Epoxy-Bonded, Steel Fiber-Reinforced Thin Cementitious Overlay at Orlando International Jetport, Florida

RODNEY J. STEBBINS, CHARLES W. JOSIFEK, and JOHN D. JENIEC

ABSTRACT

The reasons for selecting an epoxy-bonded, steel fiber-reinforced, cement/fly ash, superplasticized thin overlay are discussed. Each project field application procedure from existing concrete preparation through project completion is also discussed. A total of 40,000 ft^2 was applied from 1.5 in. to 3 in. thick with no signs of delamination or visible cracking evident after testing at 90 days' maturity. To date, this is the largest project of its type in the state of Florida.

The structure that received the repairs is best described as an elevated cast-in-place structure that receives light-to-heavy vehicular traffic. The areas repaired (4 each of 10,000 ft^2) were the baggage unloading areas for major airlines. The experience gained on this project should provide assistance for future design, specifications, and construction for thin concrete overlays on suspended and elevated structures.

The project was accomplished in two phases. Phase 1 (10,000 ft^2) was completed in fall 1982. Phase 2 (30,000 ft^2) was implemented and completed in the fall of 1983 after testing Phase 1 for delaminations and cracking at 28 and 90 days, visual inspections, and chain dragging through fall and winter 1982, and spring and summer 1983.

PROJECT AREA AND DESCRIPTION OF PHYSICAL REQUIREMENTS

Orlando International Jetport is a recently constructed facility located south of Orlando, Florida. Four individual areas each measuring approximately 10,000 ft^2 required an application of thin overlay to correct or to reduce vibrations to the structure caused by small tractors pulling hard rubber-wheeled carts (used to transport baggage from the airplanes to the baggage unloading areas) rapidly over drain "crickets" that are cast into the floor. The anticipated structural deflection did not occur, thus requiring the engineer to modify the drainage crickets during construction from an original two-column pattern to a one-column pattern. Because the drains had been set at the designed elevation, the drainage angles became very pronounced. When the tractors and towed carts traveled the waves of crickets, they caused pronounced and unacceptable vibrations throughout the structure. The tractors and carts have hard rubber tires but do not have shock absorbers.

REPAIR DESIGN

Scarification to below-the-top reinforcing and placing new concrete was considered. However, it was dismissed due to the cost and customer inconvenience. An asphalt overlay was considered. However, it was dismissed as being a temporary repair. Rapid-setting concrete products were considered and were dismissed due to their lack of history in very thin cementitious overlay applications. A fear of high shrinkage and cracking was instrumental in dismissing these types of products. Epoxy mortars were considered for the complete overlay. However, economics dictated that this was not feasible.

The best solution for an overlay would require the following:

1. Positive bond to existing concrete,
2. Ability to place from 0 in. to 3 in. of thick concrete,
3. No crack propagation,
4. No delamination,
5. No excavation or demolishing of existing concrete,
6. Minimal construction time,
7. A reasonable dust-free environment to protect machinery and baggage, and
8. Mutual occupancy (contractor/airlines).

Steel fiber-reinforced concrete was selected. It has the ability to be placed easily, resist crack propagation, and it can be placed as thin as 1.5 in. thick without tremendous problems provided a good mix design is provided to the contractor. An epoxy (fresh to existing concrete) binder was selected through the results of slant-shear testing that would satisfy the positive bond and delamination requirements. Epoxy-bonded steel fiber-reinforced concrete as a composite system satisfied all of the foregoing needs except that the thinnest it could safely be applied was 1.5 in.

An epoxy mortar (epoxy and graded silica sand) was specified to be used from 1.5 in. to 0 in. Originally, feathering to zero was not allowed. The contractor was required to saw 0.5 in. deep and excavate an area 18 in. wide to provide a key. Subsequent testing proved the key was not necessary and the contractor was allowed to "featheredge" the mortars.

MIX DESIGNS AND PRODUCTS

Epoxy Fresh Concrete Binders

Products considered acceptable for this project were required to meet the following physical properties.

Physical Properties (Unmixed) at 25°C (77°F)
Component A (Resin)

- Weight per gallon, lb = 10.4±1
- Viscosity = 2,000-2,600 centimeters per second (cps)
- Specific gravity = 1.236-1.260
- Shelf life (closed containers) = 2 yr

Component B (Catalyst) at 25°C (77°F)

- Weight per gallon, lb = 8.3+0±0.1
- Viscosity = 150-180 cps
- Specific gravity = 0.984-1.008
- Shelf life (closed containers) = 2 yr

Physical Properties (Mixed) at 25°C (77°F)

- Weight per gallon, lb = 10.0
- Viscosity = 1,900-2,300 cps
- Specific gravity = 1.18-1.22
- Solids by weight = 100%
- Pot life = 26-32 min
- Mixing ratio =
  By weight--A = 84%; B = 16%
  By volume--A = 81%; B = 19%

Must Conform to ASTM C881-78, Type II Application = 12-15 mil

Concrete Substrate Temperatures

	86°F (30°C)	68°F (20°C)	32°F (0°C)
Contract time	1.5 hr	3 hr	18 hr
Bond strength	(ASTM C 882)	1,500 psi	

Epoxy Mortars

Physical Properties (Unmixed) at 77°F (25°C)
Component A (Resin)

- Weight per gallon, lb = 9.3±0.1
- Viscosity = 500-700 cps
- Specific gravity, gr/cc = 1.116±0.012
- Shelf life (closed containers) = 2 yr

Component B (Catalyst)

- Weight per gallon, lb = 8.2±0.1
- Viscosity = 150-250 cps
- Specific gravity, gr/cc = 0.984±0.012
- Shelf life (closed containers) = 2 yr

Physical Properties (Mixed) at 77°F (25°C)

- Weight per gallon, lb = 9.08±0.1
- Viscosity = 350-500 cps
- Specific gravity = 1.089±0.012
- Solids by weight = 100%
- Pot life = 20-25 min
- Mixing ratio =
  By weight--A = 80%; B = 70%
  By volume--A = 78%; B = 22%

Compressive: ASTM C109-75

- Age: at 25°C (77°F) = 7 days
- Compressive strength, psi = 10,000

Tensile: ASTM C190-72

- Age: at 25°C (77°F) = 7 days
- Tensile strength, psi = 1,090
- Must conform to ASTM C881--Type III

Mortar Mix Design

- Combined A and B = 16.69 lb
- Silica 20/30* = 50.09 lb
- Silica 30/65* = 50.09 lb
- Total weight per ft^3 = 116.87 lb
- Aggregate/resin ratio = 6/1

*The Standard Sand Company, Tampa, Florida.

Steel Fiber-Reinforced Concrete

Mix design for SFRC/yd^3

- Cement = 540 lb, Type I FM and MC (ASTM C150)
- Fly ash = 165 lb, Type F FM and MC (ASTM C618)
- Coarse aggregate = 1,323 lb, PM and MC Broco (ASTM C33)
- Fine aggregate = 1,433 lb, Jahna-Clearmont (Silica) (ASTM C33)
- Admixture = 54 oz, WRDA 79--Type D (ASTM C494)
- Admixture = 4 oz, WRDA 19--Type F (ASTM C494)
- Water = 282 lb
- Steel fibers = 100 lb, 2-in. corrugated
- Slump = 3-6 in.
- Air = 2-4%
- Unit weight = 142 lb
- Water-cement + fly ash = 0.40
- Field sampling = ASTM C172 and C31
- Strength testing = ASTM C94
- Laboratory testing = ASTM C39 and E329

Test Results

Epoxy Mortar Compressive Strength, psi--ASTM C109:

Days	No. 1	No. 2	No. 3	No. 4
3	8,100	8,500	9,400	4,250
7	8,525	9,250	9,550	5,000
28	10,000	10,000	10,500	6,625

Compressive Concrete Strength without Steel Fibers, psi--ASTM C39:

Days	No. 1	No. 2	No. 3	No. 4
3	5,447	5,200	5,412	5,412
7	5,766	5,695	6,615	5,730
28	6,200	7,782	7,711	7,888

Flexural Strength of Concrete Specimen with corrugated deformed steel fibers, psi--ASTM C293:

Days	No. 1	No. 2	No. 3
3	834	751	801
7	1,068	959	1,008
28	1,240	1,651	1,118

CONSTRUCTION PROCEDURES

Surface preparation is most important to assure bond. Steel wheel-cutter type machinery was used on the first 10,000 ft^2 with satisfactory results. The only undesirable feature was the time required for the preparation. The customer's baggage conveyor equipment precluded sand-blasting the concrete.

The surface needed to be textured or roughened to the extent that no laitance (cement paste) was evident and that the sand-aggregate particles were visible. Care was taken to prevent traffic or contamination on prepared surfaces. The remaining 30,000 ft^2 were prepared using a steel shot-blaster. This equipment allowed the contractor to prepare the concrete surface with considerably more speed than with the steel wheel-cutting type equipment mentioned previously.

THIN OVERLAY

Where the overlay was thinner than 1.5 in., the epoxy mortar was placed to the final grade with 1.5-in. wood forms lined with construction plastic to prevent the epoxy from sticking to the wood-forming materials. The mortars were sloped to the existing floor a distance from the form of about 2 ft. Initially, the contractor was required to saw into the existing concrete 0.5-in. deep and remove about a 12-in. wide section for the length of the epoxy mortar repair. However, after testing of the epoxy mortar in place, the engineer allowed the contractor to place the remainder of the areas without removing any material.

EPOXY MORTAR MIXING

The contractor mixed the epoxy mortars as follows:

1. Mix the A component.
2. Pour the B component into the A component mixture and mix until streak-free.
3. Pour in the 30/65 silica and mix until a homogenous mass is evident (maximum 2 min).
4. Pour in the 20/30 silica and mix until all particles are coated.

A 0.75-in. variable-speed drill motor was used with a Jiffy blade mixer. (Paddle mixtures cause segregation and do not blend the materials properly.) Plastic pails (5-gal size) were used to mix the epoxy mortars. Before placing the mortars, 10 to 15 mil of the mortar resin (neat and without aggregates) was painted on the concrete to prevent starvation of the mortar bond line. The mortar (epoxy with aggregates) was mixed and poured in place for screeding with a 2 x 4 board screed. No troweling was required.

The final finish was completed when loose 20/30 silica sand was broadcast into any standing pools or wet areas of mixed resin. This allowed the contractor to provide a nice blend of texture from the epoxy mortar to the concrete at the 0-in. line. Within 2 to 4 hours the forms could be stripped, and the fresh concrete bonder and the steel fiber-reinforced concrete could be placed using the epoxy mortar (at the 1.5-in. thick side) as a screed edge.

FRESH CONCRETE BINDER

The fresh concrete binder was mixed in 5-gal quantities by pouring the premeasured B component into the A component pail and mixing with the Jiffy mixer until streak-free. The binder was then poured in strips on the prepared concrete surface and squeegied to a thickness of approximately 0.015 in. (15 mil = $107 \pm ft^2$/gal).

Before the binder became "stringy" or "tack-free," the fresh concrete was placed right on the epoxy binder. No mixing of the epoxy and concrete was required. Had the epoxy been allowed to become stringy or tack-free, another application of 15 mil before 24 hr had passed would provide the originally desired results.

STEEL FIBER-REINFORCED CONCRETE (SFRC)

Elevations

The finished elevation was established with the use of pipe (screed rails) and threaded chairs. All final elevations were carefully established with a transit before placing the epoxy binder and SFRC.

Concrete

The mix design was provided by the manufacturer and the concrete was delivered to the project in transit trucks batched to a 2-in. slump. Superplasticizer was introduced into the transit truck before the fibers. The fibers were poured from bags into the transit mixer and mixed for 5 min. The SFRC was dumped into a 3-yd bottom dump bucket, craned up one story, and dumped into motorized Georgia Buggies, driven to the screed and placed. The superplasticizers allowed the concrete mix to be fluid enough with a slump of 8 in. to allow easy placing, screeding, and finishing. No balling of the fibers was evident. A vibrating screed machine mounted on standard 2 x 8-in. boards was used.

Internal vibration was not performed due to the depth of the overlay. No problems were encountered by the contractor in providing the owner/engineer a well-consolidated SFRC overlay mainly as a result of a combination of steel fiber and mix design selection, coarse and fine aggregate, gradation, cement/fly ash content, superplasticizer, and quality cement finisher personnel.

CURING

Hydration was carefully monitored because of fairly high cement content, depth of overlay, warm days, and warm substrates. The contractor elected to blanket the overlay with burlap, apply trickling water for curing, and to cover the burlap with construction plastic sheets. The water curing continued for 3 to 5 days.

EVALUATION

The first 10,000-ft^2 overlay has been in place more than 1 yr with the subsequent 30,000-ft^2 area in place for more than 120 days. To date, there is no evidence of delaminations or visible cracks. It is sufficient to state that the project is successful and that thin SFRC overlays can be placed easily and effectively yielding a "Monolithic Composite." All tests indicated that the anticipated results were achieved and that all specifications were easily met. The contractor completed each phase of construction ahead of schedule.

CONCLUSIONS

1. Thin (1.5-in.) overlays can be accomplished without complications by usual contractor personnel.
2. Epoxy mortars can be used as an effective material to overlay concrete from 0 in. to 1.5 in. without special aggregates or concern.
3. Epoxy-bonded SFRC overlays are an effective and economically feasible solution to resurfacing of suspended slabs for vehicular traffic.

ACKNOWLEDGMENTS

The following gentlemen provided their valuable expertise to the contractor, engineer, and material suppliers, and their contributions were instrumental in making the project a success: Milton D. Anderson, David W. Fowler, David R. Lankard, V. Ramakrishnan, John P. Roebuck, and R.M. Broley.