

Inverted Pavement

VULCAN MATERIALS COMPANY'S
EXPERIENCE

11/16/2022

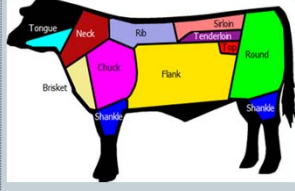
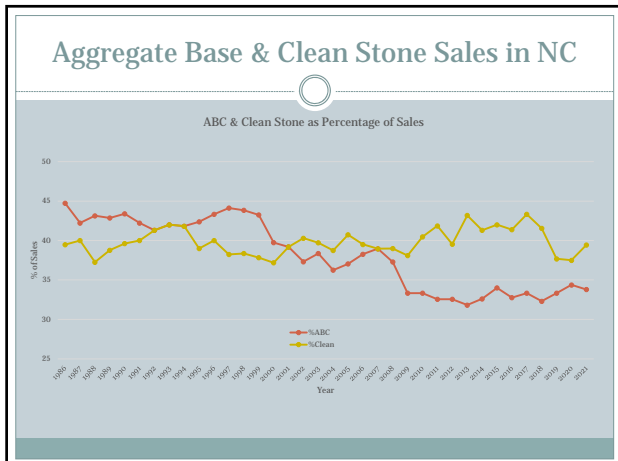
Inverted Pavement

- Why is the aggregate industry interested
- Overview of inverted pavement
- Vulcan's experience with inverted pavement
- Current & Future Research

Aggregate Industry's Interest in Inverted

Construction Aggregates

- Like the beef industry
- Multiple cuts of beef are made
- Can't make only tenderloin
- Someone has to buy the other cuts
- Otherwise, the tenderloin would be un-affordable

No End in Sight

- Trend is for more clean stone compared to aggregate base and Fines
- In some areas, we are buying land to store excess product
- This is not a sustainable way for us to do business
 - Bad for the environment
 - Bad for future aggregate costs

How Does Inverted Pavement Help?

What is an Inverted Pavement?

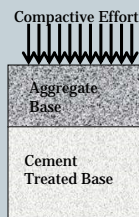


Inverted Pavement History

- Developed in South Africa
 - Traffic levels increasing in the 1960s and 70s
- US and Europe relied on thicker asphalt & increased concrete use
 - Not economically viable in South Africa
- Investigated ways to improve roads by improving the aggregate base
 - Instituted strict gradation limits
 - Limited plasticity
 - Required better aggregate quality

Inverted Pavement History

- Wanted to improve/increase the density aggregate base
- Led to a cemented subbase being used as an "anvil" on which to compact the aggregate base
- Enables high level of compaction



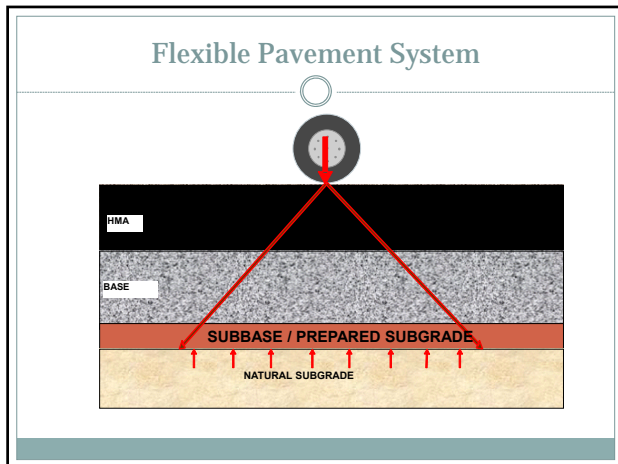
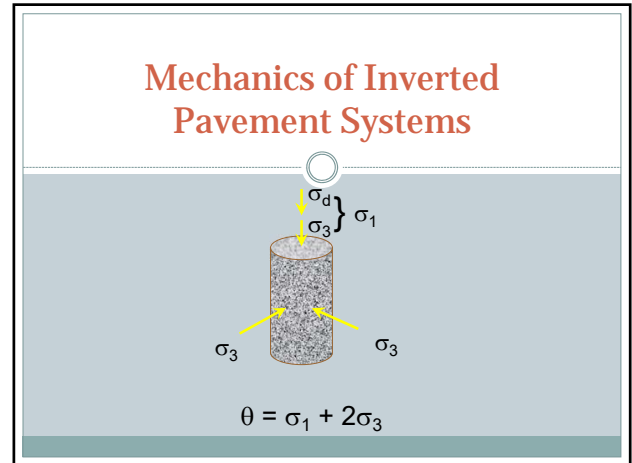
Inverted Pavement History

- Soon discovered that this pavement
 - Could handle the highest traffic loads
 - Was impervious to water ingress
 - Performed well even when wet
- Decades of research have shown these pavements can be used on roads up to 50 to 100 million ESALs

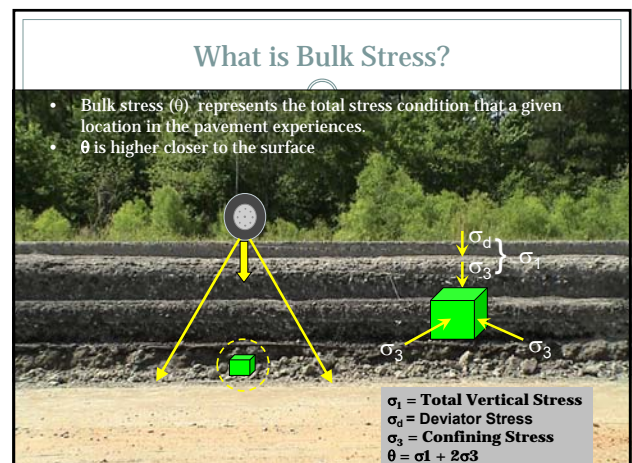
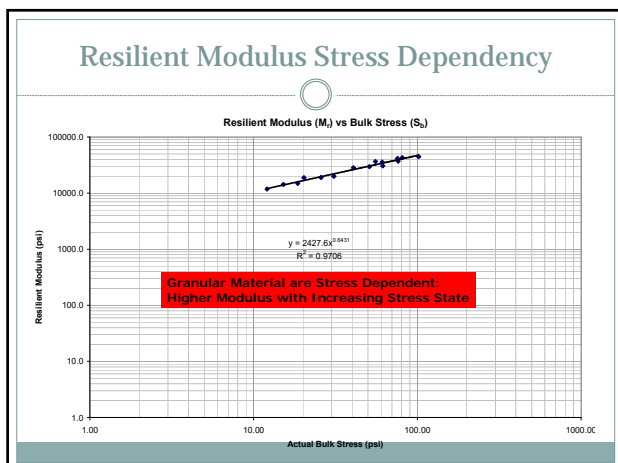
Typical Pavement Structural Designs South Africa

		GRANULAR BASES						(WET REGIONS)			
		PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE)									
ROAD CAT.	ES0.003	ES0.01	ES0.03	ES0.1	ES0.3	ES1	ES3	ES10	ES30		
	< 3000	0.3-1.0x10 ³	1.0-3.0x10 ³	3.0-10x10 ³	0.1-0.3x10 ⁴	0.3-1.0x10 ⁴	1.0-3.0x10 ⁴	3.0-10x10 ⁴	10-30x10 ⁴		
A					1.6"	6"	12"	30A 150 G1 200 C3	40A 150 G1 300 C3 (250 C3)	50A 150 G1 400 C3 (300 C3)	ESALS 3M 10M 30M

Structural Design of Flexible Pavements, Draft Technical Recommendation for Highways (TRH) 4, Pretoria, South Africa, 1996

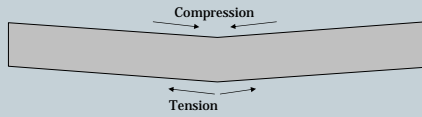


- ### Inverted Pavement
- Changes the way we think about pavement
 - Utilizes the stress dependency of graded aggregate base



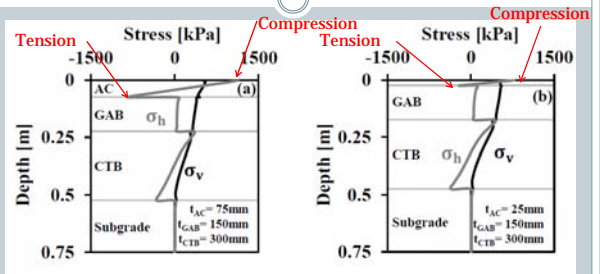
Is the Asphalt Too Thin?

- Research at Georgia Tech on inverted systems
- Traditional pavement, asphalt acts like a beam



- Inverted pavement, thin asphalt performs like a membrane

Beam versus Membrane



Source: Papadopoulos, "Performance of Unbound Aggregate Bases and Implications for Inverted Base Pavements", May 2014

Inverted Pavements

- CTB used as strong foundation
 - Anvil on which to compact aggregate base
- Aggregate base placed in the optimal position in the pavement
 - Near the surface
 - High bulk stress increases stiffness
- Thin asphalt protects the aggregate base
 - Acts like a membrane
 - Reduced tension

Inverted Pavements in the U.S.

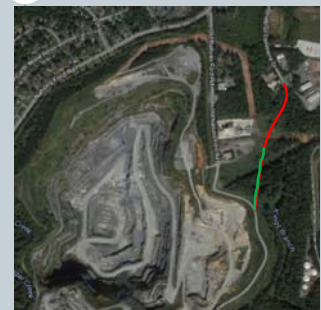


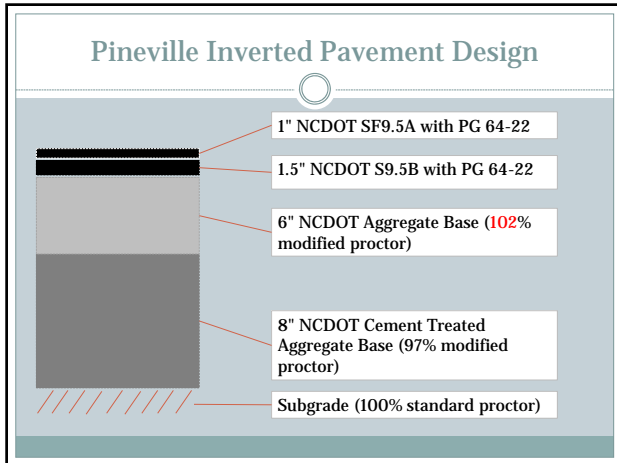
Recent Inverted Pavement Projects

- Blue Circle Quarry – Morgan County GA 2003
- LaGrange Bypass – LaGrange, GA 2009
- Luck Stone Quarry – Bull Run, VA 2011
- I-25 – Raton, NM 2012

Vulcan's Inverted Pavement

- Need to relocate a road in our Pineville Quarry near Charlotte, NC
- Great opportunity for an inverted pavement
 - New road was long enough for a test section and control section
 - Cement silo and pugmill on site at the quarry





Unbound Aggregate Base

- Used standard NCDOT Aggregate Base Course
- Required 102% modified proctor
 - Proctor: 153.8 pcf @ 5.3% moisture
 - Target: 156.9 pcf
 - Pineville Apparent SG: 2.95
 - Target: 85% of Apparent

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT
1.5	100	100
1	94	75 - 97
0.75	82	
0.5	64	55 - 80
#4	42	35 - 55
#10	31	25 - 45
#40	20	14 - 30
#200	9	4 - 12



Unbound Aggregate Base

- Compacted the UAB on the conventional section and the inverted section at the same time
- Density on conventional: 99.8%
- Density on inverted: 103.4%
 - 86.4% of apparent

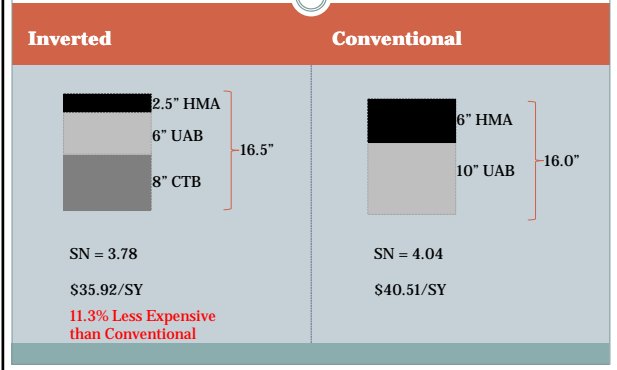
Hot Mix Asphalt

- Normal HMA construction in accordance with NCDOT
 - 1.5" 9.5mm B mix
 - 1" 9.5mm A mix as final lift

Final Density Comparison

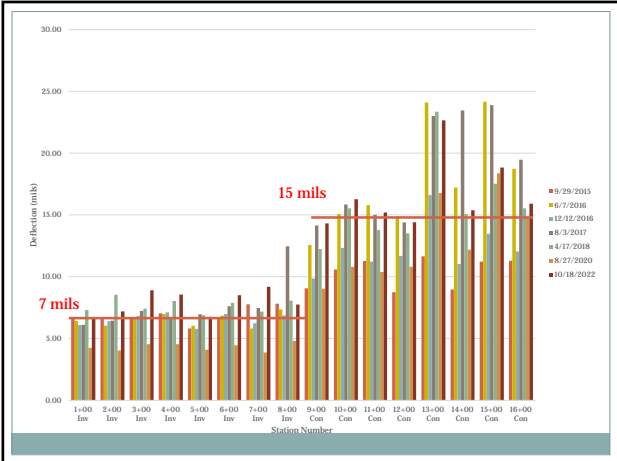
- Achieved better density on all layers of inverted pavement
- Shows the importance of a good foundation in compaction

Final Pavement Sections



Falling Weight Deflectometer Testing

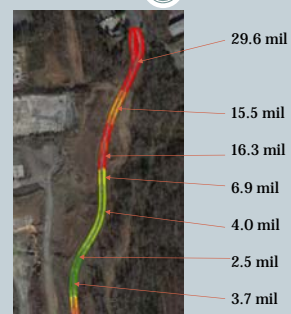
- NCDOT Performing FWD Testing periodically
 - September 2015
 - June 2016
 - December 2016
 - August 2017
 - April 2018
 - August 2020
 - October 2022
- NCDOT also tested it with a traffic speed deflectometer in 2021



Traffic Speed Deflectometer



Traffic Speed Deflectometer

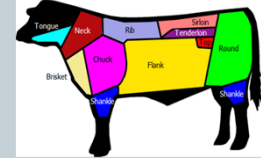


Conclusions to Date

- **Inverted Pavement relatively easy to construct**
 - No changes in techniques to achieve higher density levels
 - Better density on all subsequent layers
- **Inverted Pavement results in stiffer pavement than similar conventional section**
- **Inverted Pavement approximately 11% less expensive than conventional pavement**
- **Stronger pavement at lower cost**

A Sustainable Pavement

- **Makes greater use of Aggregate Base**
- **Can help quarries to balance production vs. sales**
- **Better use of our natural aggregate resources**



Current & Future Research

Current Research

- **NCDOT commissioned project with NCSU**
 - Literature review of inverted pavement
 - Deflection testing of Pineville inverted (different than FWD)
 - Core testing
 - Final Report due soon
- **University of Illinois – UC**
 - Working on synopsis of inverted projects in US

FHWA Research

- **FHWA research on inverted pavement in 2023**
- **Accelerated Loading Facility (ALF)**
- **Two test lanes dedicated to inverted pavement**



Test Plan

- **Two pavement designs (different thicknesses)**
- **Two different types of cement treated base**
 - Normal CTB
 - Cement treated screenings
- **Test until we begin to see failures**
- **If time allows, perform maintenance**

Lane 10	Lane 11
North End	North End
1.25" Screen A	1.75" Screen A
6" Unbound Base	6" Unbound Base
6" Cement Treated 21A	12" Cement Treated 21A
South End	South End
1.25" Screen A	1.75" Screen A
6" Unbound Base	6" Unbound Base
6" Cement Treated #12 Screenings	12" Cement Treated #12 Screenings

The slide features a red header with the word "Questions" in white serif font. Below the header is a white section with a thin black border. A small white circle is centered on a horizontal line that separates the header from the text. The text is centered and reads: "KEVIN VAUGHAN", "VULCAN MATERIALS COMPANY", and "VAUGHANK@VMCMAIL.COM". A thin teal bar is at the bottom of the slide.

Questions

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