THEORY VERSUS REALITY IN CONCRETE AIRFIELD PAVEMENT ENGINEERING

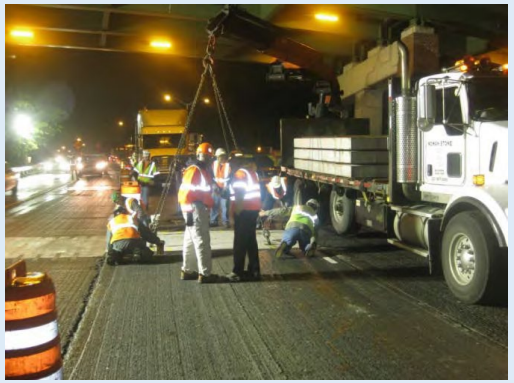
Presented for the Shiraz Tayabji Honorary ACI Session

Ray Rollings
Beaufort SC

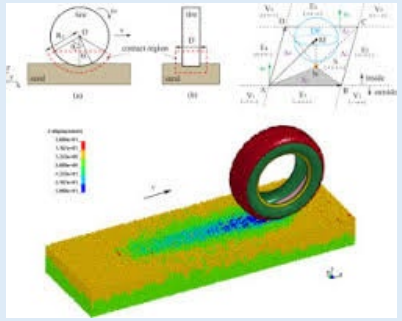
SHIRAZ TAYABJI

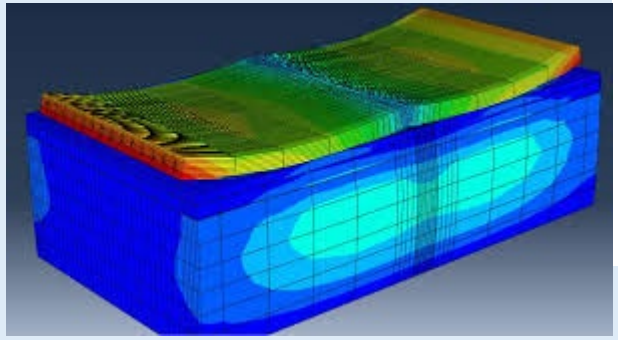
- Professional Colleague
- Collaborator
- Friend

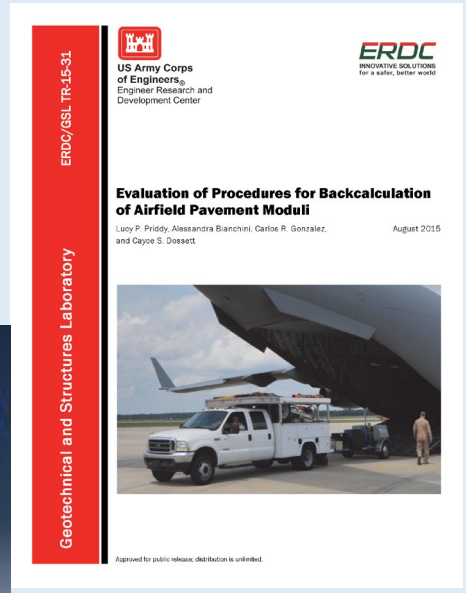
But above all Shiraz is a master practitioner of the black art of concrete pavement engineering



WE LIVE IN A HIGH TECHNOLOGY ENVIRONMENT!







QUESTION: DOES ALL OF THIS TECH REALLY HELP AVOID FAILURE IN THE FIELD!?

TODAY'S PRESENTATION

- Let's look at three failure case studies and the fundamental issues that underlie these failures.
- This is not a knock on technology; technology is an engineering godsend but …
- I would like to challenge us today with the thought that the failures that I really see in the field are overwhelmingly:
  - Human related
  - Failure to do what we already know how to do
  - In our arrogance, we sometimes forget Mother Nature has a say in what happens
- I am seldom invited to a job that has gone well; hence my view may very well be skewed!

Shiraz has always been a pragmatist so I will welcome his thoughts at the end.

Ali Al Salem Airbase, Kuwait

- 1,000’ keel of runway replaced
- 16” thick, conventional DOD design for medium load airfield
- Returned to operation 17 Dec. 2013; cracks appear Feb. 2014
- Claimed Failure Causes:
  - Military const. agent blames Gatch (local silty sandy soil w/evaporites) used as base & too weak
  - Contractor’s AE blames faulty design

INEXPERIENCED CONTRACTOR

- Formed the job and placed by hand
- Placed in checkerboard pattern
- Doweled all construction joints

  (i.e., all four sides)
- Government QA inspectors infrequently on site and inexperienced, i.e., the contractor has a free rein

SERIOUS PROBLEM
PAVEMENT CLOSED TO A/C

2016 photos by USAF
316th Air Expeditionary Wing

FURTHER INVESTIGATION

English specification for *greased epoxy-coated dowel bar* became in Arabic *dowel inserted in grease-filled plastic pipe*

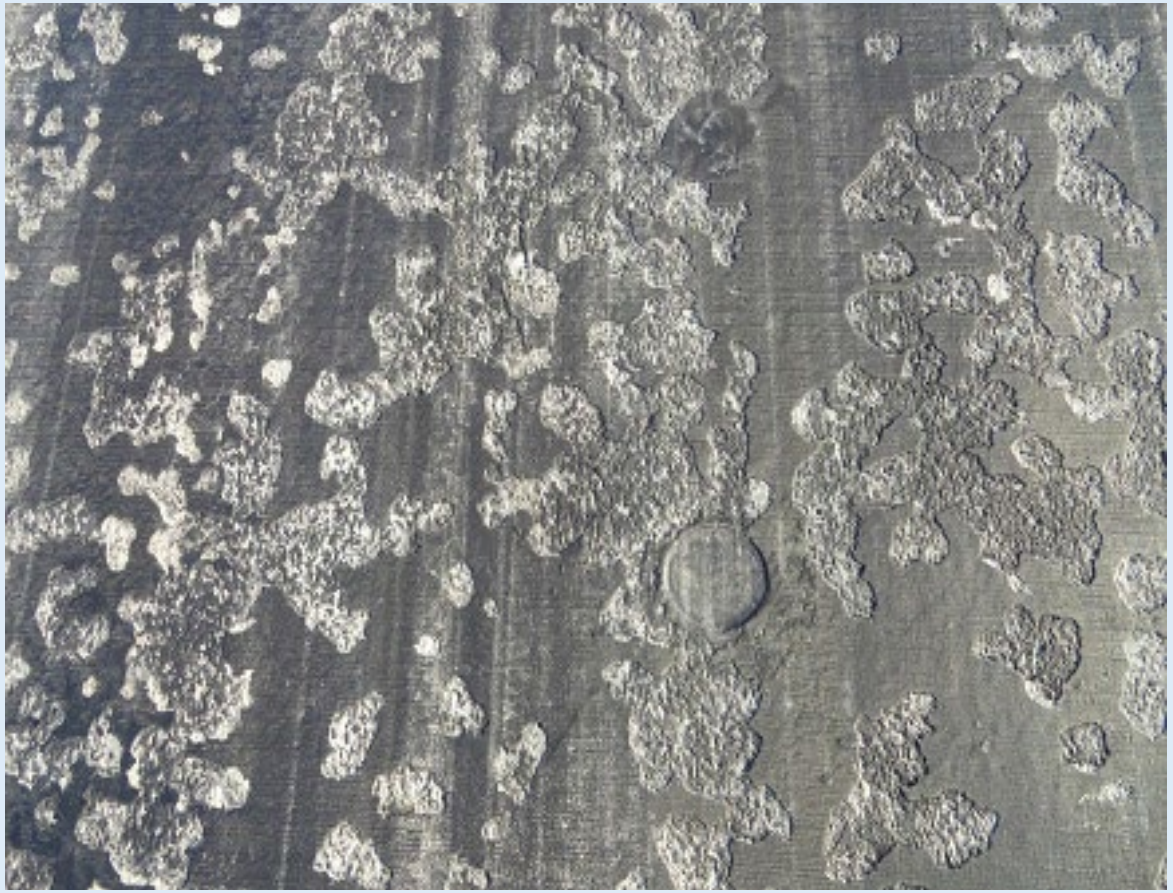
RESULTS & OBSERVATIONS

- F-15s flew combat missions without full fuel & munitions load
- Cracks – structural, lack of load transfer (design used 25%)
- Runway keel “re-replaced” 2018
- Why did this failure happen?
  - Contractor inexperience
  - Translation issues
  - Lack of QA/QC
  - Inexperienced government QA, project engineer, & manager (construction side of the house)

MANAS AIR BASE, KYRGYZSTAN

- Shared Runway with Int. Airport
- Primary USAF Mission
  - Logistical support to Afghanistan (C-17)
  - Refuel combat aircraft over Afghanistan (KC-135)
- Replace & extend 3,000 ft ends of runway with new concrete pavement
- To be built as two successive phases in subsequent years

EXTENSIVE SCALING DEVELOPS ON PHASE I



DEVELOPMENT

- 18 Aug. 2012 – phase 1 runway end opened to traffic
- Immediately minor scaling appears in touchdown areas
- Worsens during 2012-2013 winter
- Appearing in both trafficked and untrafficked areas
- Traffic suspended from damaged areas (last 3,000 ft of runway) because of FOD hazard

INVESTIGATION

Standard DOD UFGS Except for

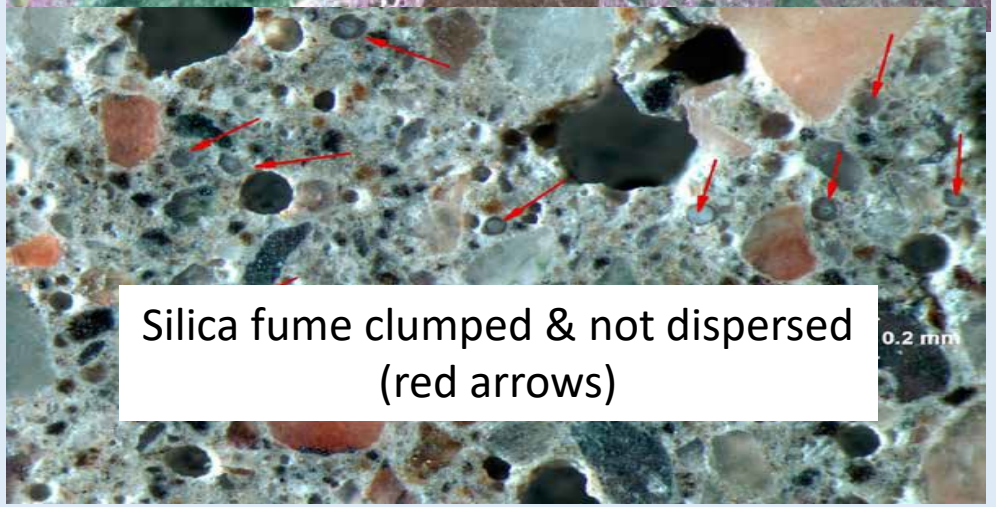
- Silica Fume (SF) required
  - One DOD office requires SF in paving
  - Also needed here for ASR mitigation
- 4% air required in specification
  - DOD UFGS would require 6% here
- Concrete spec. copy of one used in Southwest Asia (gov. design error)
- Wet cure required for SF, poorly executed (QA/QC construction error)

USAF Field Investigation

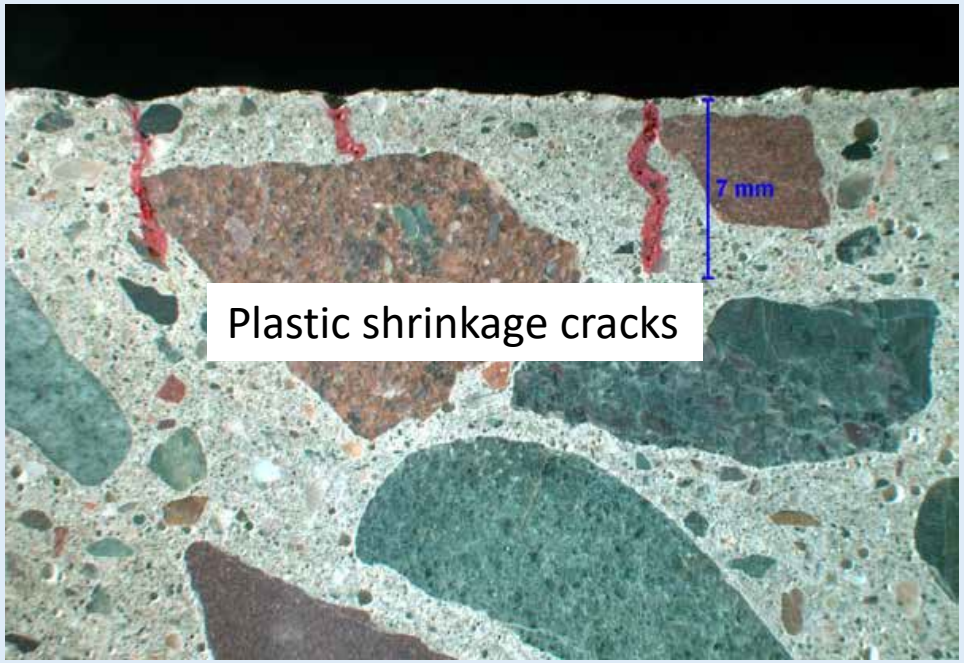
- Most of scaling $\leq$ 6mm deep
- Max scaling depth 7.5 mm
- Popouts 1 to 5 per slab
- Significant FOD hazard to aircraft
- Visible plastic shrinkage cracks
- Cores taken for petrographic evaluation

PETROGRAPHIC EXAMINATION

6-mm thick weak, carbonated surface paste
(range 1-9 mm thickness)
Upper 25 mm readily absorbs water



Silica fume clumped & not dispersed
(red arrows)



Plastic shrinkage cracks

Poorly cured surface of silica fume concrete left a Thin, weak, nondurable surface paste that crushed under aircraft (initial prewinter scaling) and suffered damage from freezing and thawing in the 1st winter

GOVERNMENT 4% AIR CONTENT SPECIFICATION ERROR

Total Air, %	Spacing Factor, in.
2.3	0.012
2.9	0.010
4.3	0.009
3.0	0.008
4.8	0.008
5.1	0.008
7.3	0.005
7.8	0.004

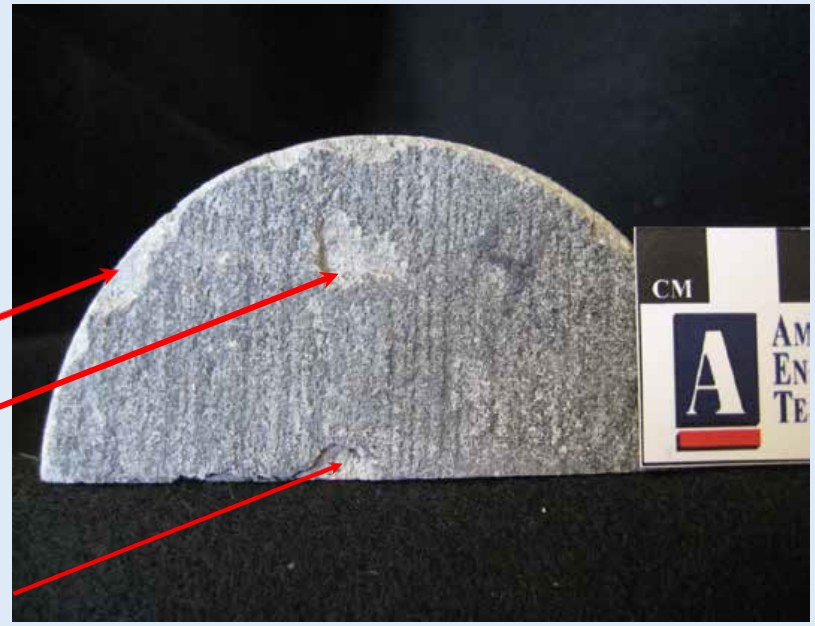
Spacing Factor Criteria

Fail

Border-line

Pass

- ASTM C-666 Accel. F-T Tests
  - Weight loss at 301 cycles <0.5%
    - <4.0% ~ DFE>80%
    - Despite questionable spacing factor probably have F-T resistant PCC

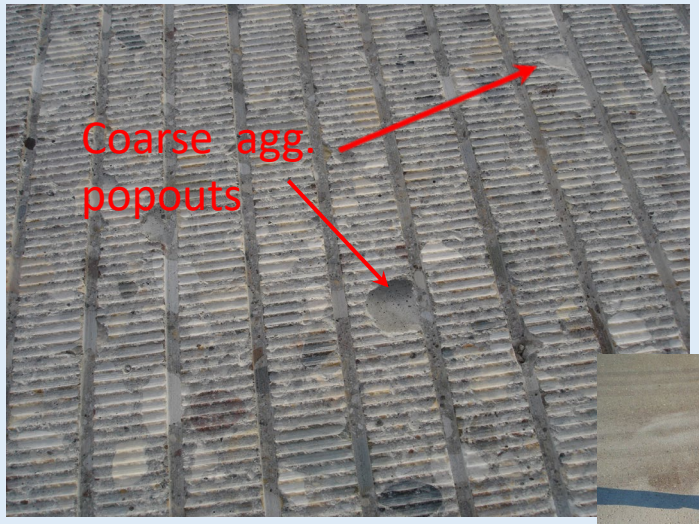


Despite passing test to 301 cycles thin mortar surface scales off as early 23 cycles

SOLUTION?

- Grind 6-mm from surface to remove failing surface paste
- US subcontractor brought in
  - Surface smoothness out
  - Some scaling areas missed
  - Some grinding > 20mm
  - Popouts appearing
  - Revealed widespread wood & clay balls
  - Same contaminants in sand stockpiles to be used in phase II

- Why we limit grinding to 6-mm



Laughlin AFB, TX
25-mm deep grind

MANAS AB IMPACT

- More C-17 and KC-135 missions needed to meet Afghan logistical and refueling combat missions
- Phase II canceled as contractor showed no ability to meet specification
- Inferior runway construction infuriated local Kyrgyzstani officials
- Added to tensions that led to air base lease not being renewed the next year
- Cause of the problem: Inadequate construction skill, inadequate QC/QA, and poor specification preparation

HOLLOMAN AFB, NM

- Site Conditions
  - Fluctuating high water table
  - High sulfate content soils & ground water
  - 24” fill and Type V cement standard requirement on base
- GAF 1 project: extend apron & add hanger
- Another project removing 5- to 38-year old concrete pavements on base
- Removed pavement structurally inadequate for new mission but in good shape and all made with Type V sulfate resistant cement
- Removed pavement crushed to base course gradation and placed 24- to 60-inches thick under all GAF 1 facilities

A YEAR LATER (2000) PROBLEMS APPEAR

Concrete-filled bollard
founded in recycled base

Pavement on left with
recycled base, on right without

Heaving of apron on recycled base
Fuel trench founded below recycled base.

Continuing to grow (2004)

Expansion in base cracking
fuel trench wall (2004)

Fuel trench wall
failures (2017)

INVESTIGATION

- Microscopy & x-ray diffraction
  - Calcium sulfate hydrate (gypsum) abundant
  - Ettringite & thaumasite (expansive minerals in sulfate attack) present in recycled base but not elsewhere
- Heaving
  - 1 inch in 24-inch thick recycled base areas
  - Up to 3 inches in thickest base course areas
  - Scattered locations but most prevalent where ample moisture and fill thickest

- Why would this happen with recycled concrete with Type V cement?
  - Performed fine as a pavement for 38 yrs.
  - Crushing
    - More permeable (water is driving agent for sulfate attack)
    - Abundant water under paved areas and hangar
    - Crushing exposes more of alumina in Type V cement
- All evidence indicates the recycled concrete base/fill is undergoing classical sulfate attack on concrete

LESSONS FROM HOLLOMAN AFB FAILURE

- The standard approved solution (Type V sulfate-resistant cement in this case) may not work in every case
- Relatively small changes in conditions may cause unexpected responses
- This is a case where our knowledge was insufficient

Holloman AFB airmen deployed at Agadez (2018)

Mother Nature is always out to git ya!

CONCLUSIONS

- Most pavement failures are simple, basic human errors
- Ali Al Salem & Manas Air Bases
  - Ignorance/lack of skill
  - Ineffective QC/QA – both government and contractor error
  - Written specifications that are wrong, not understood, or ignored
- Technology cannot solve these
- Holloman AFB-the standard answer didn't work
- The number of failure examples is limited only by time today rather than by a paucity of examples

Pavement failures in USAF are mission critical

QUESTIONS OR DISCUSSION?