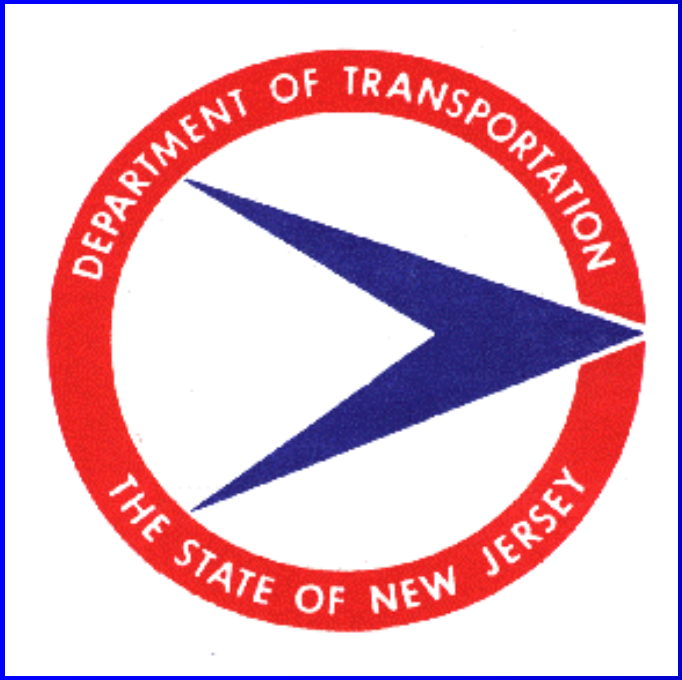
Concrete Pavement Rehabilitation Techniques



By

Robert W. Sauber
Supervising Engineer II

July 2009

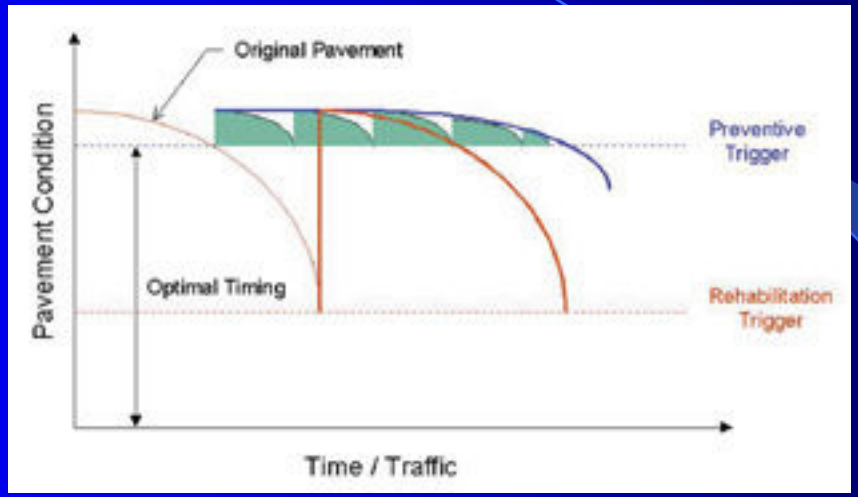
Bureau of Materials

NJDOT

Business as usual will not work !

Preventive Maintenance

Applying the right treatment… To the right pavement… At the right time…



"The planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system"

AASHTO's Standing Committee on Highways

Pavement Preservation

- Purpose of Pavement Preservation :
  - Extend pavement service life
  - Improving ride quality
  - Correcting surface defects
  - Improving safety characteristics
  - Lower life cycle costs
  - Avoid costly reconstruction

Concrete Treatments (CPR)

- Stabilization/Undersealing
  - High Density Polyurethane foam
  - Fly Ash/Cement grout
- Diamond Grinding
  - Improved ride quality, texture & cross slope
  - Reduces dynamic loads, less tire noise
- Precast & Fast Track Concrete
  - Full Depth Patching: Precast,VES & LMVES
  - Partial Depth Patching: Type 1 Quick Setting, TechCrete
- Load Transfer Restoration
  - Retrofit Dowel Bars & Crack Stitching
- Joint Resealing & Crack Sealing
  - Hot Poured Rubberized Asphalt or Silicone

Concrete Pavement Restoration (CPR)

Purpose of CPR Techniques

- Repair specific distress
- Prevent recurrence of distress
- Improve pavement ride quality

CPR Techniques

- Slab Stabilization/Undersealing
- Full-Depth Patching
- Partial-Depth Patching
- Retrofitting Dowel Bars
- Crack Stitching
- Diamond Grinding
- Seal Joints & Cracks
- Longitudinal Edge Drains

Fly Ash-Cement Grout

- Fluid mixture of cement, fly ash & water
- Requires pressure injection and high speed mixer
- Flow cone used to measure consistency
- Set-up time is approximately 2 hours with 6 to 12 hours before any substantial strength gains
- Cement grouts used primarily for undersealing of pavement joints

Cement Grout Injection

HDP Injection Equipment

HDP Pump and 5/8”Drill

HDP Injection

HDP Slab Jacking

Rt. I-287 Slab Jacking

slab stabilization

HDP Grout

- Two component chemical grout
- Low pressure application
- Initial set-up time of 15 to 20 seconds
- 90% of the compressive strength attained within 15 minutes
- Expanding foam compacts soil
- May lift slab

Urethane Grout

- Proprietary grout with an in-place density of approximately 4-6 pcf
- In-place compressive strength of 80 psi (11,500 psf)
- In-place tensile strength of 90 psi (13,000 psf)
- Many different types available


WESTCOTT


1
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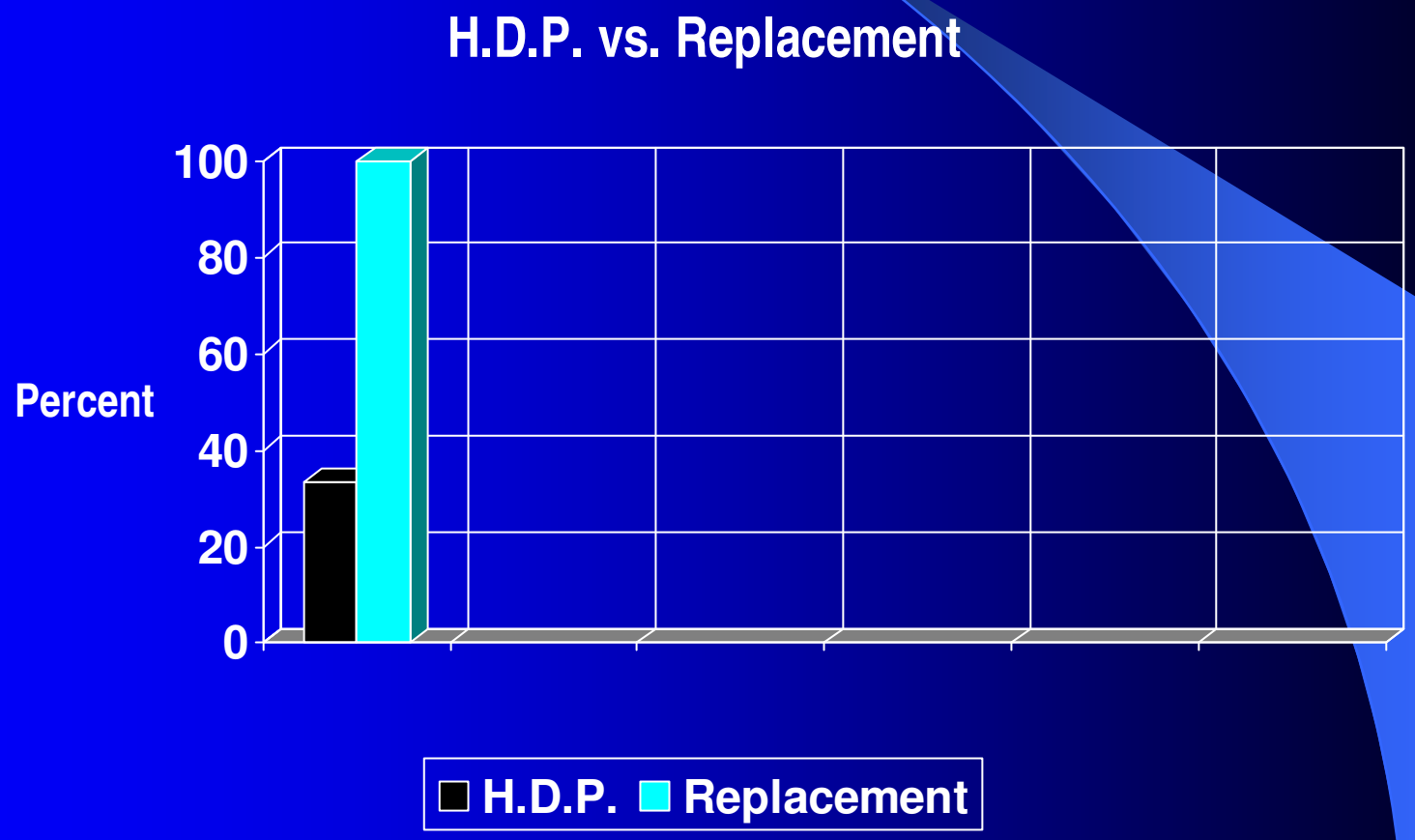
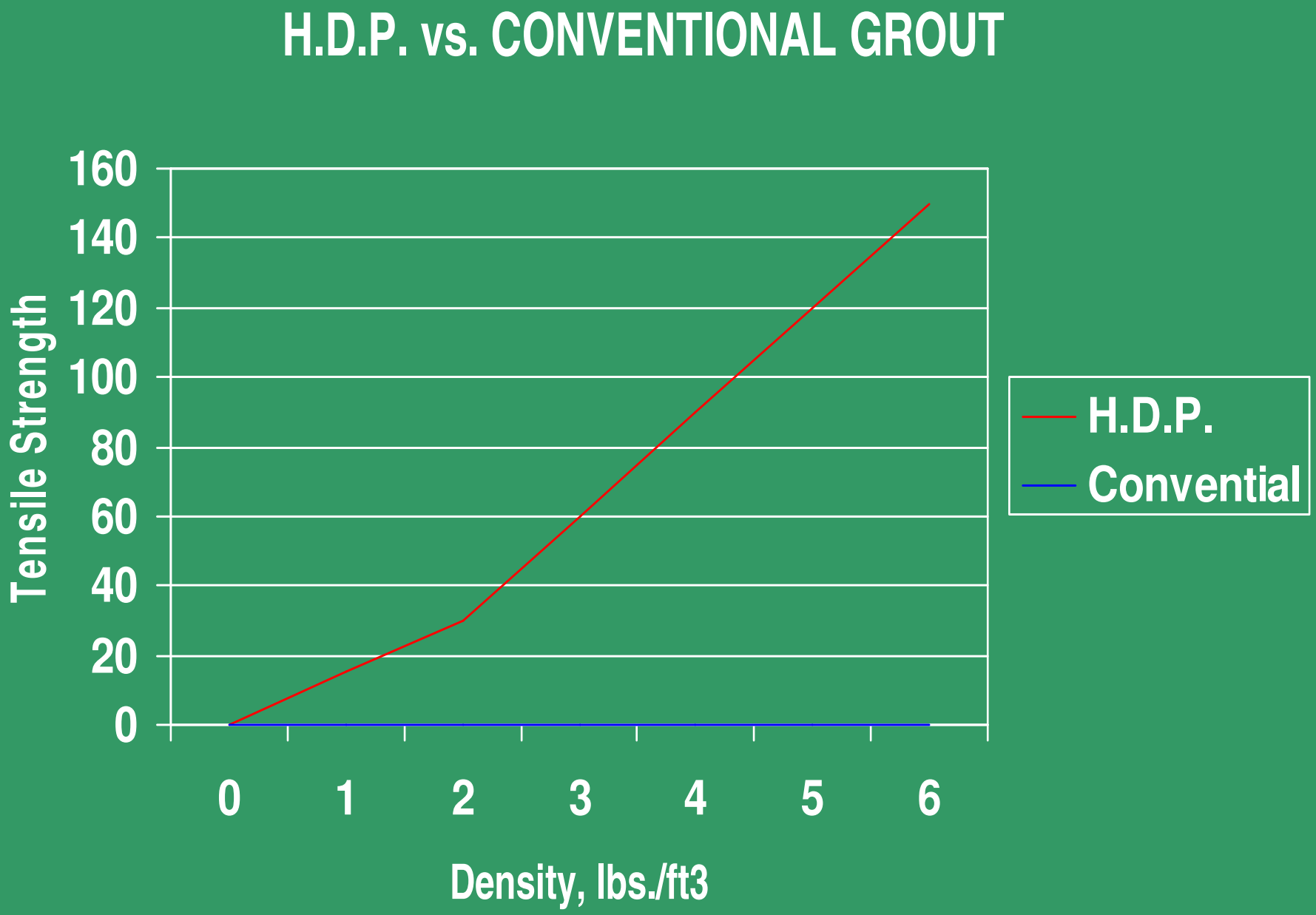
USA
STAINLESS

Slab Jacking vs. Slab Replacement

PRICING COMPARISON



TENSILE STRENGTH



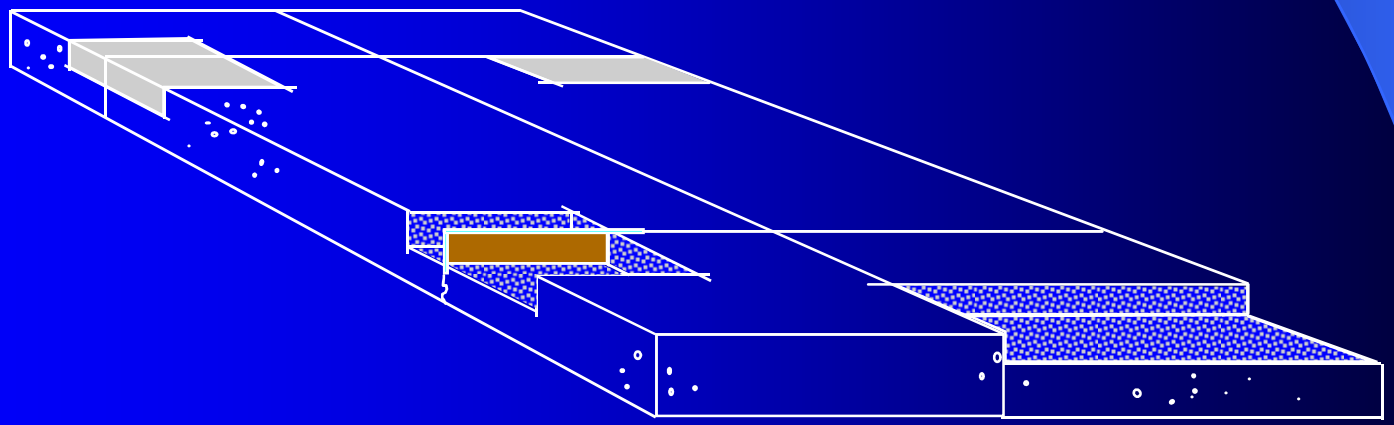
Hot-Pour Joint Sealants

Key Factors

- Field control of heating
  - 175-200°C (350-400°F)
  - Double boiler
  - Agitation
  - Insulated hoses
- Shape factor (filler/sealant)
- Clean and dry sidewalls!!
- Material selection, ASTM 6690 Type 2 or Type 4

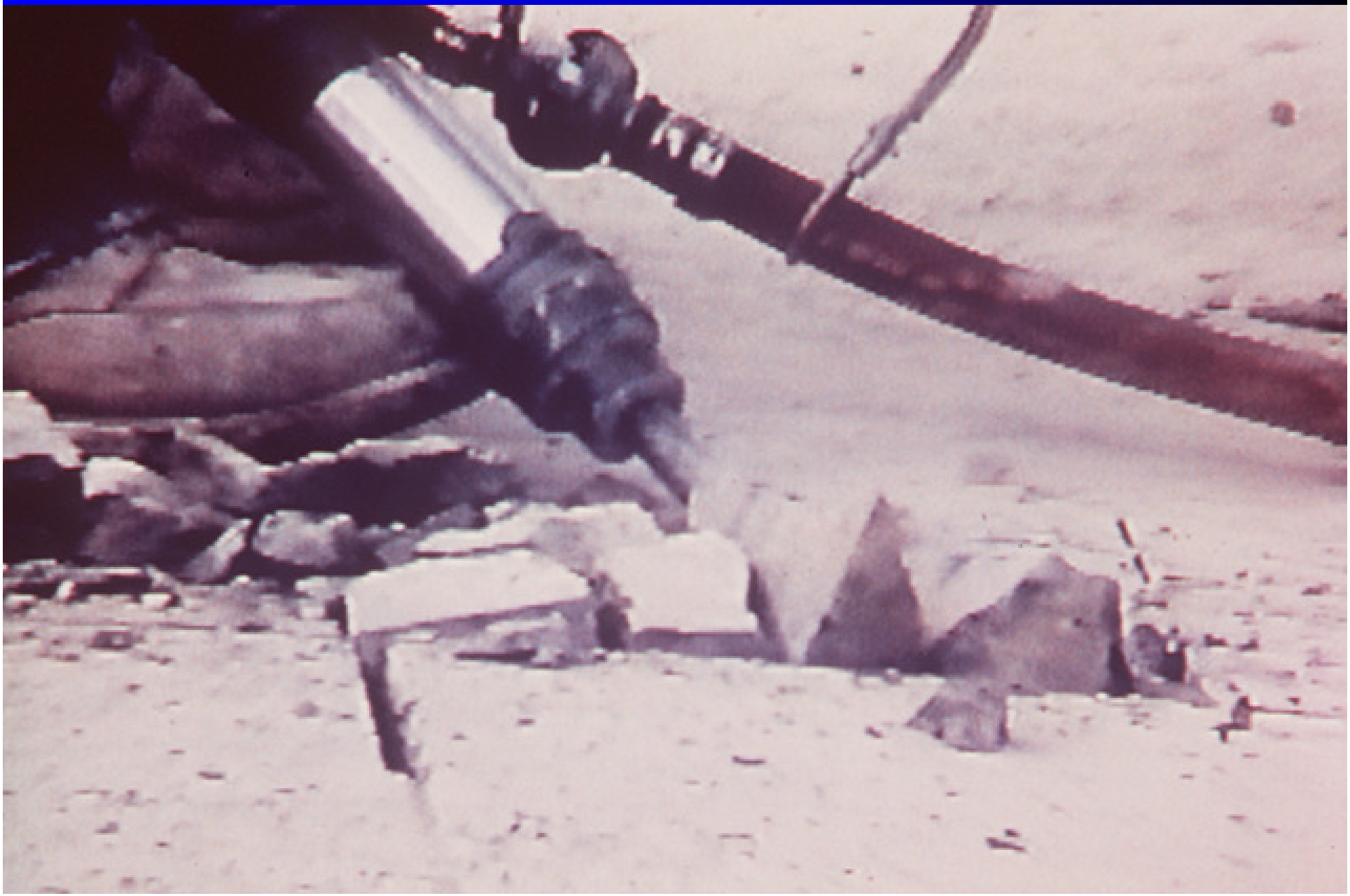
Partial Depth Repairs

- Repairs deterioration in the top 1/3 of the slab.
- Generally located at joints, but can be placed anywhere surface defects occur.

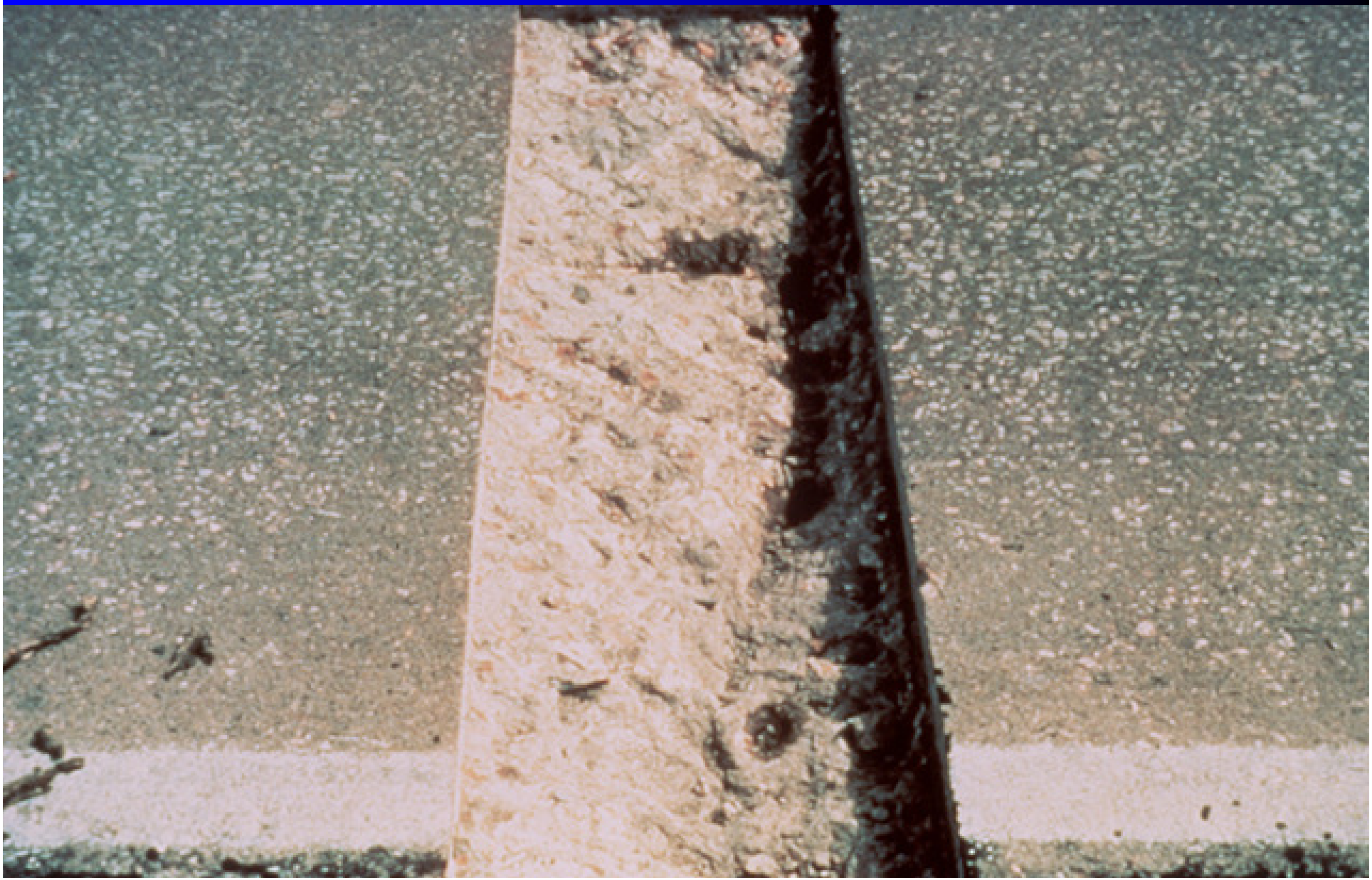


Transverse Joint Spalling

Removal of Concrete with Demolition Hammer



Repair Area after Sawing & Chipping



Compressible Joint Insert

Rt 21 TechCrete

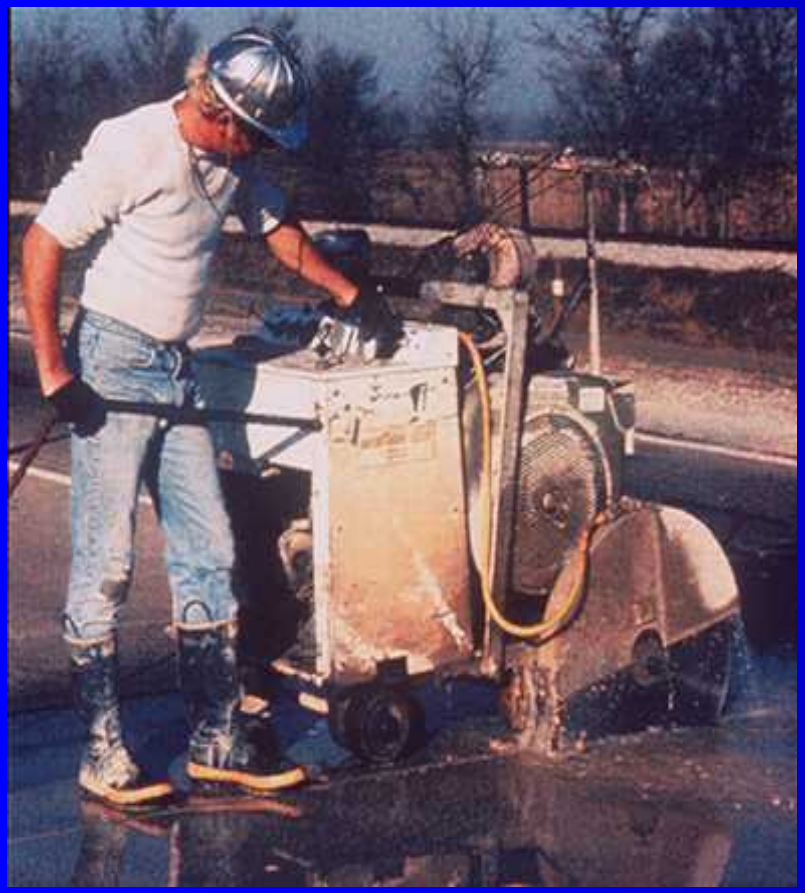
p/d synthetic resin patch


Full Depth Slab Repair

Rt 295 South Jersey

The volume of heavy trucks is projected to increase 3% each year over the next 20 years

Sawing Boundaries



Combine Patches!!

Liftout

Pin and Chain

Torque Claw

Lateral Pressure

Self-Propelled Slab Reference

Injecting Epoxy Grout

Placement of Bond-Breaking Board

Concrete Placement

Finishing

Texturing

Why Precast PCCP in NJ?

- Precast concrete has quickly become the preferred method for intermittent full depth slab repair, contractors and RE's like it.
- Portland cement fast track mixtures require 6.5 hr cure, are temperature sensitive and have questionable long term durability
- Polymer concretes are too expensive
- Some hydraulic cements perform well but require calibrated mobile mixers and on site strength testing

Why Precast PCCP in NJ?

- Cast in place requires on site flexural beam test that require agency staff and equipment
- Some concrete plants don't want to open at night for only a few loads of concrete
- Some towns prohibit concrete plants from operating at night
- Precast is more expensive than cast in place fast track and cost competitive with proprietary hydraulic cement mixtures
- Precast has better quality control because slabs are cast in a controlled environment

NJDOT's Experience with Precast PCCP

- Route I-295 Burlington County (completed)
  - $8.7 million total, *$2.4 M for slab repairs
  - Award 9/1/06 Precast Qty 62,000 SF
- Route 21 Essex & Passaic Co. (completed)
  - $9 million total, $2.3 M for precast slabs
  - Letting 1/31/08 Precast Qty 44,000 SF
- Route I-280 Essex County (active)
  - $21.6 million total, $2.6 M for precast slabs
  - Award 6/5/08 Precast Qty 38,000 SF

NJDOT Precast PCCP

- Route 42 Camden & Gloucester Co. (active) 7,400 SY @ $547 (66,600 SF)
- Route 130 Mercer & Burlington County (to bid this year)
- Route I-295 Burlington County (to bid this year)
- Route I-78 Warren County (to bid this year)

NJDOT TYPICAL INTERSTATE JRCP

- 78’ 2” slab length with *expansion joints*
- 9” thick JRCP over 12” granular subbase
- Three 12’ wide lanes each direction
- HMA shoulder pavements
- NJ is the most congested state, night work with 8 hour work window typical

Precast PCCP Benefits

- Lane can be opened to traffic immediately after slab placement
- Slabs can be removed and reset if not seated properly
- Better for correcting localized subsidence
- Lower risk for opening lane on time
- Can work in cooler weather

NJDOT's 1st precast slab project

- Superslab full and partial slab replacement
- 6 pcf polyurethane grout slab stabilization
- Synthetic resin partial depth repairs
- Diamond Grinding final surface
- Productivity 2 flat bed trucks per shift, 8 panels
- FWD to measure deflection and % joint load transfer

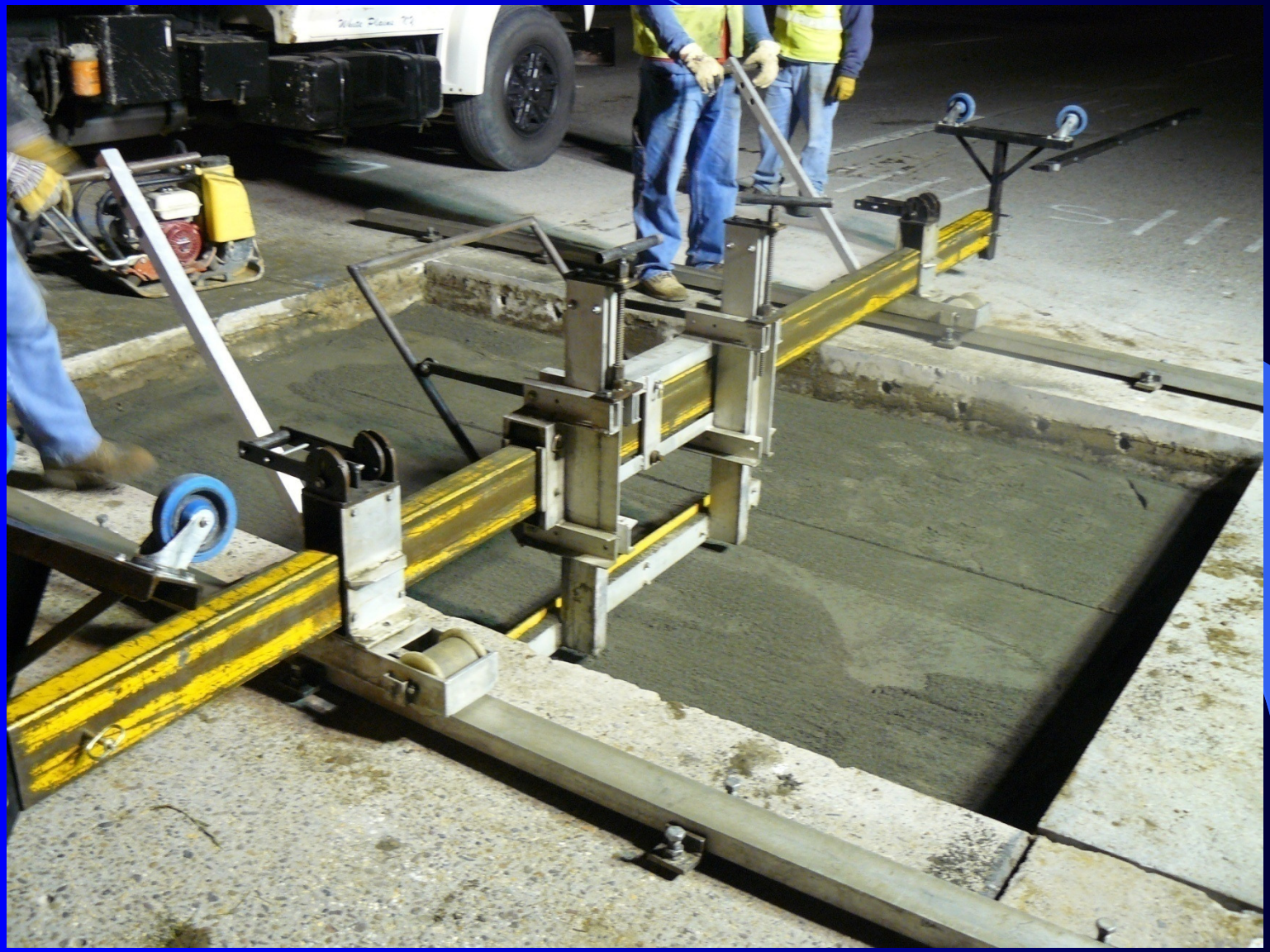
NJDOT's 1st precast slab project

- Rt. I-295 in Burlington County
- Constructed in 1972
- AADT 100,000
- Traffic Operations and Contractor could not agree on TCP for center lane
- Precast was only method deemed acceptable to both parties

Dowel bar layout

Subbase preparation

Fine grading stone sand



Base compaction

Repair at expansion joint,

don’t install ties on both sides

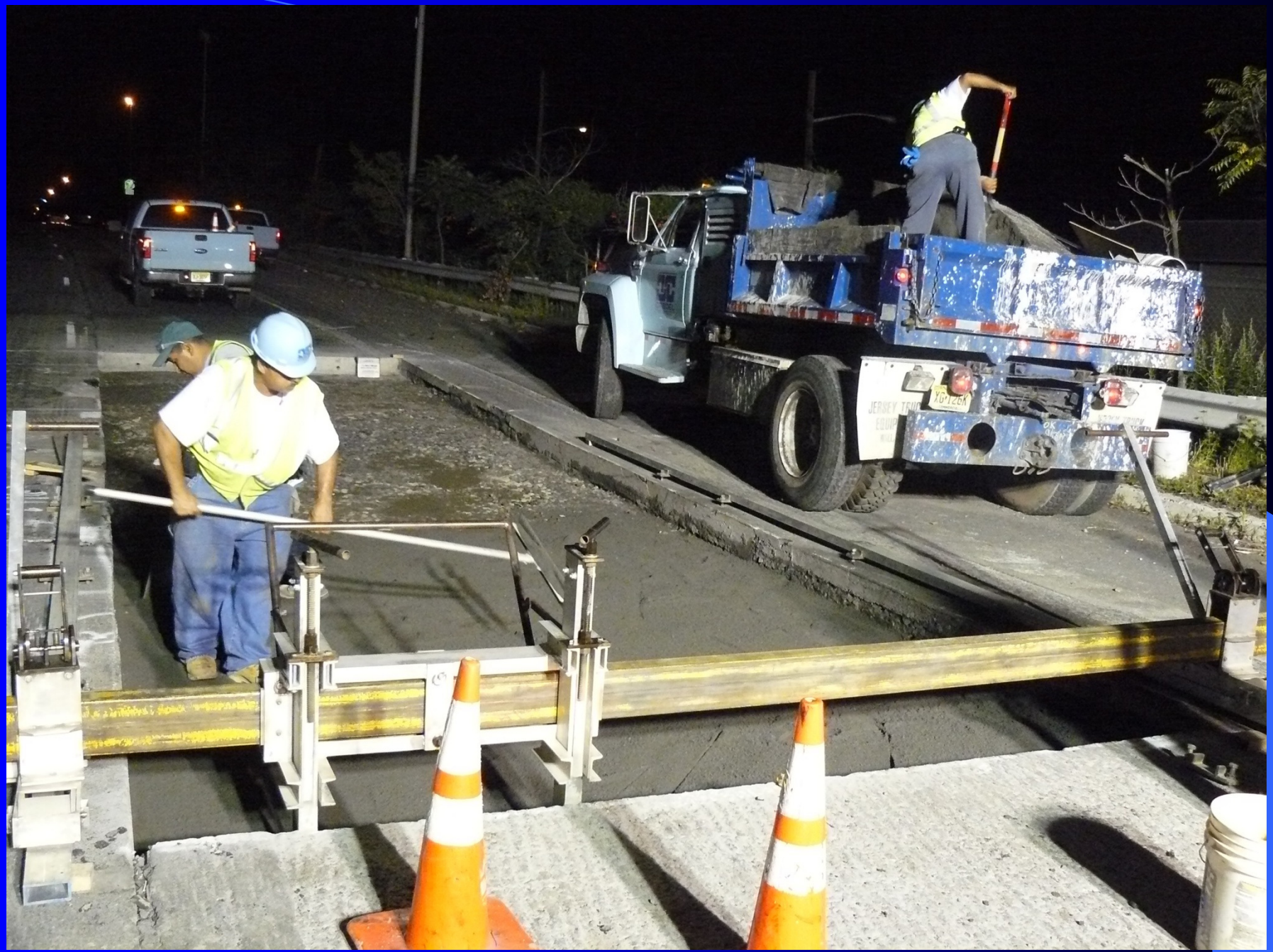
NJDOT's 2nd precast slab project

- Route 21 Essex & Passaic Counties
- MP 5.0 to 6.5 constructed in 1931
- MP 6.5 to 10 constructed in 1958
- AADT 70,000
- Pavement had been overlain with microsurfacing twice, was removed prior to slab repairs

NJDOT's 2nd precast slab project

- Superslab full depth repairs
- Synthetic resin (TechCrete) partial depth repair material
- 6 pcf polyurethane grout slab stabilization
- Diamond grinding final surface
- Productivity 2 flat bed trucks shift, 8 slabs


CRISDEL



Oops!!


CRISDEL
SOUTH PLAINFIELD, NEW JERSEY
KOMATSU

NJDOT's 3rd precast slab project

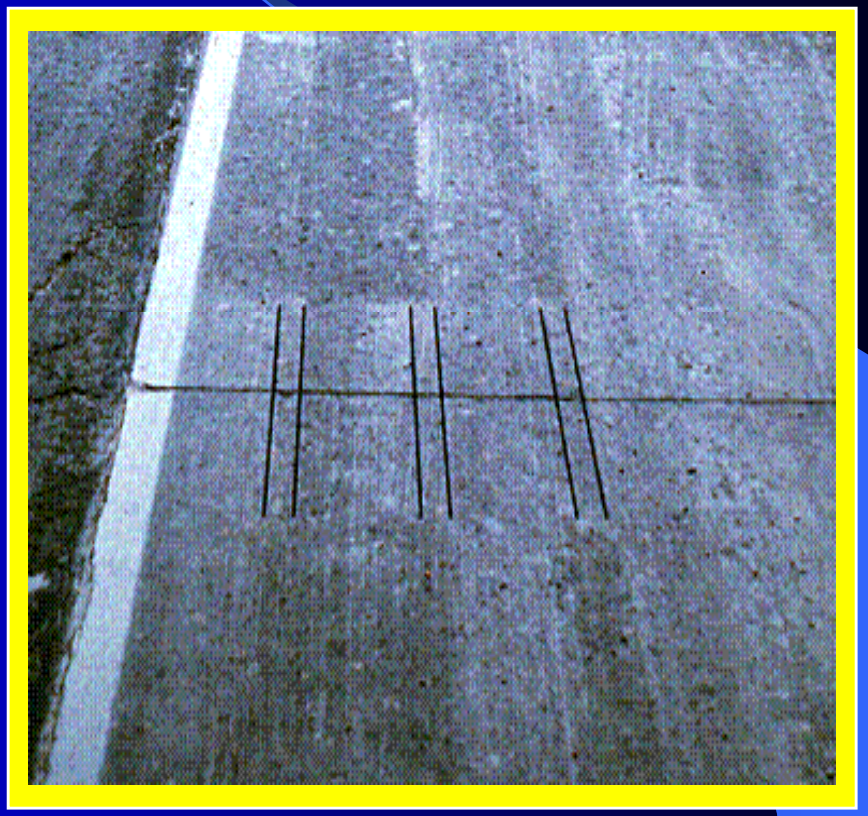
- Route I-280 Essex County MP 6.2 to 13.3
- Constructed between 1966 to 1973 under various contracts
- +/- 40 overpass structures in this segment
- AADT 120,000
- Awarded June 5, 2008
- 38,000 SF of precast slab repairs

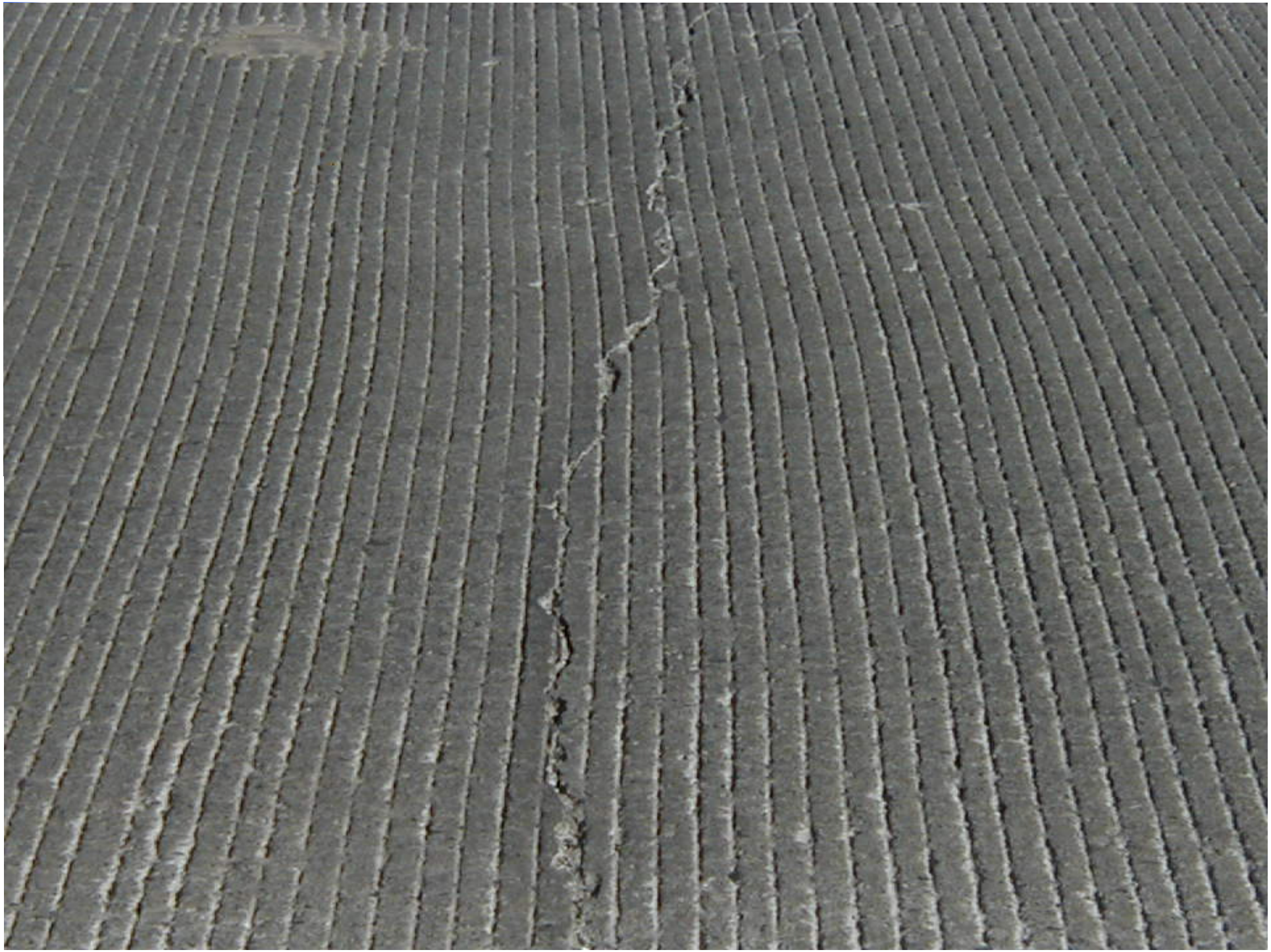
Future Needs

- Generic Specification & Details
- Best material to fill gaps at joints?
- Contractor and inspector technical knowledge of concrete pavement construction
- Training with certification would help, currently done for HMA construction
- Incentives/disincentives to reward good contractors and penalize sloppy work
- Attention to detail, slab dimensioning

Load Transfer Restoration

- Diamond saw slot cutter
  - Cuts multiple slots in a single pass.
  - Cuts form the edges of the slots
  - Fins are removed later
  - Can cut 3 or 6 slots in a single pass
- Modified milling machine
  - Cuts multiple slots without fins
  - Scarifies edges of slots
  - May spall pavement surface



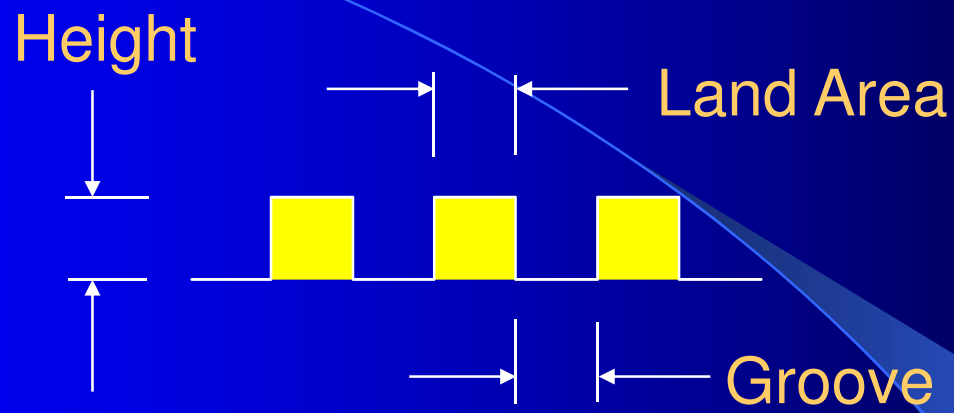


What is Diamond Grinding?

- Removal of thin surface layer of hardened PCC using closely spaced diamond saw blades
- Results in smooth, level pavement surface
- Remove faulting & reduce dynamic loads
- Longitudinal texture with desirable friction characteristics
- Frequently performed in conjunction with other CPR techniques, such as full and partial depth repairs, retrofit dowel bars, retrofit edgedrains & undersealing
- Reseal joints
- Replace RPMs and traffic striping

What is Diamond Grinding?

Removal of thin surface layer of hardened PCC using closely spaced diamond saw blades



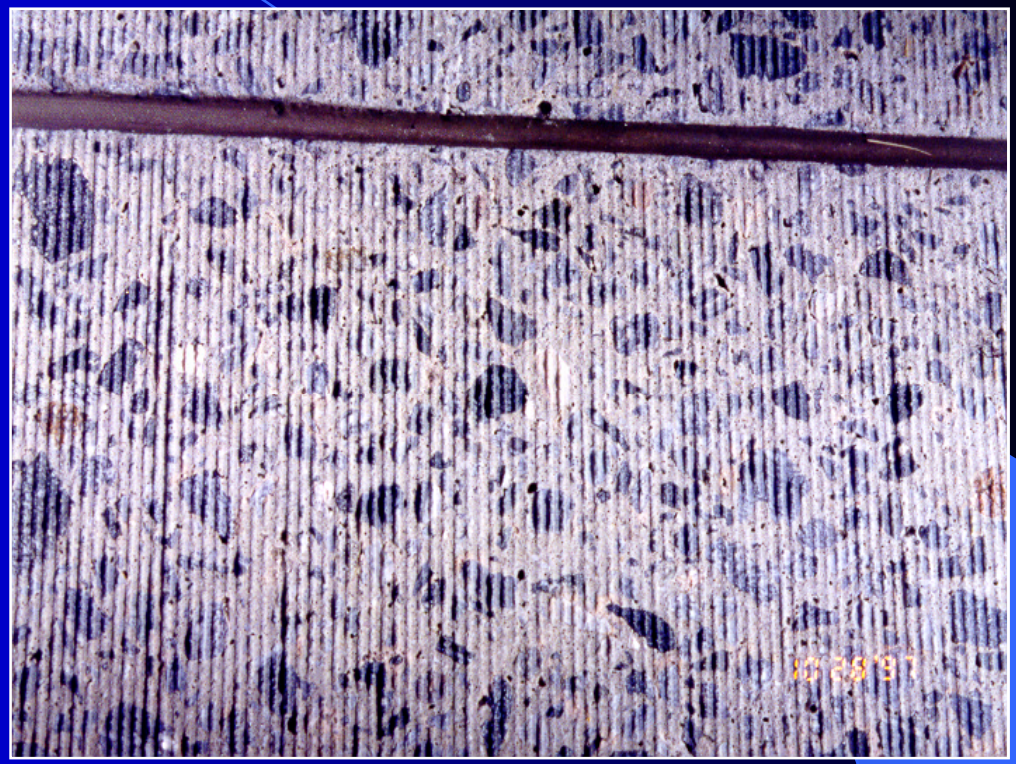
	Range	Hard Aggregate	Soft Aggregate
Grooves	2.25-3.75 mm	2.50-3.75 mm	2.50-3.75 mm
Land Area	1.50-3.25 mm	2.00 mm	2.50 mm
Height	1.50 mm	1.50 mm	1.50 mm
Grooves/m	164-197	174-197	164-177

Diamond Grinding

- Improves ride by removing:
  - Faulting at joints
  - Slab warping
  - Surface deformations caused by studded tires
  - Smooth rough patches
- Restores skid resistance
- Corrects cross-slope
- Reduces tire noise

Result of Grinding

Longitudinal texture with desirable friction characteristics



Advantages of Diamond Grinding

- Does not raise the pavement surface elevation
  - Does not affect overhead clearances
  - Eliminates the need for tapers at highway entrances, exits, and side streets
  - Eliminates barrier curb replacement
- Does not affect the hydraulic capacity of curbs and gutters
- Need be applied only to the portion of the pavement where restoration is needed

Diamond Grinding


Collect the Slurry!!!

Diamond Grinding

Conclusions

- Diamond grinding results in a smooth pavement surface with desirable friction characteristics
- Significant increase in surface texture and corresponding improvement in skid resistance
- Results in noise reduction and reduced dynamic loading

NJDOT's Experience with Rubblization

- Route I-295 Burlington & Camden County
  - Contractor: RE Pierson
- Route I-78 Essex & Union Counties
  - Contractor: Union Paving
- Route I-295 Gloucester County
  - Contractor: RE Pierson
- All pavements were 78' long x 12' wide, 9" thick JRCP over 12" granular subbase

Why Rubblization?

- Rubblization is a viable, rapid, and cost-effective rehabilitation method for deteriorated PCC pavements
- Rubblization is cost effective when the amount of patching exceeds approximately 10 percent of the project area (NJ)
- Lower Risk to Owner and Contractor
  - Reduced subgrade exposure to moisture damage

Why Rubblization?

- Rubblization Saves Time
  - Typical rubblization process recycles one lane mile per day, with no material hauling
  - 4X faster than breaking, excavating, hauling and placing DGA using traditional methods
- Rubblization Saves Money
  - Approximately 50% cost savings compared to reconstruction with PCCP
  - Approximately 33% cost saving compared to reconstruction with HMA

Environmental Benefits

- Water Consumption: 41% Reduction
- Energy Consumption: 44% Reduction
- CO_2 Emissions: 43% Reduction
- NO_x Emissions: 26% Reduction
- PM_{10} Emissions: 48% Reduction
- SO_2 Emissions: 40% Reduction
- CO Emissions: 38% Reduction

source: RMRC case study of a NHDOT project

NJDOT's first project

- Rt. I-295 Burlington & Camden Counties
- One centerline mile proposed
- Borderline subgrade support
- Contractor submitted VE proposal to increase the amount of rubblization
- Rubblization also used in removal areas
- Results exceed expectations
- Multi-Head Breaker used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SOUTH
295


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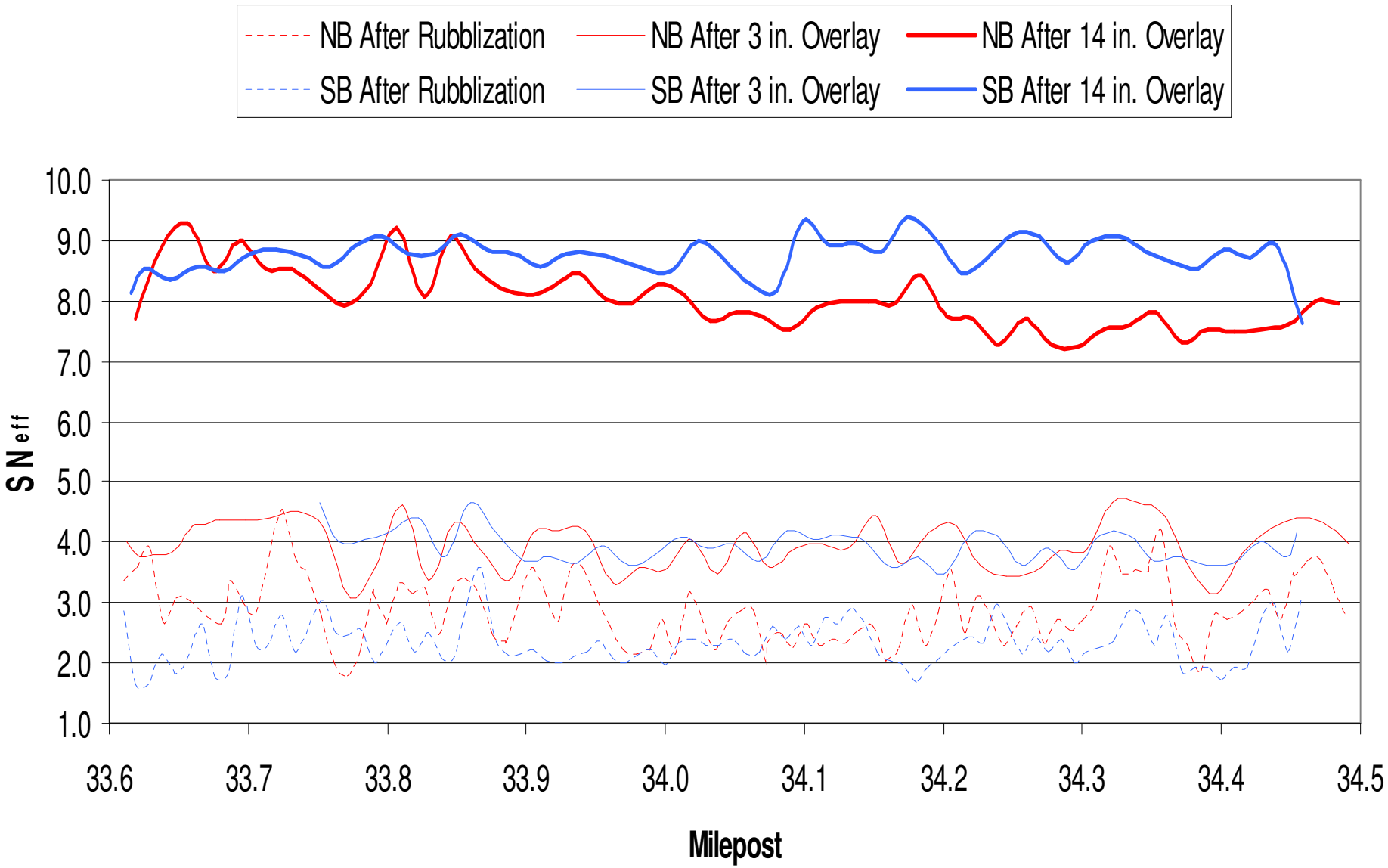
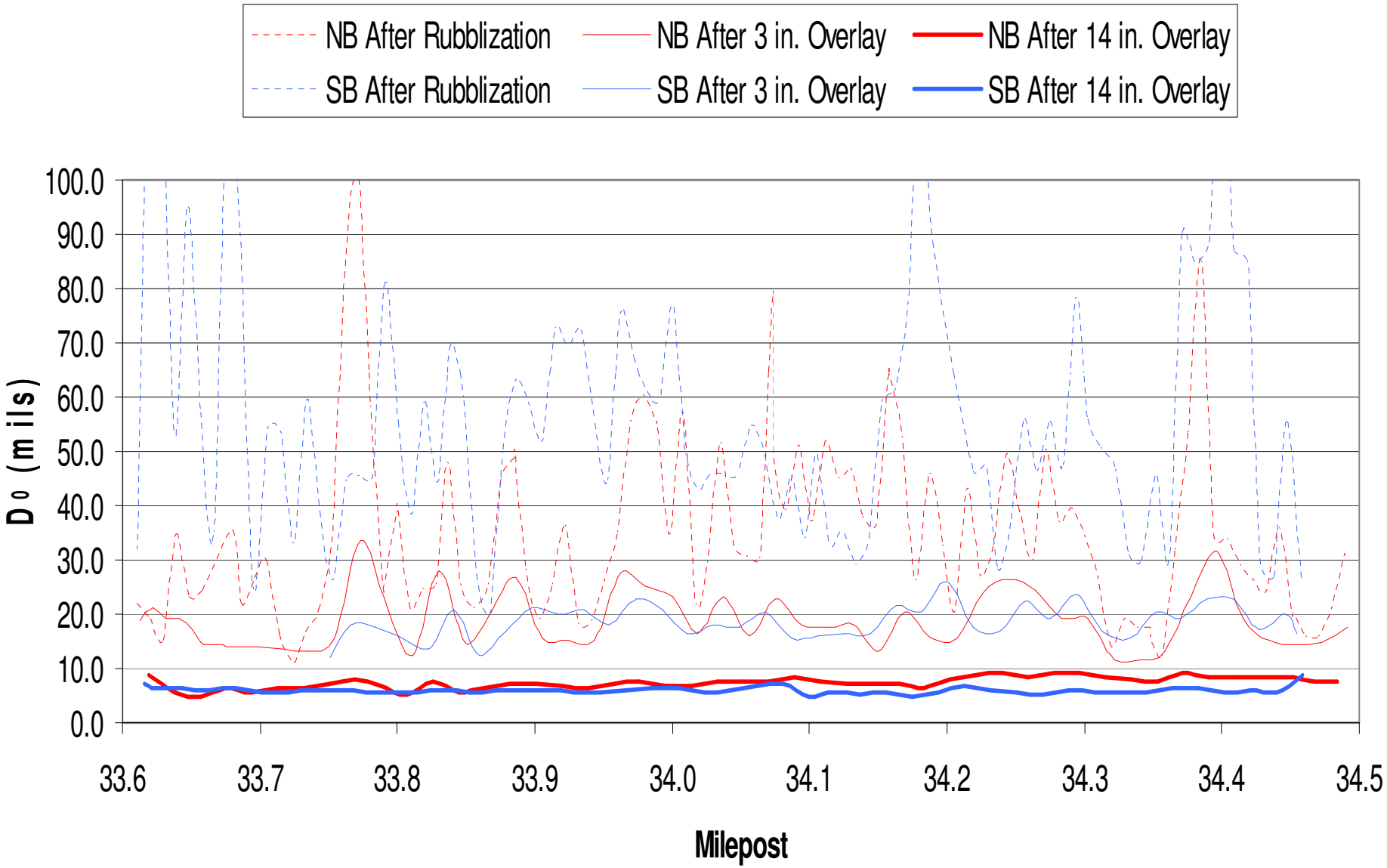
RAVEN

Effective Structural Number for Route I-295 Northbound & Southbound Left Lanes After Rubblization, After 3 in. Overlay, and After 14 in. Overlay



Maximum Normalized Deflections for Route I-295 Northbound & Southbound Left Lanes After Rubblization, After 3 in. Overlay, and After 14 in. Overlay



NJDOT's second project

- Route I-78 Union & Essex Counties
- Accelerated schedule with incentive
- Union Paving awarded bonus for early completion
- Full depth reconstruction areas require undercuts, cost overruns
- Multi-Head Breaker used
- Rutgers performed PSPA testing


Route I-78 Essex & Union
Counties

Route I-78 Essex & Union Counties

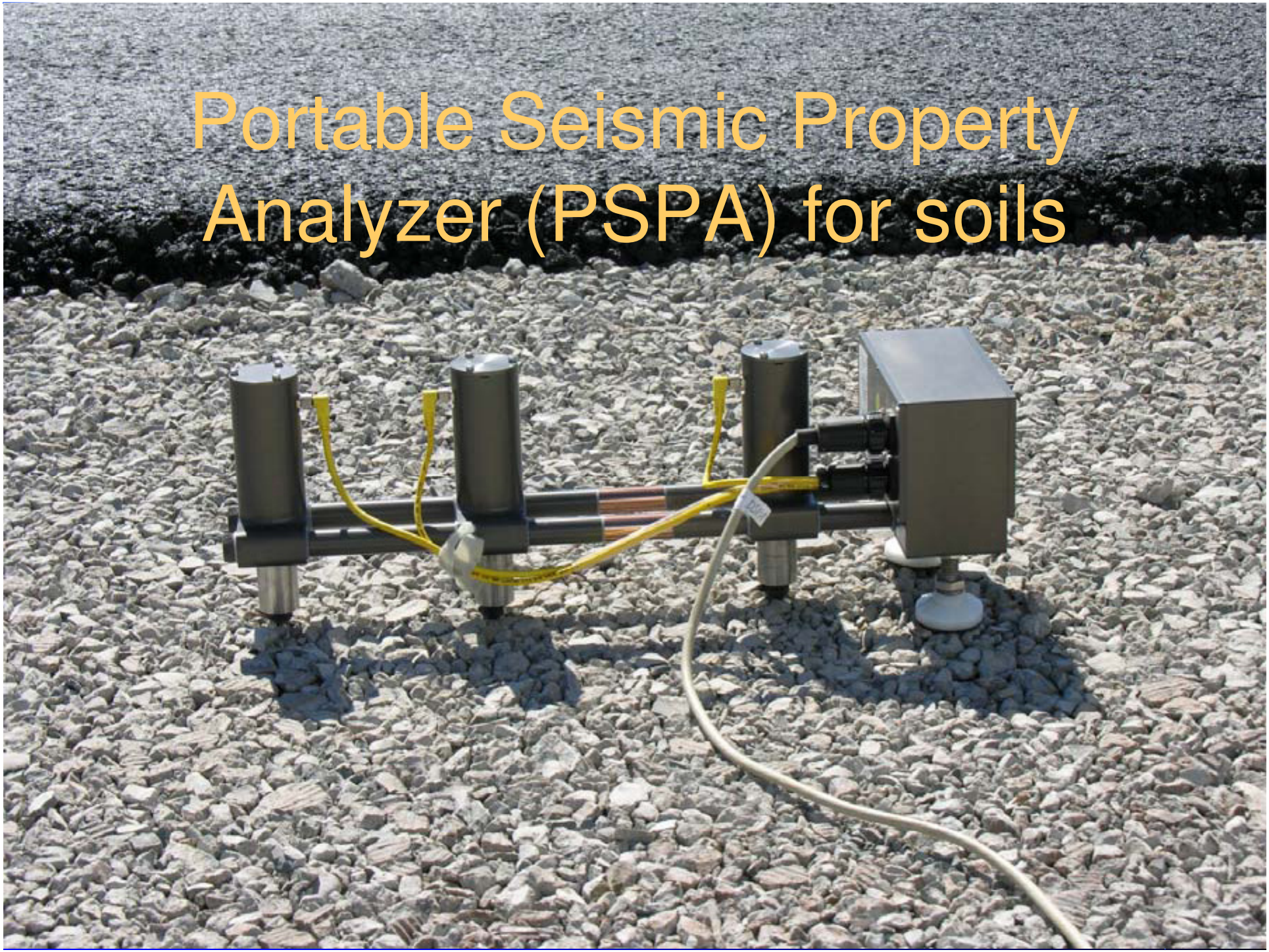

Route I-78 Essex & Union


I-78 MP 54 Sept '06


Rubblized and compacted PCCP


Cross section of rubblized PCCP

Portable Seismic Property Analyzer (PSPA) for soils



Route I-78 PSPA Test Results

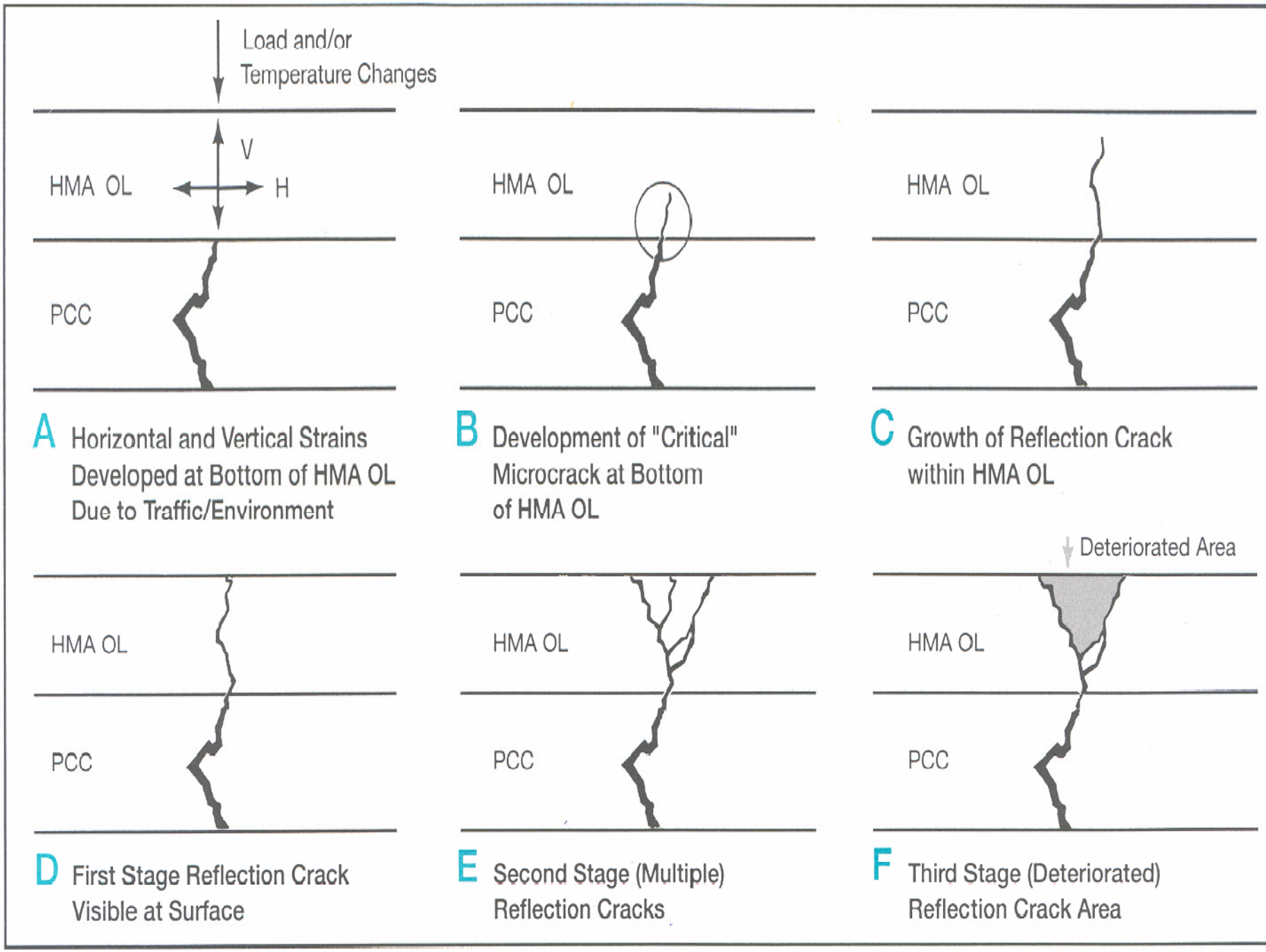
- Elastic modulus is evaluated from the average velocity of surface waves
- Seismic testing is a low strain modulus, reductions should be made to describe it as resilient modulus
- Modulus varied between 80 and 400 ksi
- Average modulus was 217 ksi

NJDOT's third project

- Route I-295 Gloucester County
- RE Pierson using MHB (Antigo Constr.)
- Currently under construction
- Rubblization completed in full depth reconstruction areas
- Good results to date

Objective of Rubblization

- **Eliminate reflection cracking in the HMA overlay by the total destruction of the existing slab action**
- **Slab is reduced to small pieces and diminished to a high-strength granular base**
- **Restoration of structural capacity is accomplished with an HMA overlay**


Load and/or
Temperature Changes
V
H
HMA OL
PCC
A Horizontal and Vertical Strains Developed at Bottom of HMA OL Due to Traffic/Environment
B Development of "Critical" Microcrack at Bottom of HMA OL
C Growth of Reflection Crack within HMA OL
Deteriorated Area
D First Stage Reflection Crack Visible at Surface
E Second Stage (Multiple) Reflection Cracks
F Third Stage (Deteriorated) Reflection Crack Area

- Every rough, worn-out PCC pavement may not be a candidate for rubblization with an HMA overlay
- Evaluate the existing pavement, traffic, subgrade, and environmental conditions
- Understand the soil and moisture conditions for the pavement system prior to making a decision
- Most PCC pavements can be rubblized in an appropriate manner and overlaid with HMA

Wisconsin DOT considers rubblization when one or more of the following conditions are met:

- Greater than 20% of the concrete pavement joints are in need of repair;
- Greater than 20% of the concrete surface has been patched;
- Greater than 20% of the concrete slabs exhibit slab breakup distress; and
- Greater than 20% of the project length exhibits longitudinal joint distress greater than 4-in. wide

General Rubblization Info

- rubblized PCCP is an order of magnitude less than a concrete slab, say 300,000 psi as compared to 3 million psi for concrete
- rubblized modulus values are at least twice the modulus values typically used for crushed stone base

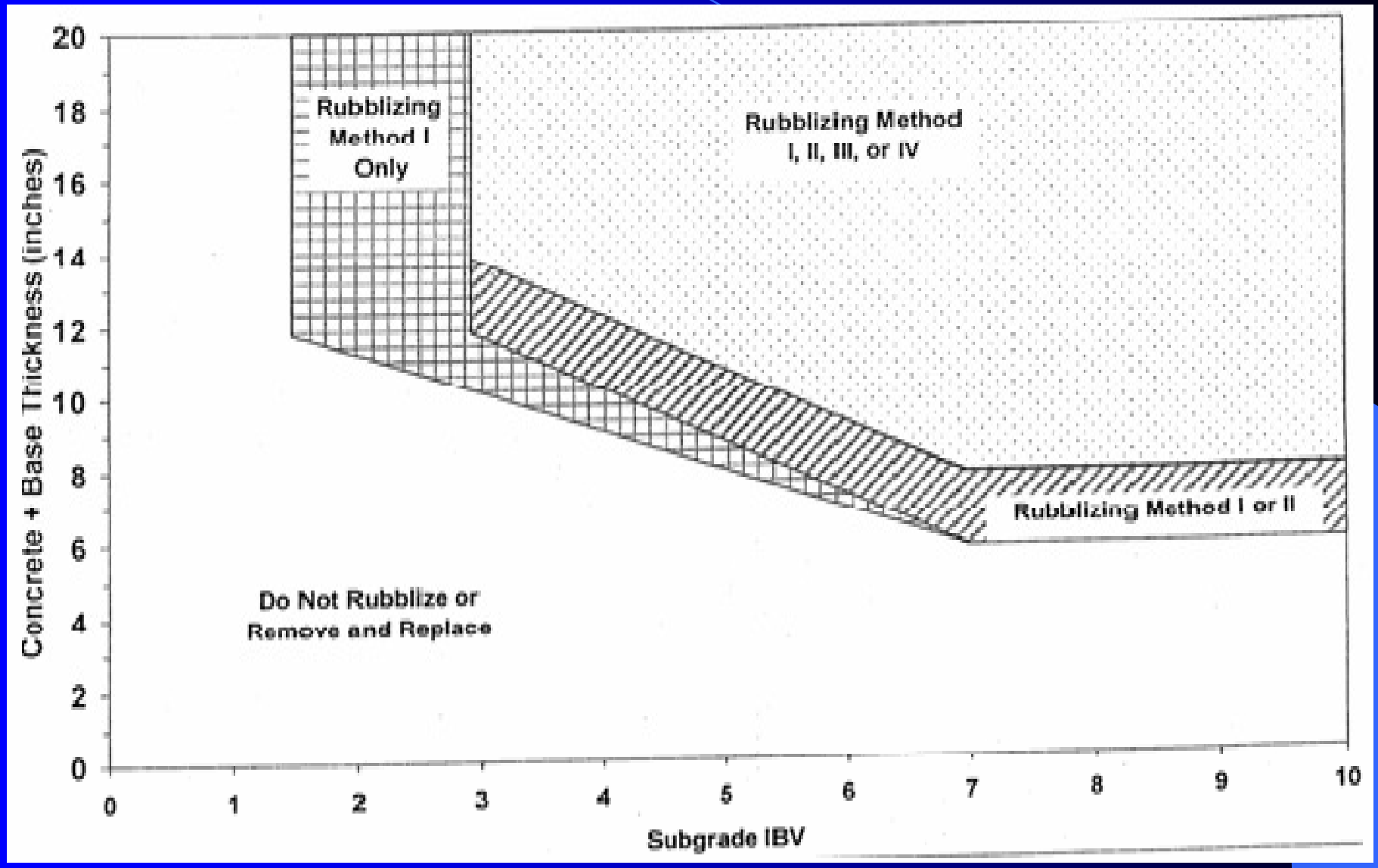
General Rubblization Info

- For thicker slabs, rubblized particles tend to be larger and interlocked stronger, leading to a higher modulus
- For thinner slabs on subgrade, reduced support results in poor particle interlock leading to a lower modulus
- No traffic (including unnecessary construction traffic) should be allowed on the fractured pavement surface

Rubblization Design Criteria

- AASHTO M-E Design Guide for Highways 150 ksi for PCCP 8 to 12 inches thick
- Asphalt Institute Airfield Project 2007
  - Slabs 6 to 8 in. thick: Moduli from 100 to 135 ksi
  - Slabs 8 to 14 in. thick: Moduli from 135 to 235 ksi
  - Slabs >14 in. thick: Moduli from 235 to 400 ksi

Illinois Rubblization Guide



Rubblization Design Criteria

- 5 inches recommended as a minimum overlay thickness over rubblized PCCP
- At least two lifts of HMA are necessary to meet grading and smoothness requirements
- The first lift must be at least 3 inches thick to achieve compaction, lack of fine particles hinders confinement

Rubblization Design Criteria

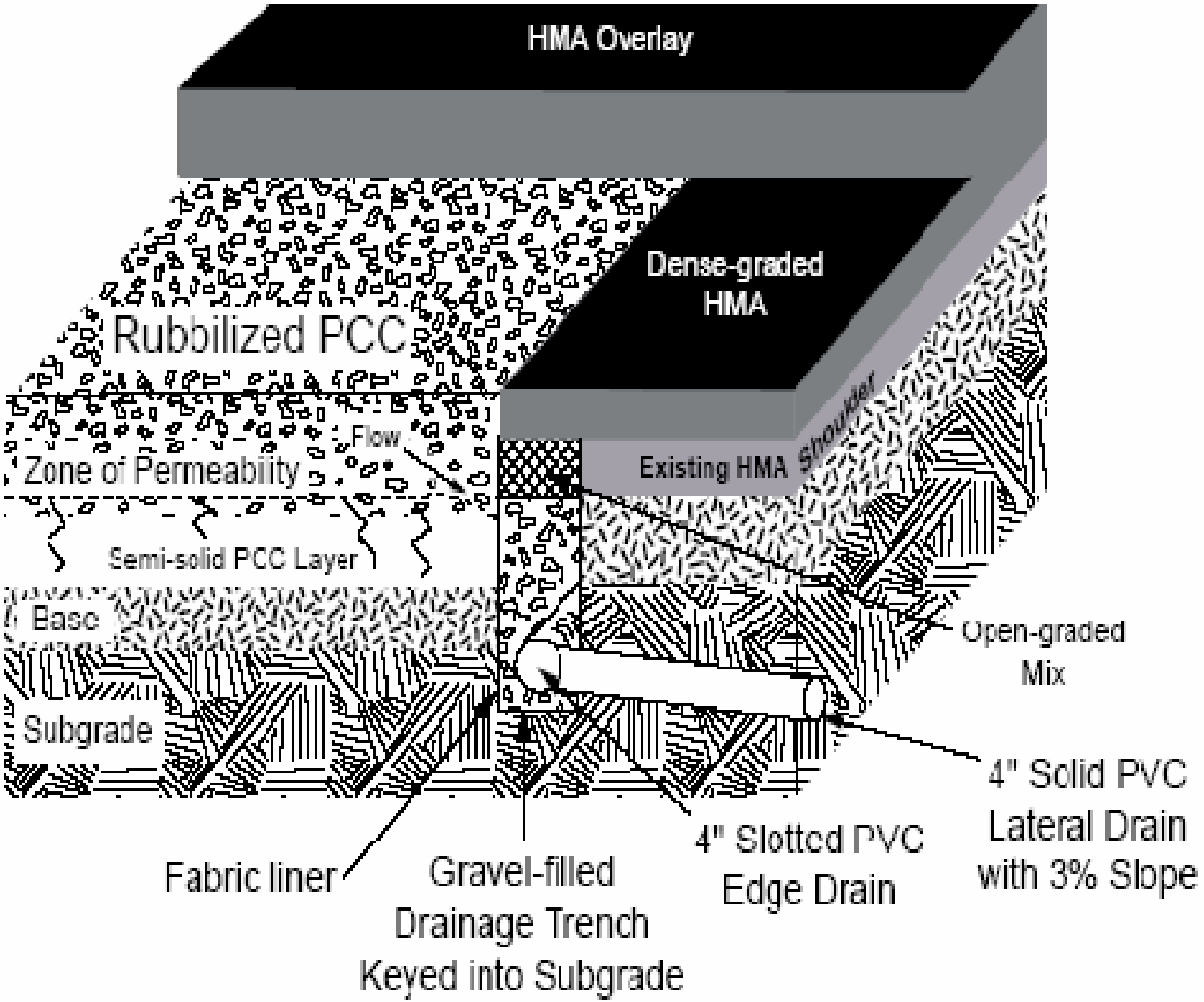
- Moduli of typical rubblized PCCP 100-400 ksi compared to crushed aggregate base with a typical range of 50-60 ksi
- Rubblized modulus (E) appears to be influenced by slab thickness; thicker slabs tended to have higher modulus
- Rubblized modulus related to the pre-rubblized PCC modulus, retained modulus
- no differences in rubblized moduli between the two types of rubblization equipment (MHB and RPB)

Rubblization Design Criteria

- Rubblized modulus is dependent on the level of rubblization, too much can reduce the concrete to a granular base with moduli in the 50-60 ksi range
- Reinforcing steel reduces the effectiveness of rubblization, may be minimal breakage below the steel
- Reinforcing steel increases both the pre and post-rubblized modulus

General Rubblization Criteria

- Subgrade condition is crucial for success in rubblization. Wet subgrades and/or soils with low bearing capacity may not rubblize
- Typically no change in subgrade moduli after rubblization
- When specified, underdrains should be installed and operational at least 14 days prior to rubblization


HMA Overlay
Dense-graded HMA
Rubbilized PCC
Flow
Zone of Permeability
Existing HMA
Shoulder
Semi-solid PCC Layer
Base
Subgrade
Open-graded Mix
4" Solid PVC Lateral Drain with 3% Slope
4" Slotted PVC Edge Drain
Fabric liner
Gravel-filled Drainage Trench Keyed into Subgrade

Multi-Head Breaker (MHB)

- MHB is a self-propelled unit with multiple drop-hammers mounted at the rear of the machine
- hammers are set in two rows, and strike the pavement approximately every 4.5 in
- 1,200 lb - 1,500 lb hammers have variable drop heights and variable cycling speeds
- can break pavement up to 13 ft wide in one pass
- production is approximately 1.0 lane-mi per day
- Z-pattern steel grid roller, a vibratory roller with a grid pattern, must be used in conjunction with the MHB to complete the breaking process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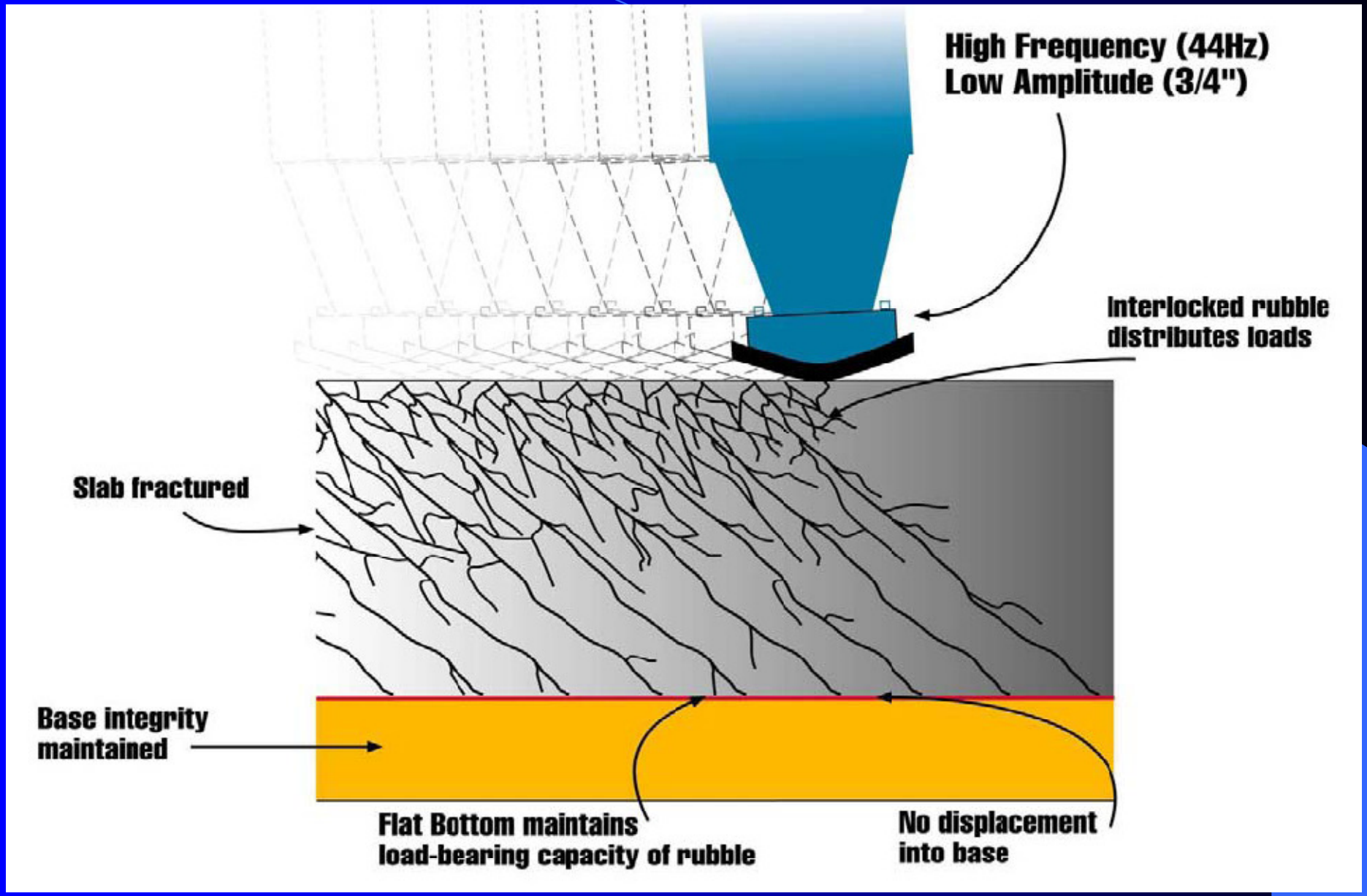
Resonant Pavement Breaker

- Resonant breaker hinders traffic flow because the machine encroaches 3 to 5 feet on the adjacent lane when rubblizing the centerline
- breaking pattern is approximately 8 inches wide, and requires 18 to 20 passes to break a 12-foot lane width
- 20,000 lb wheel load and 60,000-70,000 lb weight can damage rubblized pavement


RMI
RB 500
RESONANT
PAVEMENT
BREAKER


RB 500

Illustration of PCC fracturing resulting from Resonant Rubblization



Resonant broken PCC pavement

Crack & Seat

- **The Crack and Seat is recommended for Jointed Plain Concrete only**
- **Crack spacing (18” to 36” is typical) is a function of the overall stiffness of the existing subbase-subgrade foundation.**
- **Seating of the broken slabs after cracking is intended to re-establish support between the base and the fractured PCC**

Break and Seat

- Suitable for JRCP, steel debonding required
- Largely replaced by rubblization because of more consistent results
- Sometimes used prior to rubblization for thicker pavement slabs such as airports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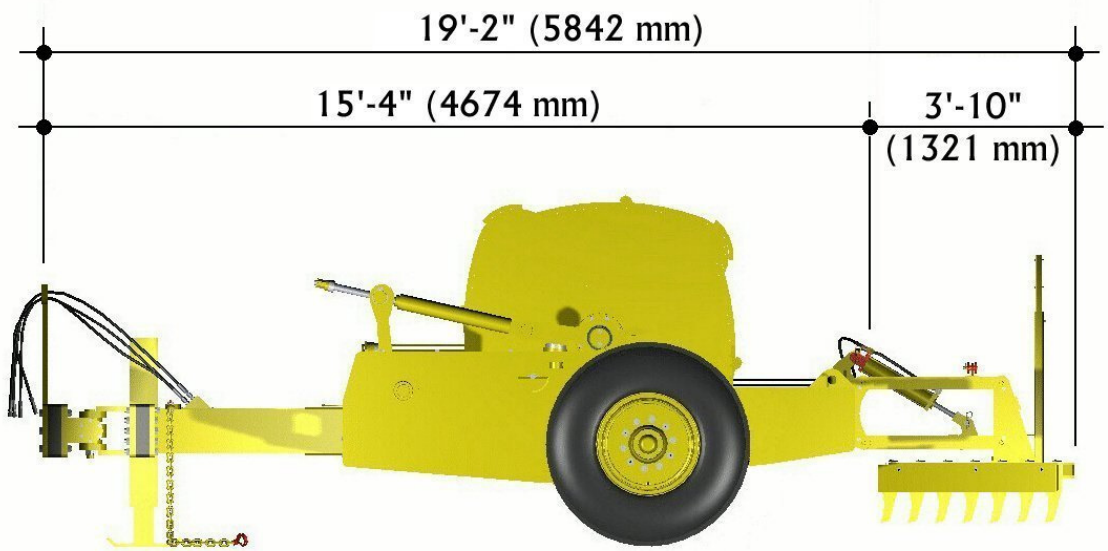
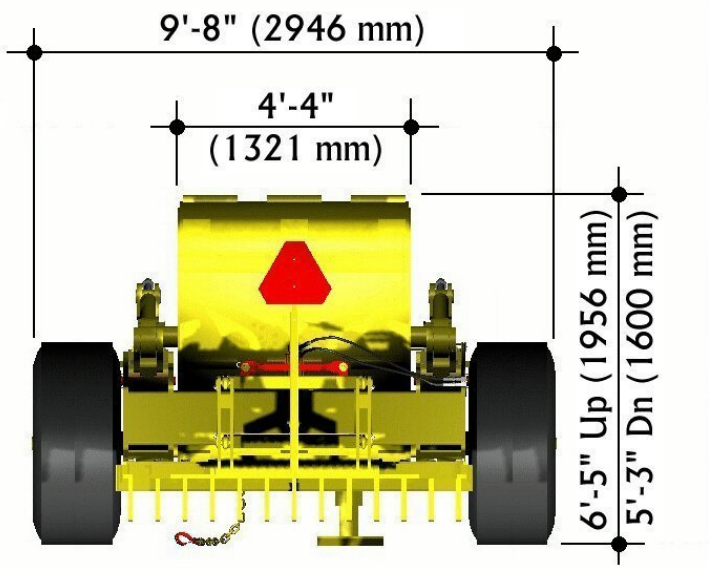
IMPACTOR 3000 SPECIFICATIONS





IMPACTOR 2000 SPECIFICATIONS	
Total Unit Weight (approx.)	28,000 lbs. (12,700kg)
Drum Weight W/Axle (approx.)	19,000 lbs. (8618kg)
Towing Unit Required (Breaking)	Tractor 175-hp flywheel (approx. 130 FKW)
Towing Unit Required (Compaction)	Tractor 200-hp flywheel (approx. 150 FKW)(4WD may be required depending on soil condition)
Max Recommended Operating Speed	8 mph (13km/h) compaction, 7 mph (11km/h) breaking.
Blows Per Second	approx. 2 @ maximum recommended speed
Breaking Force	approx. 30,000 psi (206,820 kPa)
Compaction Energy	approx. 22,000 ft. lbs. (30,000 joules) per blow
Effective Compaction Width	7 ft (2.13 meters) includes wheel roll
Lift Thickness	1 to 4-feet (0.3 to 1.2-meters) depending on type of material and moisture content
Tires	12.00R20 (tubeless)
Drum Hydraulics*	2 cylinders for lifting of drum to transport mode, 2250 psi (15 500 kPa) (155 bar)
V-Grader Hydraulics	1 cylinder for operation of V-Grader, 2250 psi (15 500 kPa) (155 bar) (float capability recommended)* Used to raise the drum off the ground, for trailering or operating where drum contact is not desired

IMPACTOR 3000 SPECIFICATIONS	
Total Unit Weight (approx.)	38,000 lbs. (17,240kg)
Drum Weight W/Axle (approx.)	29,000 lbs. (13,155kg)
Towing Unit Required (Breaking)	Tractor 200-hp flywheel (approx. 150 FKW)
Towing Unit Required (Compaction)	Tractor 200-hp flywheel (approx. 150 FKW)(4WD may be required depending on soil condition)
Max Recommended Operating Speed	8 mph (13km/h) compaction, 7 mph (11km/h) breaking.
Blows Per Second	approx. 2 @ maximum recommended speed
Breaking Force	approx. 45,000 psi (314,370 kPa)
Compaction Energy	approx. 33,000 ft. lbs. (44,750 joules) per blow
Effective Compaction Width	8.5 ft (2.59 meters) includes wheel roll
Lift Thickness	1 to 5-feet (0.3 to 1.5-meters) depending on type of material and moisture content
Tires	Call
Drum Hydraulics*	2 cylinders for lifting of drum to transport mode, 2250 psi (15 500 kPa) (155 bar)
V-Grader Hydraulics	1 cylinder for operation of V-Grader, 2250 psi (15 500 kPa) (155 bar) (float capability recommended)