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UNITED STATES AIR FORCE RESEARCH ON AIRFIELD PAVEMENT REPAIRS USING PRECAST PORTLAND CEMENT CONCRETE (PCC) SLABS (BRIEFING SLIDES)

Athar Saeed, PhD, PE

**Applied Research Associates
P.O. Box 40128
Tyndall Air Force Base, FL 32403**

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**AIRBASE TECHNOLOGIES DIVISION
MATERIALS AND MANUFACTURING DIRECTORATE
AIR FORCE RESEARCH LABORATORY
AIR FORCE MATERIEL COMMAND
139 BARNES DRIVE, SUITE 2
TYNDALL AIR FORCE BASE, FL 32403-5323**

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USAF Research on Airfield Pavement Repairs Using Precast PCC Slabs



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*Athar Saeed, Ph.D., P.E.
Principal Engineer
Applied Research Associates, Inc.
August 20, 2008*



Background / Objective



- Background
 - Precast slabs are used for repairing high-volume highway rigid pavements
 - Repairs made at off-peak traffic times to be ready for normal traffic operations by next rush hour
 - Get in, do it **right**, get out, and stay out
- **Needs**
 - Rapidly and efficiently repair rigid airfield pavements with minimal impact on aircraft operations
- Research Objective
 - Assess/understand state-of-the-art
 - Evaluate competing technologies
 - Prepare ETL and technology transfer

AFRL is developing a method for contingency rigid pavement Portland cement concrete (PCC) slab repairs using precast PCC slab panels. AFRL is leading the technology development by critically reviewing the research conducted to date in this arena by the air force and the highway and civil aviation agencies and adopting the techniques for Air Force needs. The repairs must be made at off-peak traffic times (often at night), and the airfield must be ready for aircraft operations by the time of next high operations tempo which might be within six to eight hours.

The research objective is to critically review the pre-cast slab repair research conducted to-date by AFRL and to optimize the equipment, materials, and techniques for precast slab repair including technology transfer activities including, but not limited to, training, reports and preparation of ETLs.



Advantages / Concerns

- Advantages
 - Precast panels can be cast and cured under more controlled conditions resulting in higher-quality concrete
 - Precast panels can be stored on or off site until needed
 - Repairs with precast panels can be made under a variety of weather conditions.
 - Aircraft operating surfaces can be opened to aircraft operations without waiting for the concrete to mature
- Concerns
 - Load transfer
 - Non uniform support
 - Poorly fabricated precast panels
 - Roughness from poor field installation

The use of precast concrete slabs for repair of PCC pavements is perceived to have several advantages over the conventional cast-in-place slab replacement method, including, but not limited to, the following:

Precast panels can be cast and cured under more controlled conditions resulting in higher-quality concrete.

Precast panels can be stored on or off site until needed.

Repairs with precast panels can be made under a variety of weather conditions.

Aircraft operating surfaces can be opened to aircraft operations without waiting for the concrete to mature.

Several concerns related to the using precast panels for slab repair include the following:

Lack of load transfer. The Air Force's rigid pavement thickness design procedure assumes 25 percent of the aircraft-induced normal stresses at a joint are transferred to the adjacent slab across the joint through mechanical means such as dowel bars, aggregate interlock, etc.

Non-uniform support (voids) beneath the panels can result in stress concentrations and rocking of panels.

Poor workmanship of field cast panels.

Surface roughness resulting from poorly-installed panels.



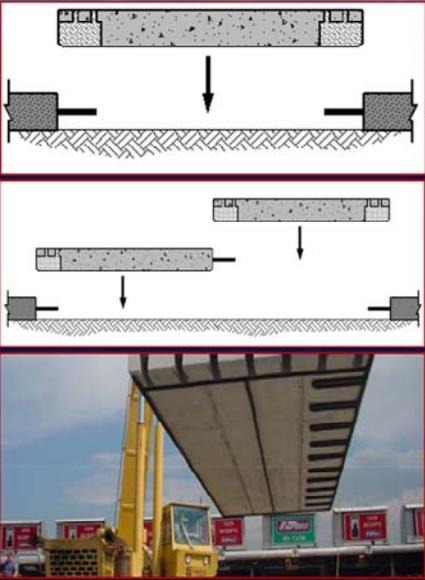

Repair method	Application type	Load transfer	Base support	Patent protection
Super-Slab®	Single or connected panels	Dowels inserted into the existing pavement	Manufactured sand followed by grouting	Yes
Michigan DOT	Single panel	Dowels cast into the precast panel	Flowable fill	No
URETEK	Single or connected panel	Fibreglass ties inserted after the precast panel is placed	Grouting using injected polyurethane foam	No
Other	Single or connected panels	Dowels inserted after the precast panel is placed; other means	Any of the above	Possibly

A literature review and contact with other agencies indicated that achieving load transfer is a critical aspect of successful performing repairs using precast slabs. The most common repair methods using single panels or several connected precast panels employ different means to ensure load transfer. Current procedures to repairs using precast slabs include the Fort Miller Super-Slab® Method, the Michigan Method, and the URETEK Method. There are other methods which are basically variations of the three preceding methods. The main characteristics of the repair methods using single panels or several connected precast panels are summarized here.





- Unique features
 - Precast slab
 - Support material
 - Precision leveling and screeding
 - Grout distribution



The Fort Miller Super-Slab[®] Method is a patented proprietary method. The characteristic features of the Fort Miller Super-Slab[®] Method is the method in which the precast panel is tied to the existing pavement and the type of bedding used to support the precast panel. The Super-Slab[®] panel is manufactured with slots in the bottom of the slab. The slots are on the transverse joint faces and are used to accommodate load transfer dowels that have been pre-installed into the existing pavement. The precast slabs are installed on a thin leveling course of crusher screenings (manufactured sand). If several of the precast panels are connected, dowel bars and slots are cast alternatively at the transverse joints.

 **Michigan Method** 



- Unique features
 - Self leveling flowable fill
 - Single slab repair
 - Dowels for load transfer



- Unique features (cont.)
 - Preinstalled dowels
 - Dowel slots in existing slab
 - Limits on repair area
 - Flowable fill

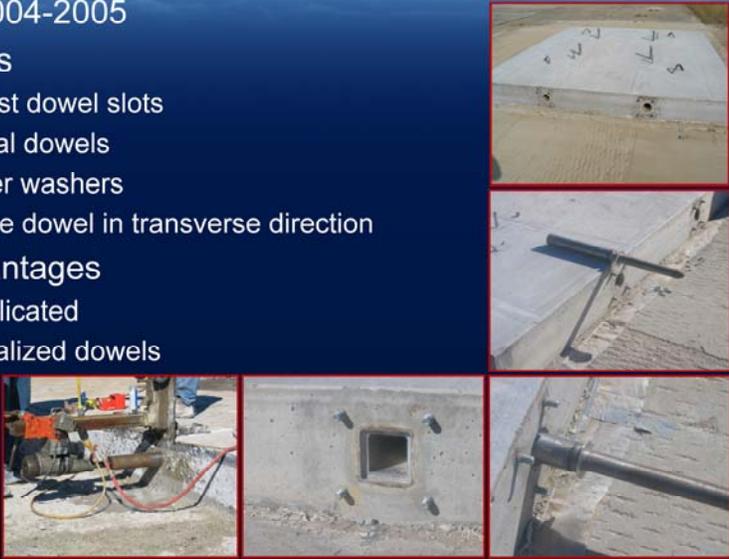
The Michigan method, developed and used by Michigan Department of Transportation, uses single precast panels to carry out full-depth repairs of highway concrete pavements. The panels are typically 1.8 m (6 feet) wide and 3.66 m (12 feet) long. The length of the panels corresponds to the typical width of older PCC pavements in Michigan. The panels are manufactured with load transfer dowel bars installed, which fit into the slots cut out in the existing pavement.



The URETEK method injects polyurethane foam through the portholes in the precast panel in order to provide bearing support for the panel and to lift the panel to the desired grade. After the precast panel is placed and lifted to the desired grade, panel is tied to the existing PCC pavement using fiberglass-reinforced polymeric inserts.

 **AFRL Pin Load Transfer**  THE AIR FORCE RESEARCH LABORATORY
LEAD | DISCOVER | DEVELOP | DELIVER

- Circa 2004-2005
- Features
 - Precast dowel slots
 - Special dowels
 - Spacer washers
 - Square dowel in transverse direction
- Disadvantages
 - Complicated
 - Specialized dowels



Load transfer between the existing pavement slabs and the precast slab is probably the most critical variable governing the success of the repair. Dowel bars are the preferred method for load transfer. The dowel bars can be integral to the precast slab where they are tied to slots in the existing slab using a rapid setting concrete material. An alternative method, illustrated here, has the dowel bar in a metal jacket; the dowel bar is pushed into position using grout pressure after the precast slab has been raised to the desired grade.



Experiment Design



1. Removing distressed area
2. Manufacturing precast slab
3. Installing precast slab





Slab Leveling Technique			
		Mud Jacking	Foam Injection
Load Transfer	AFRL Pin	X	
	Cast Dowel		X

It is important to prepare the distressed area so that the precast slab can be lowered in properly. There are several saws available that could easily cut the area to the precast slab dimension. However, these have to be precise cuts ensuring that the area must be a perfect square or rectangle fitting the precast slab dimensions. Also, the cuts have to be perfectly vertical so the precast slab can be lowered in place.

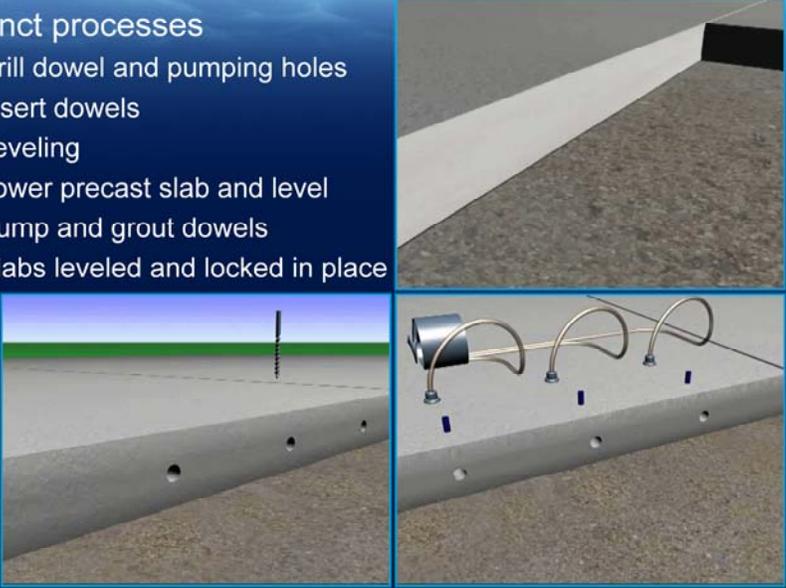
The typical concrete Soff-Cut® saw or walk-behind saw cannot provide cuts in straight lines even with an experienced operator under ideal conditions. AFRL has successfully tried a wall-saw setup where the saw travels on tracks providing perfectly straight cuts that are truly vertical. The wall-saw setup is uses hydraulic power to operate and needs a water supply to keep the saw blade from overheating.

Casting a standard size slab and installing it properly is the key to success for repairs using precast slabs. The concrete mix and the ability of the form to retain its size and shape during concrete pour and curing appear to be most critical.

The techniques to jack the slab to grade using mud jacking or polyurethane foam are being investigated. Mud jacking involves using a flowable fill to level the prepared ground before the slab is lowered in place than jacking the slab to the desired grade by pumping the same flowable fill material under pressure. Jacking the slab to the desired grade using polyurethane foam is slightly more involved. It requires that holes be drilled to pump the polyurethane material under the slab as well as weep holes to ensure that the material has been distributed uniformly.

 **AFRL Pin Load Transfer** 
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LEAD | DISCOVER | DEVELOP | DELIVER

- Distinct processes
 - Drill dowel and pumping holes
 - Insert dowels
 - Leveling
 - Lower precast slab and level
 - Pump and grout dowels
 - Slabs leveled and locked in place



This slide illustrates AFRL's thinking for an innovative methods to achieve load transfer between the precast panels and the surrounding slabs. The advantage of this method is that the precast slabs do not contain dowels, so they are easier to handle. The method begins with drilling dowel and grout injection ports into the existing slab. The precast panel is then lowered into place, and grout is injected into the ports to push the dowels into the precast slabs. The panel is then grouted into place .

 **AFRL Pin Load Transfer** 
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LEAD | DISCOVER | DEVELOP | DELIVER

- Alternate Method
 - Preinstalled dowels
 - Move dowels using foam injection
 - Pump and grout dowels
 - Problems with dowel movement



Load transfer between the existing pavement slabs and the precast slab is probably the most critical variable governing the success of the repair. Dowel bars are the preferred method for load transfer. The dowel bars can be integral to the precast slab where they are tied to slots in the existing slab using a rapid setting concrete material. An alternative method, illustrated here, has the dowel bar in a metal jacket; the dowel bar is pushed into position using grout pressure after the precast slab has been raised to the desired grade.

 **Alternate AFRL Approach**  **AFRL**
THE AIR FORCE RESEARCH LABORATORY
LEAD | DISCOVER | DEVELOP | DELIVER

- Combine
 - Dowels load transfer
 - Dowels inserted in precast slab 12 inch c/c
 - Slots in exiting slab to accommodate dowels
 - Foam injection to level the slab
- Grout dowels in place
 - Fast setting grout



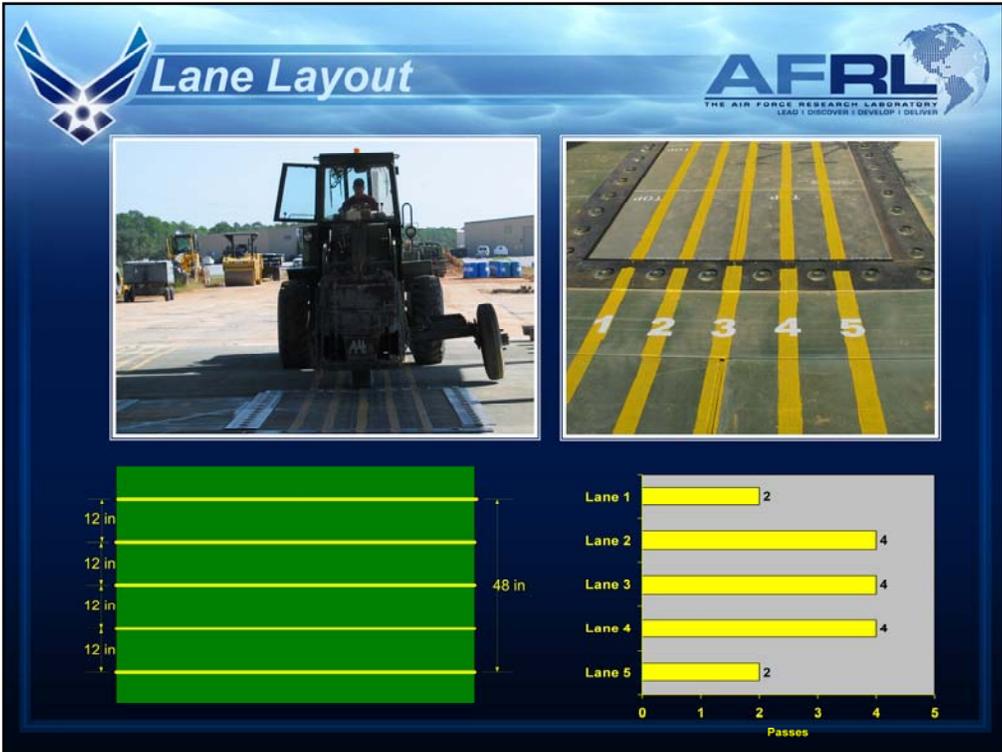
The use of precast panels is an alternative rehabilitation treatment to the use of cast-in-place slabs for full-depth repair of concrete highway and airfield pavements. Full-depth repair of PCC pavements is a rehabilitation method that involves the removal of an entire slab, or a substantial portion of the entire slab (full-depth), the installation of load transfer devices, and the replacement of PCC material. The objective of the repair is to restore smoothness, the structural integrity of the pavement, and to arrest further deterioration.

 **Field Testing** 

- Accelerated loading
 - F-15E load cart
 - 315 psi tire pressure
 - 35,200-lb total wheel load
 - Trafficking
 - 1,500 passes or failure
 - Loading normally distributed across 48-inch “wander” width in 5 lanes spaced at 12 inches center to center
 - One pass will be defined as one half circuit of the test section
 - Data collected after 0, 112, 256, 512, 752, 1008, 1248, 1504 cycles
- Heavy weight deflectometer testing
 - Load transfer
 - Before and after repairs and during trafficking



The optimized procedures will be evaluated and confirmed with the help of field trials. The field trial would include installing the precast slab and loading with the F-15E load cart. The load transfer efficiency of the joint was measured using the heavy weight deflectometer before removal of the original slab and will be measured periodically during field tests after application of 0, 112, 256, 512, 752, 1008, 1248, 1504 cycles.



The repairs will be trafficked with AFRL's F-15E load cart using the loading pattern shown here. This loading pattern is used by AFRL and ERDC for the F-15 load.



Data Collection Plan



- Load transfer
 - Before slab removal (see below)
 - After installation of the precast slab
 - During F-15E load cart trafficking
- Failure
 - Shattered slab (3 or more pieces)
 - $LT \leq 25$ percent
 - $LTE_{\delta} \leq 70$ percent




LT and LTE of AFRL Test Pad

LT %	44 Removed	48 N	50 Removed	47
LTE %	90	93	93	93

The failure criteria would be the precast slab breaking into three or more pieces (shattered slab) or the load transfer efficiency reduced less than 25 percent.



Failure Definitions



- Load transfer efficiency
 - Deflection based, LTE_{δ}
 - Stress based, LTE_{σ}
- Load transfer
 - Stress based, LT
- Shattered slab
 - 3 or more pieces

$$LTE_{\delta} = \frac{\text{Deflection}_{\text{unloaded slab}}}{\text{Deflection}_{\text{loaded slab}}}$$

$$LTE_{\sigma} = \frac{\text{Stress}_{\text{unloaded slab}}}{\text{Stress}_{\text{loaded slab}}}$$

$$LT = \frac{\text{Stress}_{\text{free edge}} - \text{Stress}_{\text{loaded slab}}}{\text{Stress}_{\text{free edge}}}$$

$$= 1 - \frac{\text{Stress}_{\text{loaded slab}}}{\text{Stress}_{\text{free edge}}}$$

$$LT = \frac{LTE_{\sigma}}{1 + LTE_{\sigma}}$$




Load transfer efficiency can be defined as a function of deflection and stress. Relationships exist to convert from deflection –based definitions to stress-based definitions. In the DoD airfield design criteria, load transfer is defined as that portion of the edge stress carried by the adjacent slab.

Shatter slabs are a common criteria for determining failure of a rigid pavement. Shatter slabs occur when the fatigue life of the pavement has been used up by repeated aircraft loadings.

 **Path Forward** 

- Precast slab installation
- Slab leveling
 - Foam injection
 - Mud jacking
- Accelerated load testing
- Engineering technical letter



Casting a standard size slab and installing it properly is the key to success for repairs using precast slabs.

The techniques to jack the slab to grade using mud jacking or polyurethane foam are being investigated.

The optimized procedures will be evaluated and confirmed with the help of field trials.

AFRL will produce a final technical report. The final report will also be formatted as an ETL for dissemination by AFCESA.