Findings and Recommendations from AAPTP 04-01, Developing Rubblization Guidelines for Airport Pavements

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SWIFT Conference in Toronto, CA
Sept 17th, 2009
Presentation Outline

• Introduction to Rubblization
  – Two Airfield Projects in 2002 on Thick PCC Slabs

• Findings from Project 04-01
  – Thickness Design Considerations
    • Structural characterization (E)
    • Minimum HMA overlay thickness
  – Assessing Project Feasibility
    • For <9” PCC with weak or no base
  – Recommendations for “Marginal” Candidates
  – Other Recommendations
What is Rubblization?

• Fracturing techniques that:
  – Rubblizes PCC slabs into high quality agg. base
  – Eliminates slab action and other inherent distresses
    • Reflective cracking
    • D-cracking and ASR
    • Slab rocking, pumping, curling, etc.
  – Destroys bond between concrete and any steel
• Converts failed rigid system into new flexible one
• Two distinct methods and equipment types:
  – Multiple Head Breaker (MHB)
  – Resonant Pavement Breaker (RPB)
State DOTs Adopt Rubblization

- Predominate PCC rehab technique for U.S. highways since early 1990s
- From 1994 - 2004, > 50 million sq meters rubblized
  - In over 35 states
  - Market shared evenly between MHB and RPB
- Slab thicknesses generally between 20-30cm (8-12in)
- Lots of good industry references, studies, etc.
• 30 airfield projects in US through 2006
  – Shared between MHB and RPB
• PCC thicknesses range from 6 to 26 inches
  – Initial questions about very thick slabs
Rubblization Process with MHB at Selfridge ANGB w/ 21” thick PCC, 2002

- Edgedrains and Cross Underdrains
- Pre-fracture
- Rubblize
- Test Pits
- Rolling
- Aggregate Leveling Course
- HMA Paving
Pre-fracture Equipment

• Precede MHB to ensure full depth fracture
  – Typically only necessary for PCC >14in
  – Sometimes for PCC with interface (rigid overlays)
  – Spacing affects max size
    • Spec compliance
Rubblize Selfridge with Multi-Head Breaker
16-Hammer Configuration
Video of MHB and Guillotine Hammer
Selfridge Test Pit

agency approval before full scale rubblization
Z-grid Roller at Selfridge

- 14-ton vibratory modified steel drum
- Breaks flat & elongated pieces and reduces particle size at surface
- Two passes
Leveling Course and Paving at Selfridge

Aggregate Leveling Course
- Only necessary for grade and profile changes
  - Can’t fine grade rubblized surface
- Variable 4-in thick layer

HMA Overlay
- 7-in thick
- Placed in three lifts
Completed Selfridge RW

85,000 SYs rubblized in 16 days (5300 SY / day)
RB-500 at WPAFB in 2002 w/ 26” thick PCC

- 2000 lbf blows @ 44 cycles/second
- < 1 inch amplitude
- 9-12 inch wide passes
Video of RPB Close-up @WPAFB
Test pits at WPAFB confirmed:

- Complete slab destruction full depth (26 inches)
- Nominal max particle size: 12 inches
Current Guidance and Specs for Airfield Rubblization

- Air Force ETL 01-09
  - Uses guide spec in Asphalt Institute’s MS-17
    - Published in 1999

- FAA EB 66, Rubblized PCC Base Course
  - Published in 2004
  - Has particle size criteria from test pit
  - Allows either type equipment
Characterizing Rubblized Material - Background

- Airfield Engineers Always Assumed Rubblized Equivalent to Crushed Agg Base (CAB), P-209
  - Stiffness Modulus ($E_{rub}$) = 50 - 60 ksi
  - $CBR_{rub} = 100$
- Literature Suggests This is Conservative
- O4-01 Approach
  - Reviewed Literature for Back-calculations of Rubblized
  - Performed New Back-calculations on Several Projects
  - Examined Data for Relationships to Predict $E_{rub}$
What Does the Industry Suggest for a Modulus Value of Rubblized PCC?

• Witczak Study (1992)
  – 22 sections, range of 200-700 ksi, avg of 412 ksi
• Asphalt Institute MS-17 (1999)
  – At least 250 ksi
  – Range of 30-300 ksi
  – 150 ksi
Projects Where Rubblized Modulus Values Were Obtained

- From Literature
  - Selfridge ANG Runway
  - Niagara Falls ARS Runway
  - Illinois I-57
  - Indiana US 41
  - Detroit Metro Airport Trial
  - FAA’s NAPTF

- New Backcalculations
  - Texas US 83
  - Michigan I-75
  - Illinois LTPP Sites

- Data represents the wide range of factors possible: slab thickness and type, equipment and effort utilized, support conditions, etc.
- Several projects had more than one unique section.
Conclusions on Material Characterization

- Data range of in-service $E_{rub}$: 100 to 430 ksi
  - Avg of 205 ksi
- $E_{rub}$ closer to HMA base than CAB
  - For CBR designs: consider equivalency factors
    - 10” Rub = >10” CAB (CBR=100)
  - For Layer-Elastic designs
    - PCC 6-8” thick: 100-135ksi
    - PCC 8-14” thick: 135-235ksi
    - PCC >14” thick: 235-400ksi
- Larger PCC pieces, steel, interlock produce higher $E_{rub}$
Other Findings Regarding Material Characterization

• Four (of 4) Projects Show Trend of $E_{rub}$ Increasing w/ Time
• $E_{rub}$ Dependent On Rubblization Effort
  – Repeated Runs Of Either Equipment Type Reduces $E_{rub}$.
• No Change In Subgrade Moduli Before/After Rubblization
• No Consistent Differences in $E_{rub}$ between Both Equipment Types
Minimum HMA Overlay Thickness Recommendations

- If HMA Placed Directly Over Rubblized Material
  - 5 inches Minimum HMA
    - Minimum 2 lifts, but 3 preferred (for smoothness)
    - 1st Lift Minimum is 3 inches (to achieve density)

- If Unbound Material Directly Over Rubblized
  - Use Existing Minimum HMA Thickness Criteria for Placing Over that Material (RAP, CAB, Etc)
    - Typically 3 or 4 inches

- Structural Design May Require Greater HMA Thicknesses
Assessing Suitability of Project for Rubblization

- Not All Pavements Are Strong Candidates
- Marginal Candidates Are Thin Slabs (< 9”) With Poor Underlying Support
  - Thin to No Subbase or Thin Select Fill
  - Weak Subgrade (often saturated)
  - Typical of WWII Built (Now GA) Airfields
  - Issue Demonstrated on Three Runway Projects
    - Pratt KA, Kegelman OK, Tullahoma TN
  - 13 of the 30 Known Airfield Rubblization Projects were ≤8” PCC.
Pratt RW, KS

- 6” PCC, virtually no subbase, subgrade CBR of 2-4
- Spec required RPB
- Edge drains installed but no water ever drained
- Rubblization started OK on edge, but problems as moved toward centerline
Pratt RW

- 45% of first phase required full depth patching
- Project engineer said he would rubblize again under same conditions
Kegelman Auxillary Field, OK

- 5”-6.5” PCC, 0-4” sand subbase, clay subgrade
- RPB required
- Poor drainage and “couldn’t afford” edge drains
- No punch-thrus but excessive rutting (>2”)
- 30% of project had full depth patches (2-4’ in subgrade)
Tullahoma TN Airport RW

- Built During WWII
- 7.25” PCC Over Clay Subgrade
- CBRs Reported of 4 to 12
  - Variable levels of moisture and strength
- Currently Closed (Opportunity!)
- Design Called For Rubblization With 6” CAB and 5” HMA Overlay
- Suggested Trial Demo With Both Types Of Rubblization Equipment Before Project Let
Start-up of MHB, normal ht (24”) and spacing
MHB “Modified” Rubblization Process (low drop ht – 16”, large spacing – 10”) Produced Acceptable Surface, But Did Not Meet Criteria
Close-up of Same Test Pit from MHB “Modified” Rubblization
Typical PB-4 Sections (rutting, poor breakage)
Best PB-4 Sections (Dryer Subgrade)
Assessing risk of having inadequate structural support for effective rubblization (resulting in inconsistent breakage, large and shifting PCC particles, punch-thus or rutting from construction equipment).
Information to Assist with Risk Assessment Protocol

- Plans
  - Pavement structure and features
- Visual Inspection
  - Pumping and poor drainage
- GPR
  - Global look for trapped water and feature changes
- FWD
  - Range of subgrade modulus (high and low spots)
- Coring and DCP
  - PCC and base thicknesses, layer CBRs
Example of Identifying Unstable and High Risk Areas
Recommendations on Avoiding Problems for Marginal Candidates

• Conduct assessment protocol before starting
  – profile of relative risk over entire project
  – % of high, medium and low risk areas

• Install edge drain system before rubblization
  – Exceptions: one already exists/functions or self-draining subgrade
  – Eases rubblization, improves long-term performance

• Avoid wet season for rubblizing

• Proof rolling very important, especially with MHB
  – Don’t want to find weak spots when paving starts
Other Recommendations for Marginal Candidates Only

- Consider trial demo
  - Both RPB and MHB?

- Consider provision for “Modified” Rubblization
  - Waive particle criteria

- Consider other design options
  - Conventional Crack and Seat
    - Retains more of the PCC support

- Separate bid item for full depth patching
  - Provides competitive price
Cracking/Breaking PCC Pavement

- Al’s MS-17 Manual
- Other references
Other Recommendations for Marginal Candidates Only

- During rubblization
  - If saturated subgrade, turn vibrators off when rolling rubblized
- Especially with first lift of HMA:
  - No belly dumps and windrows
  - Keep trucks or MTVs on adjacent unbroken PCC or new HMA
    - Easier on airfields
  - Use tracked pavers
- Keeping Perspective
  - In Literature Review of 30 Airfield Projects, 13 were on PCC slabs ≤8”. 10 of those 13 did not reveal this issue in any significant way.
Other Items

- Must mill All HMA before rubblization
- Edge drains
- Isolation cuts
- Test strips and test pits
# 57 Open Graded Stone

3 % Slope Outlet Pipe

Filter Fabric

# 57 Open Graded Stone

3 % Slope Outlet Pipe

Subdrain Pipe

Shoulder Area

HMA

Permeable Zone of Rubblized PCC

Less Permeable Zone of Rubblized PCC

Subbase

Subgrade
Isolate Adjacent Pavements Not To Be Rubblized

Protect structural integrity of adjacent pavement with:

- wheel saw relief trench, or
- two parallel diamond blade saw cuts
Quality Assurance

- Test Strips
- Test Pits
- Particle Size Criteria
Test Strips

• For contractor to demonstrate effective rubblization and rolling practices
• Provides area for test pit
• Minimum: 300 ft long by one slab width
• New test strip for each unique feature
Test Pits

• Excavate after all fracturing and rolling within test strip
• Include a transverse and longitudinal joint
• Determine if spec criteria is met
  – Full depth fracture
    • Particle size criteria (next slide)
  – Steel “substantially” debonded
    • Dowels can be sawed
• At free edges, allow larger PCC pieces
  – Due to lack of support
Particle Size Acceptance Criteria

- Upper half of slab
  - All particles < 6”
  - 75% of material (by weight) < 3”
- Bottom half of slab or below steel
  - All particles > 2x slab thickness
Significant Non-finding from AAPTP 04-01

• No documented instance found in literature of any reflective cracking on any rubblization project
  – Hundreds of Highway Projects
  – Over 30 Airfield Projects
  – Totals over 50 Million SYs of rubblization
  • Dating back into the early 1990s
Airplanes Love Rubblization