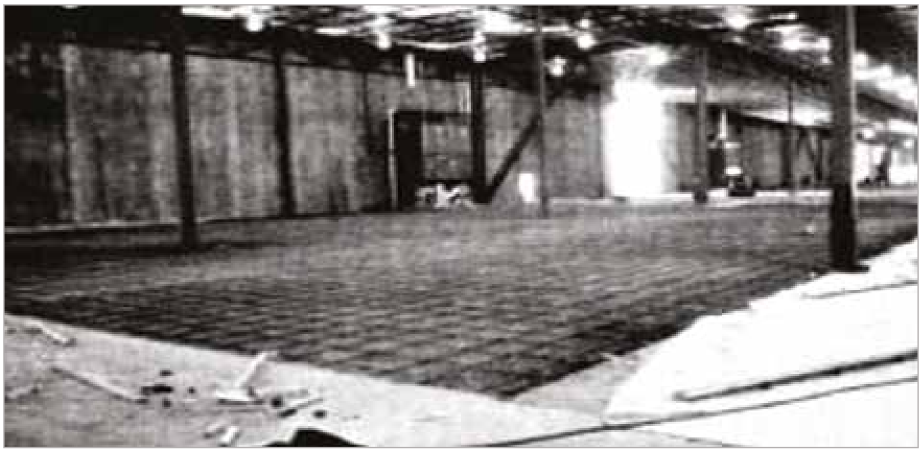

Fig. 1 – SCC floor panel almost ready for concrete placement. Note: 125 by 100 ft. (38 by 30 m) panel size with no intermediate joints; square dowels in adjacent panels with special clips (red) having cushioning side pads to allow differential horizontal movements but transfer vertical loads.

> *"Gatorade and Metric Constructors agreed to use the most advanced, state-of-the-art techniques and materials possible*

When selected by the Quaker Oats Company, makers of Gatorade, to provide engineering services for the new Gatorade Southwest Facility in Atlanta, Georgia, the design-build partnership of Metric Constructors and Lockwood Green Engineers and Architects opted for a state-of-the-art design that would use cutting-edge technology where possible. This decision would ensure a design that accommodated the many specialized functions of the bottling/warehouse facility and would eliminate or minimize the problems that occur in most typical industrial floor construction. Gatorade and Metric Constructors agreed to use the most advanced, state-of-the-art techniques and materials possible; furthermore, Gatorade and Metrick fostered a spirit of teamwork with all project participants, a cooperative endeavor that lead to a number of excellent ideas. Because of time constraints, a fast-track method of design and construction was adopted. Although the project had many special features – such as attractive precast concrete wall panels, split face concrete block, tall concrete block masonry partitions, and continuously reinforced portland-cement concrete (PCC) slabs where floors were to be covered with finishes (toppings, VCT) – the feature that set this project apart from other facilities of this type was the unique shrinkage-compensating concrete floor with joints as far as 125 ft (38 m) apart with no significant cracking.

The focus of this article is on some of the unique features of the Gatorade facility's floors, which are significantly different from typical bottling or warehouse facility floors and even far from many previously constructed high-quality floors. The final design of the floors specified over 415,000 ft. (38,000 m^2), most of which were of shrinkage-compensating concrete, the design and construction of which incorporated the most advanced techniques were combined in ways never previously used to create floors of this type.

WHAT IS SHRINKAGE-COMPENSATING CONCRETE?

Shrinkage-compensating concrete (SCC) is made with a special cement (called Type K) or an additive component that causes a volume increase of the concrete after settling. If the SCC is properly and elastically restrained, it induces compressive stresses in the concrete that are intended to

Fig. 2 – SCC floor panel almost ready for concrete placement. Note: 125 ft (38 m) joint spacing with no intermediate joints. Note: reinforcing bar mat lying on level, stiff low-friction, granular base material. Concrete trucks and laser screed will drive over reinforcing steel, which will be chaired up just behind vehicles.

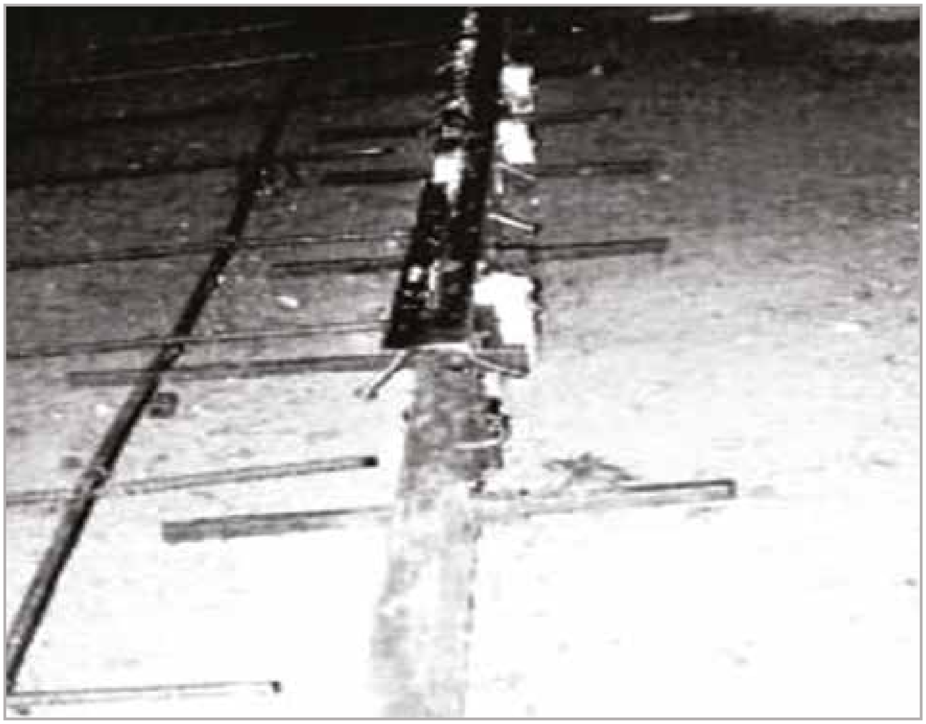

Fig. 3 – Prefabricated system consisting of steel angle armored floor construction joint, edge forms with and without armor angles, reusable dowel holders/aligners (red), etc. Note: No. 4 (12 mm) reinforcing steel at 18 in. (450 mm) on center for proper SCC expansion restraint, not structural purposes.

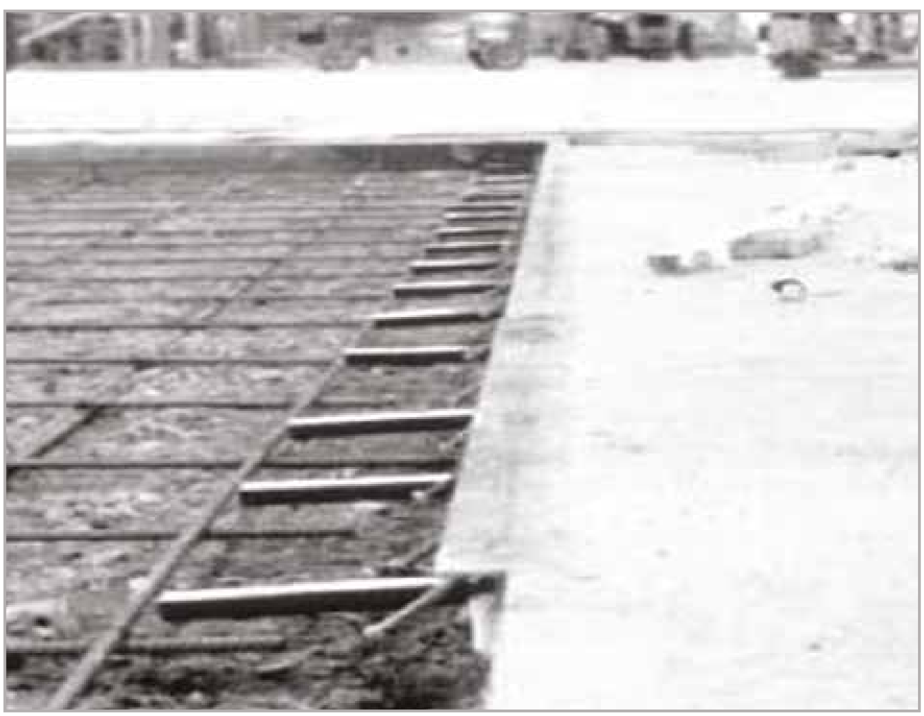

Fig. 5 – Prefabricated steel angle system for armoring floor construction joints subjected to heavy, frequent vehicle loads. For economy, armor system is located only where traffic will be. Note: square dowels with special clips (red) having cushioning side pads to allow differential horizontal movements but transfer vertical loads.

approximately offset the tendency of drying shrinkage to induce tensile stresses. In SCC floors, properly sized reinforcing steel (not too much and not too little) that is correctly located vertically in the slab provides the restraint noted, along with that provided by subgrade friction. If properly designed and constructed, the SCC expands during the first seven days, thereby stretching (actually prestressing) the mild reinforcing steel. Afterwards, the SCC shrinks like normal concrete, and the tensioned reinforcing acts like a stretched rubber band to keep the SCC in compression while it shrinks. Finally, if everything functions as it should, the concrete volume decreases to approximately its original volume. It may sound like "black magic," but a SCC slab works well in reality if constructed correctly.

WHY USE SCC IN FLOOR SLABS?

Traditionally, the main advantages of using SCC in floor slabs are being able to dramatically increase joint spacings and eliminate or greatly reduce curling of the slab panel edges; however, new design methodologies allow thinner slabs as well (see "Floor slab" structural data" below). Joint spacings in PCC slabs are typically used so that the shrinkage cracks that inevitably occur are per-located; straight cracks and more easily sealed. Curling occurs when the top portion of the slab changes to a volume less than that of the slab lower portion (whether from differential shrinkage, temperature, or moisture content). Almost all slabs made with PCC curl, but when curl becomes excessive, bad things occur, such as cracking, joint faulting, damaged vehicle tires and bearings, joint spalling, and failure of joint sealant. Thus, SCC can provide a more maintenance-free slab, although the cost savings of fewer joints and lower maintenance may or may not offset the extra costs of SCC materials and construction. A life-cycle cost analysis of SCC floors can often show overall savings.

WHY HAS SCC NOT BEEN USED SIGNIFICANTLY IN FLOORS?

SCC has not been used significantly in interior floor slabs for some of the following reasons:

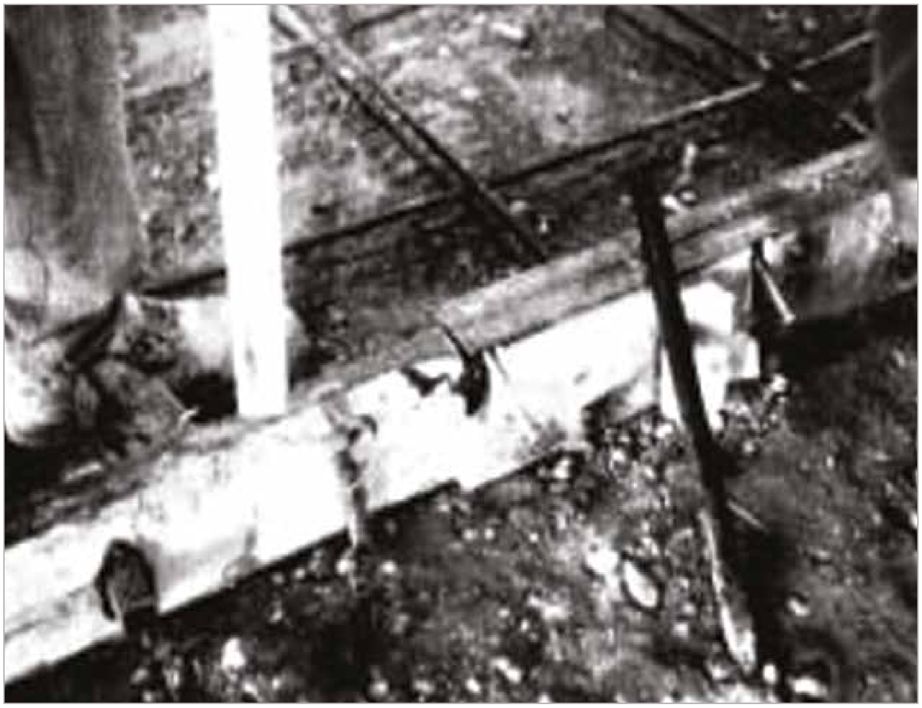

Fig. 4 – Prefabricated system consisting of steel angle armored floor construction joint, edge forms with and without armor angles, reusable dowel holders/aligners (red), etc. As adjacent slab panels shrink away from joint, elastomeric adhesive between two angles allows them to separate.

Fig. 6 – Square dowels with special clips (red) having cushioning side pads to allow differential horizontal movements but transfer vertical loads. Note: optimized concrete mixture that appears harsh and "stony" but is actually extremely workable and finishable.

1. SCC is significantly more expensive than PCC per cubic yard (15 to 50% more, depending on the location, market and concrete requirements).
2. SCC should not be totally or unevenly restrained. It must be allowed some growth and be only partially and properly restrained by the reinforcing and the subgrade; otherwise, there can be extensive cracking. This correct restraint can be achieved with appropriate design and construction. Too much restraint, however, can be cause by uneven subgrades, improperly tied-in wall panels or dock walls, or drains. These restraints have caused a tendency for excessive cracking in a few of the SCC projects in the past.
3. Differential volume changes are so much greater in SCC floors that typical smooth, round dowels can cause restraint sufficient to result in concrete cracking and spalling. Attempts to prevent this by using large amounts of grease or loose-fitting sleeves on the dowels sometimes were not successful and defeated the purpose of having dowels in the first place (that is, the transferring of vertical load from one panel to the adjacent one).
4. SCC obtains its expansion from a special cement hydration process that utilizes a great amount of water. Because of this, SCC loses slump and workability faster than normal PCC and is more likely to experience plastic shrinkage cracking, unless proper steps are taken. This is the case for SCC placements inside a building; however, for unprotected SCC floors constructed before the building enclosure is erected, the exposure situation is much more critical, especially in hot, dry weather.
5. Some early SCC projects had significant problems because of poor design, materials, construction, and a misunderstanding of SCC in general As a result, SCC got an undeserved bad reputation that it still has not totally overcome.

These potential problems with SCC floors were addressed in this project by numerous innovative approaches. Some of these are described below.

WHY "VERY FLAT?"

"Very flat" floors were required to facilitate the newer special high-lift, fast-lift trucks operating in current high-rack warehouse areas. This special degree of flatness and levelness was dictated by the speed of the truck down the aisle as well as the high-level operation of the truck. Even a slight difference in elevation of the truck. Even a slight difference in elevation of the floor beneath the truck's wheels could cause a substantial deviation from the proper relationship of the truck and upper rack locations, causing potential operating difficulties. The typical "bumpy" warehouse floor would cause the planned truck to be operated at less than maximum speed when traveling down the aisle, thereby significantly reducing the warehouse productivity over the 25 to 50 year life of the facility. Additional benefits of "very flat" floors include reduced lift truck maintenance and improved driver performance and morale.

F-NUMBERS

"Very flat" floor specifications typically use F-numbers to specify minimum floor flatness (degree of bumpiness) and levelness (conformance to a horizontal plane). F-numbers, which usually are determined by special measuring devices and statistical methods of analysis, are referenced in several ACI, ASTM, and CAN (Canadian Standards) documents. "Very flat" floors are defined as those that have a minimum FF (flatness) number of 35 to 50 and FL (levelness) number of 25 to 30. The higher the F-number, the flatter and more level the floor. F-numbers are directly proportional; thus, a "very flat" floor with FF of 35 is twice as flat as a floor with FF of 17.5 and is two and a half to three times as flat as the average non-critical industrial floor, with an F-number of FF 13-17.

LAYOUT/JOINT DESIGN AND ACCOMMODATIONS OF MOVEMENT

Construction joints (contraction/control joints, are not needed more desirable in SCC flatwork) typically were spaced 100 ft (30.5 m) apart, although some 125 ft (38 m) spacings were successfully used. The engineer for this project has used longer spacings on other jobs but believed longer spacings were not appropriate because some unavoidable restraints to slab movement were present on this project. Approximately 80% of the joints required for a normal PCC floor were eliminated by optimizing design with SCC.

Eliminating reentrant corners was one criterion for joint locations. Another was the desirability of keeping floor panels as spare as feasible. A third criterion was using special joint locations and detailing to eliminate cracking in the floor area around the dock leveler pits, which usually have some of the worst cracking and the most traffic, resulting in severe crack spalling on many projects.

Column isolation sections were round instead of diamond-shaped due to many columns not being located on joints. Polyethylene foam plank was used for all isolation joints, instead of the typical asphalt-impregnated fiber filler, because the fiber filler was too strong and would not deform adequately. The foam filler was sized for the worst expected slab movement, plus a reasonable safety factor; however, joints were kept to the minimum feasible widths to minimize joint spalling. Isolation joints were sealed using an elastomeric urethane sealant, with close attention paid to proper sealant geometry and avoidance of three-point bonding. A semirigid epoxy joint filler was used in construction joints, except for armored joints that incorporated a silicone sealant for its superior extensibility.

Kerfed shear keys are not positive means of providing load transfer between adjacent floor panels at typical joint spacings; therefore, smooth steel dowels were required. The significant differential movement expected for the SCC floor panels required ungreased, square (rather than round) dowels with cushioning side pads on clips to be specified in all locations. These padded, square dowels allowed horizontal differential movement between adjacent panels while transferring vertical loads. Close dowel alignment tolerances and other strict requirements were specified to minimize the possibility of dowel binding and the resulting slab problems.

The construction joints subjected to the most traffic were armored by steel edge angles incorporated into a unique prefabricated sideform and dowel aligner system. This system was produced by PNA, Inc., and used for all SCC forms on this project, whether the joint was armored or not. Some of the special features included the following very close tolerances, reusable dowel aligners already installed, and very straight-angles and anchors mounted on the forms. The angles have 1.5 in. (38 mm) legs and excellent anchorage, which eliminate the problems experienced for many decades with the commonly used much larger angles; they typically did not have good concrete consolidation under the horizontal leg and were not anchored sufficiently.

FLOOR SLAB STRUCTURAL DATA

The floor slab was 6 in. (150 mm) thick and had a single layer of No. 4 (12.7 mm) bars at 18 in. (460 mm) on center with 1.5 inc. (38 mm) concrete cover from the top of the slab. The reinforcing was for SCC purposes only, not for structural loading requirements. Specified concrete compressive strength was 4000 psi (28 MPa) at 28 days.

The SCC floor was designed such that it would support pallet loading for its initial use and rack loading in the future. Because a properly designed and constructed SCC floor has little or no edge curling, the very high curling flexural tension stresses usually occurring in PCC slabs (200 to 400 psi (1.4 to 2.8 MPa) curling stresses, as compared with a modulus of rupture of only 450 to 650 psi (3.1 to 4.5 MPA, typically) are not present. Lockwood Greene has developed a very unique computer program for slabs on ground that takes into account many variables not considered in traditional design methodologies, such as curl and shrinkage. This program indicated that if the slab had been designed as PCC with traditional procedures for future racks, it would have been 8 in. (200 mm) thick instead of the 6 in. (150 mm) SCC slab.

CONCRETE MIXTURE REQUIREMENTS

Some requirements specified by the engineer for the concrete mixture may have never been used for SCC floors before, while others have been used only rarely. A few of these mixture requirements follow:

1. A very important factor was the more uniform than normal aggregate particle size distribution requirement. The engineer specified that the total percentage of fine and coarse aggregates retained on any one sieve be a minimum of 8% and a maximum of 22% of the total combined aggregates (many mixtures have ranges from less than 1% to over 30%), excluding the 1 in. (25 mm) and Nos. 30, 50, and 100 (600, 300,

and 150 mm) sieves. The sieve ranges were 8 to 15% for the Nos. 30 and 50 sieves plus 3 to 5% for the No. 100 sieve. These percentages were not easy to meet due to quarry and concrete plant restrictions. The engineer and the concrete supplier (Blue Circle Williams), however, collaborated in determining a blend of aggregate size groups to meet the job specifications while being reasonably economical and allowing for proper quality control. The middle aggregate sizes, Nos. 4, 8, and 16 (4.75, 2.36, and 1.18 mm) sieve sizes, are normally used in asphalt construction and other applications; thus, the amount available for concrete is limited and causes most concrete to be somewhat gap-graded. No. 89 stone (3/8 in. to No. 16 [9.5 to 1.18 mm sieve) was required to provide the middle sizes noted above to fill in that gap.

2. The specified aggregate was to have a high percentage of large size stone to minimize shrinkage. A nominal size of No. 57 stone (1 to 3/8 in. [25 to 9.5 mm]) was specified as the largest size, rather than the No. 67 stone (3/4 to 3/8 in [19 to 9.5 mm]) sometimes used in the Atlanta area. These large sizes, combined with the middle sizes noted previously, made the mixture a quite "stony" but very workable one that minimized the quantity of cement paste, with the advantages noted below:

3. Natural sand, rather than the manufactured sand from rock crushing operations, was specified for the main fine aggregate for enhanced workability and finishability, plus reduced water and cement requirements. The coarsest sand available (fineness modulus approximately 3.0) was specified, but it had a slight amount of gap grading. By adding a small amount of clean manufactured sand, however, the grading was optimized; this theoretical optimization was confirmed by trial placements in the field. The sand blend performed extremely well.

4. A high quality Type K cement (Blue Circle) was used to provide proper expansion, maximum "window of floor finishability," and good quality control. Required minimum expansion was 0.050%.

5. Consistency of concrete at placement is a key factor. This was accomplished by close cooperation in delivery and placement, minimizing the use of admixtures (for some placements the mixture had a small amount of a low-range-water-reducer), close quality control, and other measures. The ready-mix concrete supplier provided a quality-control manager to be on-site for especially important slab placements, and tight quality control

Fig. 7 – Laser screed striking off and consolidating concrete placement by means of telescoping boom with elevation controlled by laser. Laser screed assisted in attaining high (thus good) FL (levelness) numbers. Note: optimized concrete mixture that appears harsh and "stony" but is actually extremely workable and finishable.

Fig. 8 – SCC floor finishing and application of field-mixed trap rock hardener. Note: 12 ft (3.7 m) long highway straight-edge assisted in attaining high (thus good) FF (flatness) numbers. Note: riding double-towel machine at left, which also helped in attaining a very flat floor when "pizza pans" were attached to the blades.

Fig. 9 – Column round isolation section not located at construction joints. Note: soft polyethylene foam isolation joint material (instead of stiff premolded joint filler used for typical PCC floors) to allow for SCC movement; peeled back special curling sheets of white, synthetic fiber with white plastic backing.

Fig. 10 – SCC finished floor with joints as far apart as 125 ft.(38 m). Note: steel angle armored construction joint (extending from center to left of photo) in lift truck traffic aisle; tight floor joints exhibiting very little shrinkage, considering large slab panels.

procedures were maintained at the concrete-batching plant. Because the condition of the ready-mix truck drum blades is so important for proper mixing and consistency, all trucks proposed to be used were inspected; the identification number of all trucks passing the inspection were listed, and only these trucks were allowed on the site.

The following are advantages, as compared to a typical SCC concrete mixture for the same amount of expansion, derived from these specified requirements:

1. Less water was required.
2. Less cement was required.
3. The mixture was far more workable and finishable, in spite of high coarse-aggregate content and a coarse sand blend.
4. Close tolerances were obtained.
5. More consistent concrete strengths were seen at all ages.
6. Higher 28-day concrete strengths were obtained for a given cement content.
7. There was no bleeding or segregation. The coarse aggregate stayed very high in the slab.
8. There has been significantly less shrinkage. Extra mixture requirements added only slightly.

Extra mixture requirements added only slightly more cost than the typical ready-mix SCC cost. All parties involved with the project agreed that the very small extra cost was well worth it, and the floor subcontractor stated that this extra cost was at least partially offset by the reduced labor required.

Many favorable statements were made concerning the concrete mixture, including the following comments by key participants:

1. The engineer, who has designed and observed the installation of many million square feet of specialty slabs and pavements throughout the world, stated this was one of the best performing concrete SCC mixtures he has ever seen. This was in spite of the fact that the crushed granite aggregates used in Atlanta tends to have long, slivered particles that cause a tendency towards harsh mixtures.
2. The floor subcontractor stated that this SCC mixture finished extremely well.
3. The concrete supplier was very satisfied with the way the mixture performed. There was no concern over.

BIDDING AND PRECONSTRUCTION PREPARATION

Unique floors, such as Gatorade's, require special expertise for both design and construction. Few engineering or architectural firms have designed, and even fewer contractors have constructed, such cutting-edge floors. For this reason, a prequalified bidders list was prepared for the slab package, using only subcontractors with a proven track record of consistently producing specialty floors.

Lockwood, Greene, and Metric assisted the floor subcontractor (Frick's Floor Systems) by maximizing constructibility and communication. Examples of this project teamwork are the following: scheduling the slab installation so that it could be done with the building enclosed and the roof membrane installed; specifying the mixture proportioning and ready-mix concrete quality-control requirements as noted above; and holding regular meetings, starting with the prefloor construction meeting.

PREPARATION FOR CONCRETE PLACEMENT

A good subgrade, important for all floors, is especially critical for such floors as this because of the close tolerances and heavy loads. A strong, uniform subgrade is imperative. The subgrade preparation was performed during a very wet fall and winter, causing difficult conditions. All possible measures were taken to ensure that the subgrade was of top quality; although, they involved extra cost and the possibility of significant delays to the project. These measures included replacing wet silty soils with more granular dry materials, the use of an easily compactable and trimable chrusher run as needed immediately under the slab to reduce subgrade drag, and close tolerance grading.

Side forms are crucial elements of a successful critical tolerance floor and affect most aspects of slab construction. If the tops of the forms are not sufficiently true, even the best finishers cannot meet the FI tolerances. The floor subcontractor took several measures to ensure quality form construction. The forms were handled very carefully to prevent damage and were set at the correct elevation, straight, and plumb. During concrete placement, the elevation of the forms was constantly checked and, if necessary, readjusted, The resulting high F-numbers indicate the care taken with the forms.

Proper placement of reinforcing steel was extremely important. Reinforcing steel supports had to be the correct height, spaced closely enough, and adequately secured to steel bars. Steel mislocation due to improper installation or movement during concreting operations could cause significant cracking.

CONCRETE PLACEMENT, FINISHING, AND CURING

Because of time constraints and economy, all of the concrete was tail-gated. Great care was taken to keep the concrete placement going at a consistent rate because even a short interruption can cause significantly lower F numbers and other problems.

To place the concrete by tail-gating and to use a laser screed for concrete strike-off and consolidation, the reinforcing bars were placed directly on the level, stiff base to allow the ready-mix concrete trucks and laser screed to roll over them. Between these vehicles and the just-placed concrete, the reinforcing-steel mat was lifted up and supported on chairs. By providing proper procedures for the reinforcing steel, they were not kinked by the wheel loads.

The laser screed is one of the greatest innovations in concrete floor construction in the last 15 years. It permits faster and larger concrete placements by allowing block placements rather than strip placements. Furthermore, it enables the contractor to have higher FI numbers with less effort.

The concrete around the dowels was consolidated by poker vibrators. Good concrete consolidation is extremely important to provide proper dowel function.

A field-mixed trap rock hardener was applied at 1.5 lb/ft^2 (7.3 kg/m^2) in the high traffic areas. Trap rock is an extremely hard material and impart increased floor durability to the critical top 1/8 to 1/4 in. (3 to 6 mm) of the floor wearing surface. Field-mixing and installation of the hardener involves placing the well-graded trap rock aggregate in a small mixer, dampening it, adding cement so that each particle is slightly coated with the resulting paste, and working it into the floor surface evenly before the coated particles dry.

The tools, equipment, and procedures used for finishing the slabs played a major role in meeting the close tolerances. Long channel floats and 10 and 12 ft. (3.0 and 3.7 m) highway straightedges were used to provide close surface tolerances. The straightedges were used to cut down high spots and fill in low spots.

After initial floating of the slab surface, "pizza pans" were installed on riding double-trowels to enhance floor flatness. The floor was trowelled until it had a shiny, burnished appearance that has been found to be both very attractive and cleanable, highly desirable attributes for a beverage facility.

A special curing sheet was specified and was applied as soon as possible after completion of finishing operations. This curing sheet is a type that consists of a white, synthetic fiber mat (to hold extra curing water) with a white plastic sheet backing (to provide a very low-permeability barrier to moisture loss). This curing method and material were ideal for a SCC floor subjected to high abrasion and impact because of the following:

1. To obtain maximum expansion, providing extra curing water is highly desirable because water is a necessary ingredient for expansion. The matting of the special sheet provides this extra water.
2. The best possible curing method for a highly wear-resistant floor is one that provides a 100% humidity environment during the entire curing period for the top 1/8 to 1/4 in. (3 to 6 mm) that constitute the concrete wearing surface. This special sheet provides this environment for the longest period of time with the minimum effort and without the mess and other problems of flooding or intermittently sprinkling the floor surface.
3. The white fiber mat does not produce brown stains on the floor like new burlap would, lasts longer, and is lighter in weight. Furthermore, if properly used, it does not cause as much splotchiness as plain plastic sheeting, and it seals better and more easily at the edges and laps.

4. The white plastic backing of the curing sheet reflects sunlight, thereby reducing concrete temperature.
5. The tough, cushioned sheet protects the floor surface well and makes it possible to have light traffic and work done over the slab during the curing period.

After the 7-day curing period was over, the sheets were removed and the floor surface allowed to dry. The cured concrete surface is so tight and dense that very little spilled liquid penetrates, as compared to normally constructed floors.

MONITORING FLATNESS AND LEVELNESS

As soon as feasible after the final trowel pass was made on a concrete placement, the surface tolerances were tested with a dipstick, allowing the contractor immediate feedback so that any changes necessary could be made for improvement. Many people mistakenly believe the only purpose of slab tolerance testing is to see if the contractor has met the specified requirements so they can penalize the contractor if he or she did not. Timely testing also serves as a check for the contractor to indicate needed adjustments.

RESULTS

The Gatorade "very flat" floor has been very successful and has met or exceeded owner expectations. The specified FF 35 and FL 25 were exceeded by a consistent margin throughout the project. To put these values into the proper perspective, the average F-numbers for this project are approximately four times flatter and more level than the majority of the industrial slabs on grade now in use.

THE FUTURE

Although the Gatorade floor is unique in some ways, many of the techniques and materials used may well become commonplace for the heavy-duty floor projects built in the future. As more design firms, material suppliers, and contractors get involved in these projects, they must keep abreast of the state-of-the-art techniques necessary to produce successful specialty floors. Furthermore, to minimize problems and maximize quality, owners, contractors, and engineers/architects must give the type of input and foster the kind of close teamwork that Gatorade, Metric, Lockwood Greene, and other participants provided on this project. Rather than the more typical adversarial relationship between team members, this positive teamwork produced successful results.

GATORADE PROJECT PARTICIPANTS

Owner: The Quaker Oats Company, Chicago IL; Engineer/Architect/Construction: Consultant Lockwood Greene Engineers, Inc. Atlanta, GA. Design-Builder: Metrick Constructors, Inc. Marietta, GA., A Division of J.A. Jones Charlotte, N.C.; Floor Subcontractor: Fricks Floor Systems, Inc., Fort Worth, Tex.; Concrete Supplier: Blue Circle Williams, Inc., Marietta, GA.; Type K Cement Supplier: Blue Circle Cement, Inc, Marietta, GA.; Specialty Floor Products Supplier: PNA, Inc., Mathews, N.C.; Slab Tolerance and Concrete Testing Geotechnical Engineering and Testing: Law Engineering & Environmental Services, Inc. Atlanta, GA.

Fig. 11 – Finished slab with as much as 125 ft (38 m) between joints. Note: very straight column reflections, indicating a very flat floor; shiny, burnished floor surface (there is no coating or sealer causing the shine); armored angle construction joint in foreground.

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Jerry A Holland, FACI, is a structural engineering consultant with Lockwood Greene Engineers and Architects in Atlanta, Ga. He has 33 years of experience in design, construction, and troubleshooting concrete materials and structures. Holland is past chairman of ACI Committee 360, Design of Slabs on Ground, and is currently a member of that committee; as well as 223, Shrinkage-Compensating Concrete; 301, Specifications for Concrete; 302, Construction of Floors; and 350, Environmental Engineering Concrete Structures.

David W. Knight is senior structural engineer with Lockwood Greene Engineers and Architects in Atlanta, Ga. He has 20 years of experience in all types of structural engineering, including specializing in writing computer programs and performing analysis and design of complex structures. Knight is a member of the STADD Steering Committee and is Chairman of the Graphical Interface Sub-Committee.

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