Material Selection for Concrete Overlays

Project No. 0-6590 Training Presentation

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Training Presentation

- This PowerPoint presentation was developed for Project 0-6590: Materials Selection for Concrete Overlays.
- This training presentation is intended to educate TxDOT personnel for training design engineers, construction personnel, and inspectors on concrete overlay materials selection and construction.

Presentation Outline

- Overview on Concrete Overlays
- Factors that Determine Concrete Overlay Performance
- Materials Selection Guidelines
- Construction Method Guidelines

Overview of Concrete Overlays

Purpose of Concrete Overlays

- Optimize/extend the use of the existing pavement remaining life by placing an additional layer of concrete
- By doing this, we…
  - Expedite construction
  - Reduce cost
  - Increase the structural integrity
  - Improve the riding quality
  - Protect the structure against deleterious environmental effects

Conceptual Concrete Overlay Application

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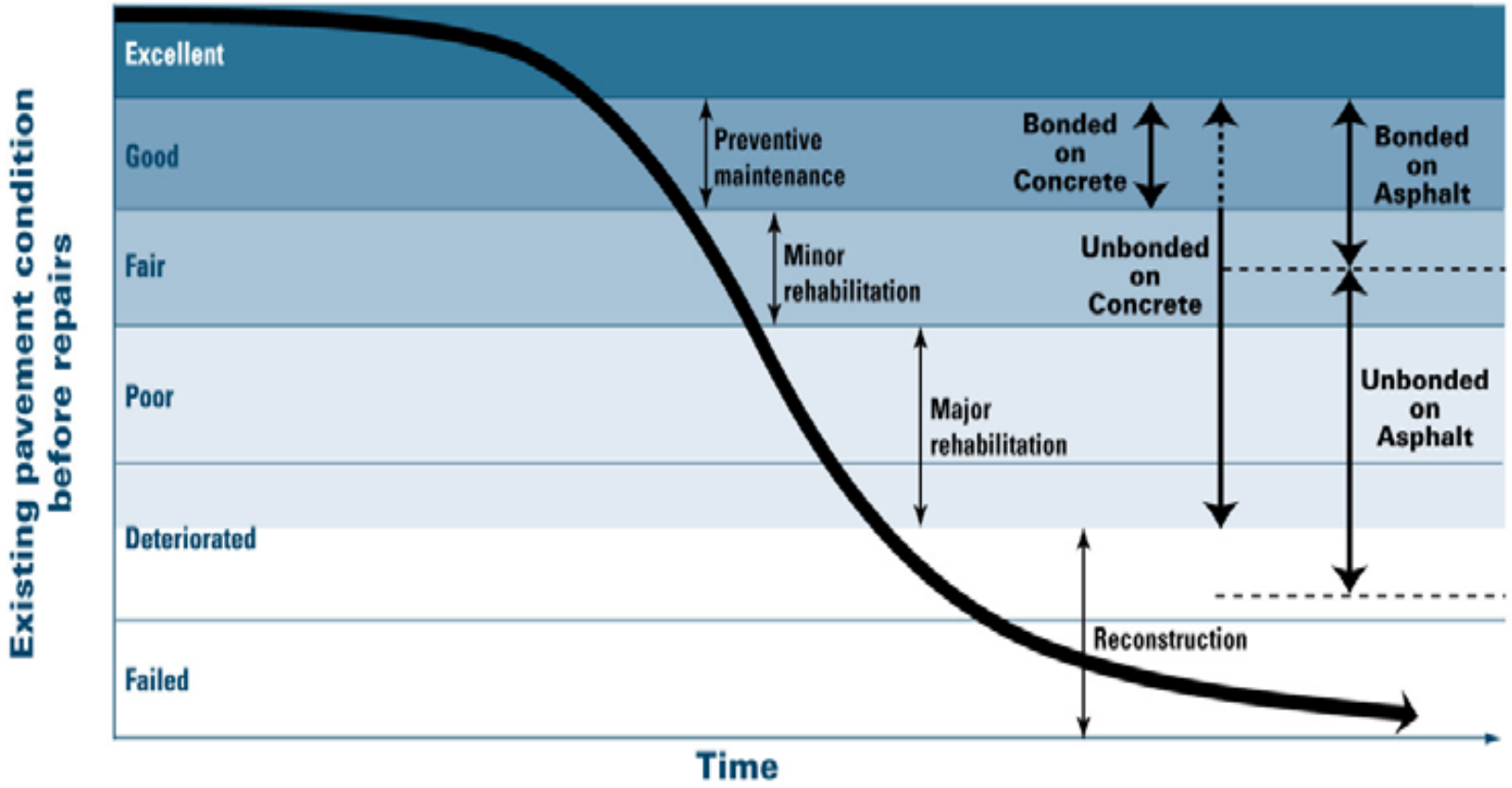
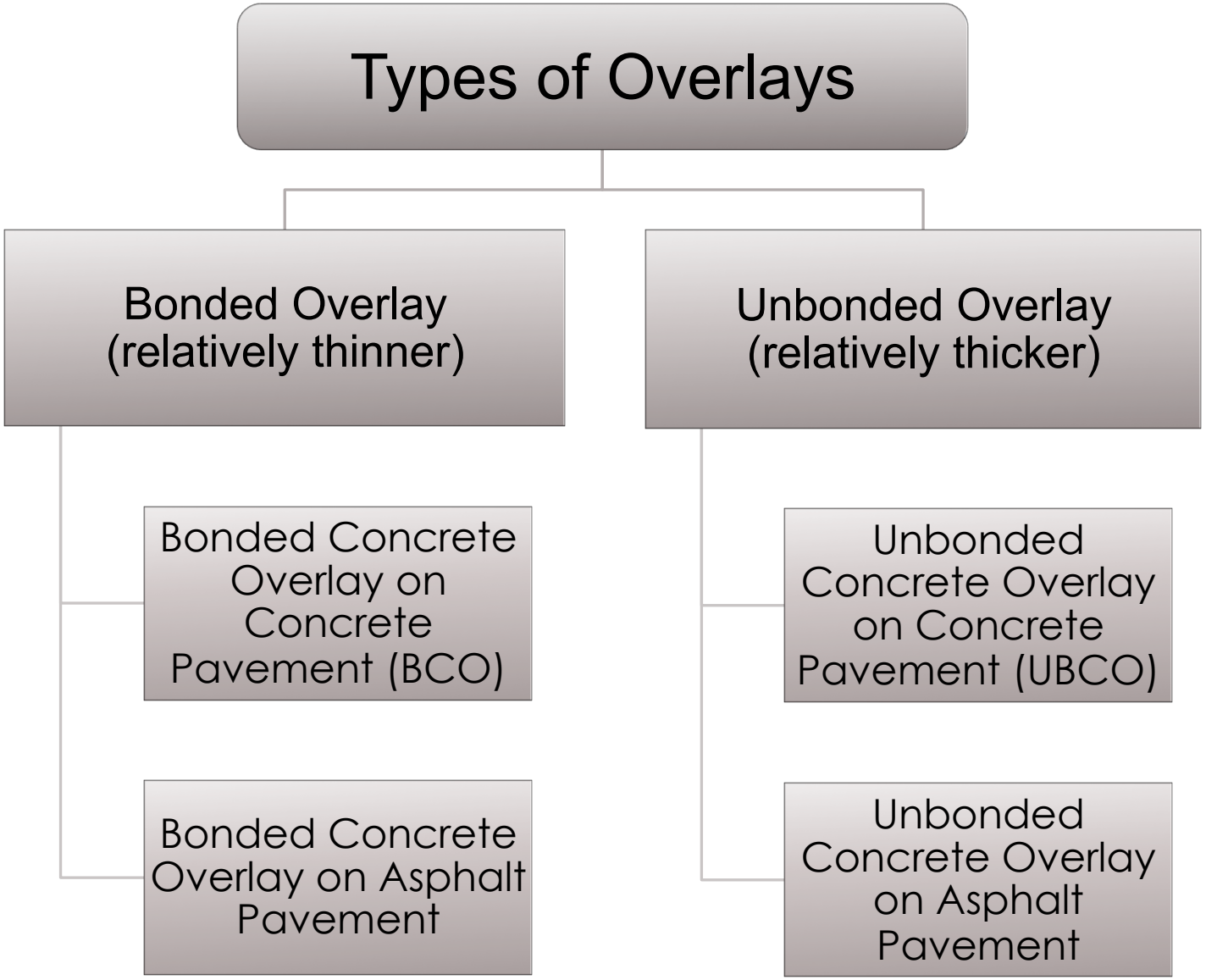
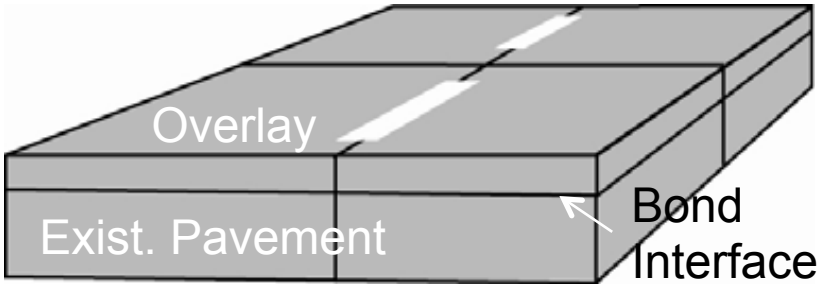



Types of Overlays
Bonded Overlay (relatively thinner)
Unbonded Overlay (relatively thicker)
Bonded Concrete Overlay on Concrete Pavement (BCO)
Bonded Concrete Overlay on Asphalt Pavement
Unbonded Concrete Overlay on Concrete Pavement (UBCO)
Unbonded Concrete Overlay on Asphalt Pavement

Bonded Overlays

- Generally between 2 to 8 inches thick
- Used when existing pavement is in good structural condition with some surface distress
- Eliminates any surface defects; increase structural capacity and improve surface friction, noise, and rideability
- Typically used directly over existing pavement without additional repair except for spot-repairing of severely deteriorated areas.

Bonded Overlays



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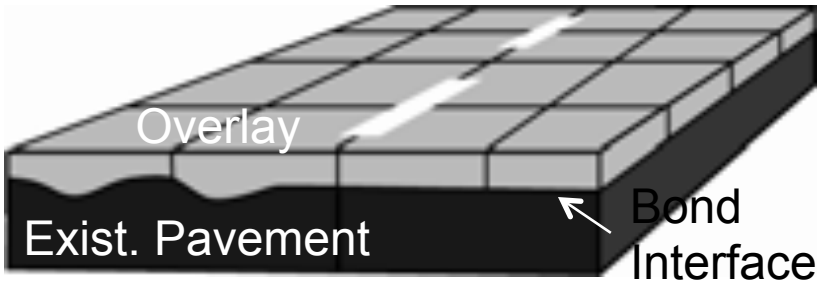
- Bonded Concrete Overlay on Concrete Pavement (BCO)



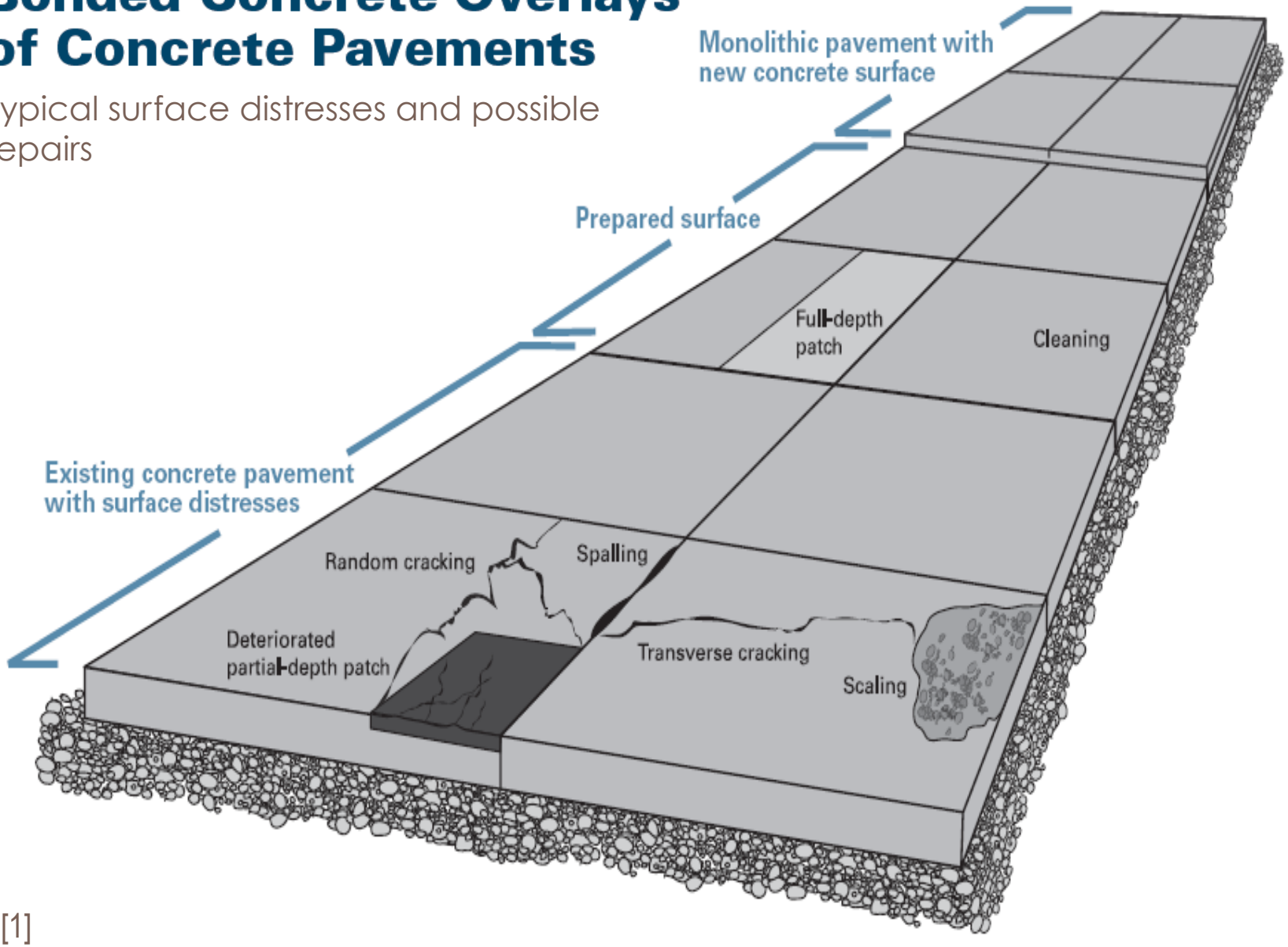
[1]

- Bonded Concrete Overlay on Asphalt Pavement
  - Often called "thin or ultrathin whitetopping" depending on the thickness

Guide to Concrete Overlays. (2008). National Concrete Pavement Technology Center

Bonded Concrete Overlays of Concrete Pavements

Typical surface distresses and possible repairs



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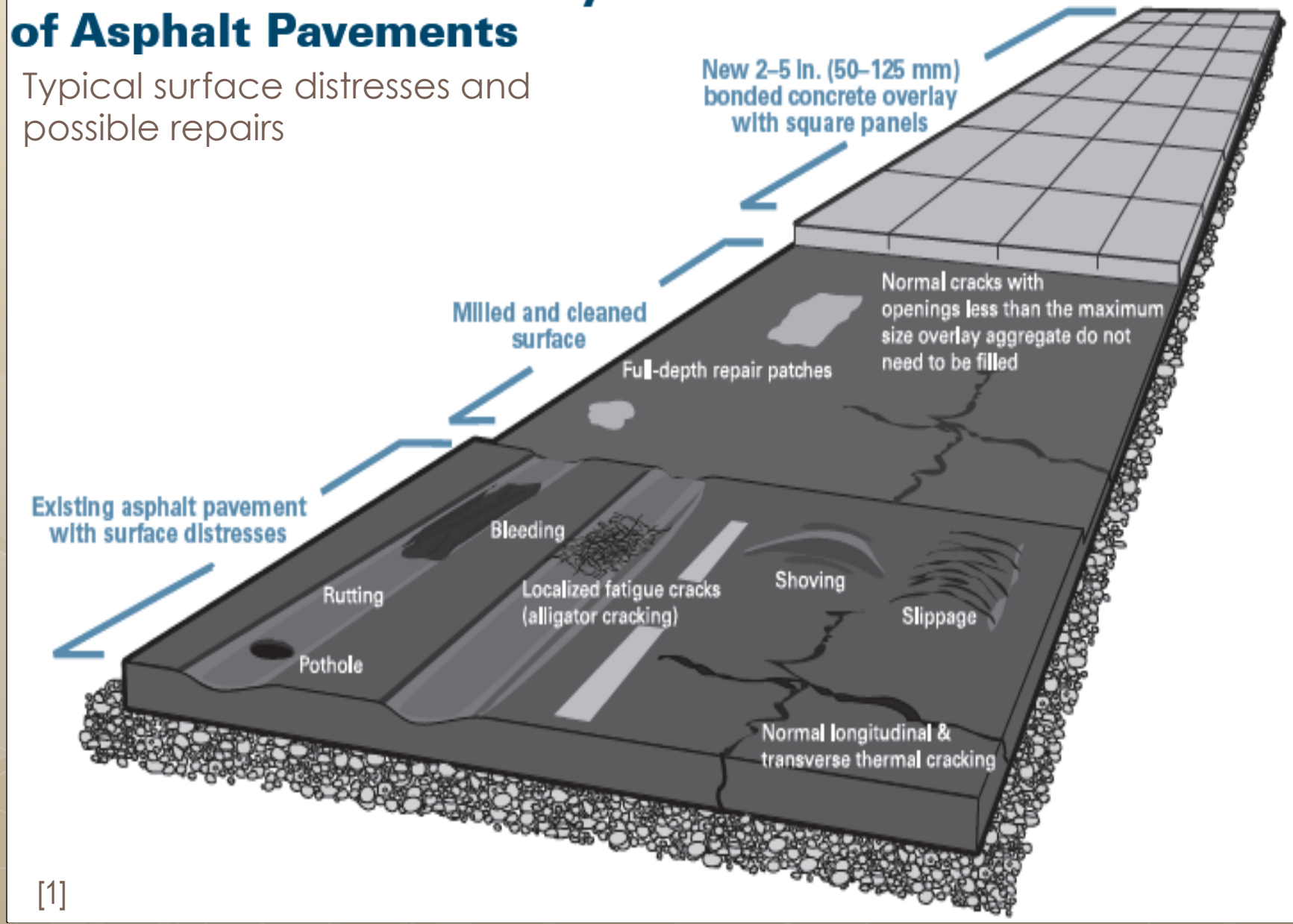
Bonded Concrete Overlays of Asphalt Pavements

Typical surface distresses and possible repairs



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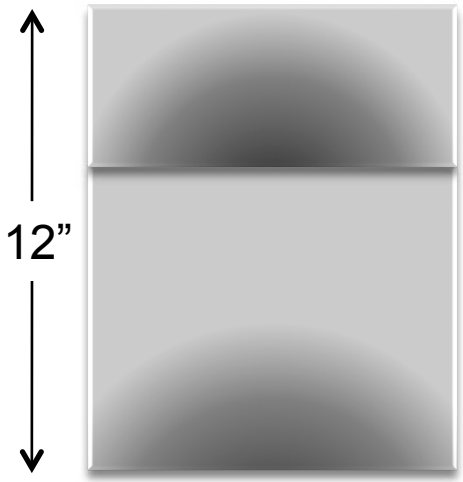
Bonded Overlays

- **Bond is very important**
  - Promotes a monolithic pavement
  - Allows the existing pavement to carry traffic load
  - Without bond, thin concrete overlay has to carry most of the traffic load
- Efforts are required to achieve efficient bond
  - Materials compatibility
  - Surface preparation
  - Construction
  - Bond criteria should be included in special specifications in every bonded overlay project

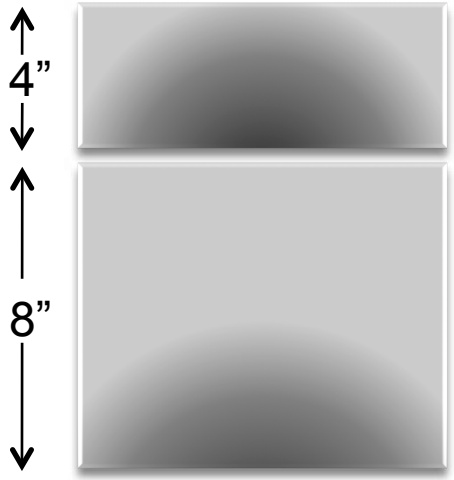
Bonded Overlays

Efficient bond…. WHY? Because bonding will create monolithic behavior WHILE de-bonding will lead to higher deflection = lower resistance to damage



Bonded

Stiffness ~ $12^3 = 1712$



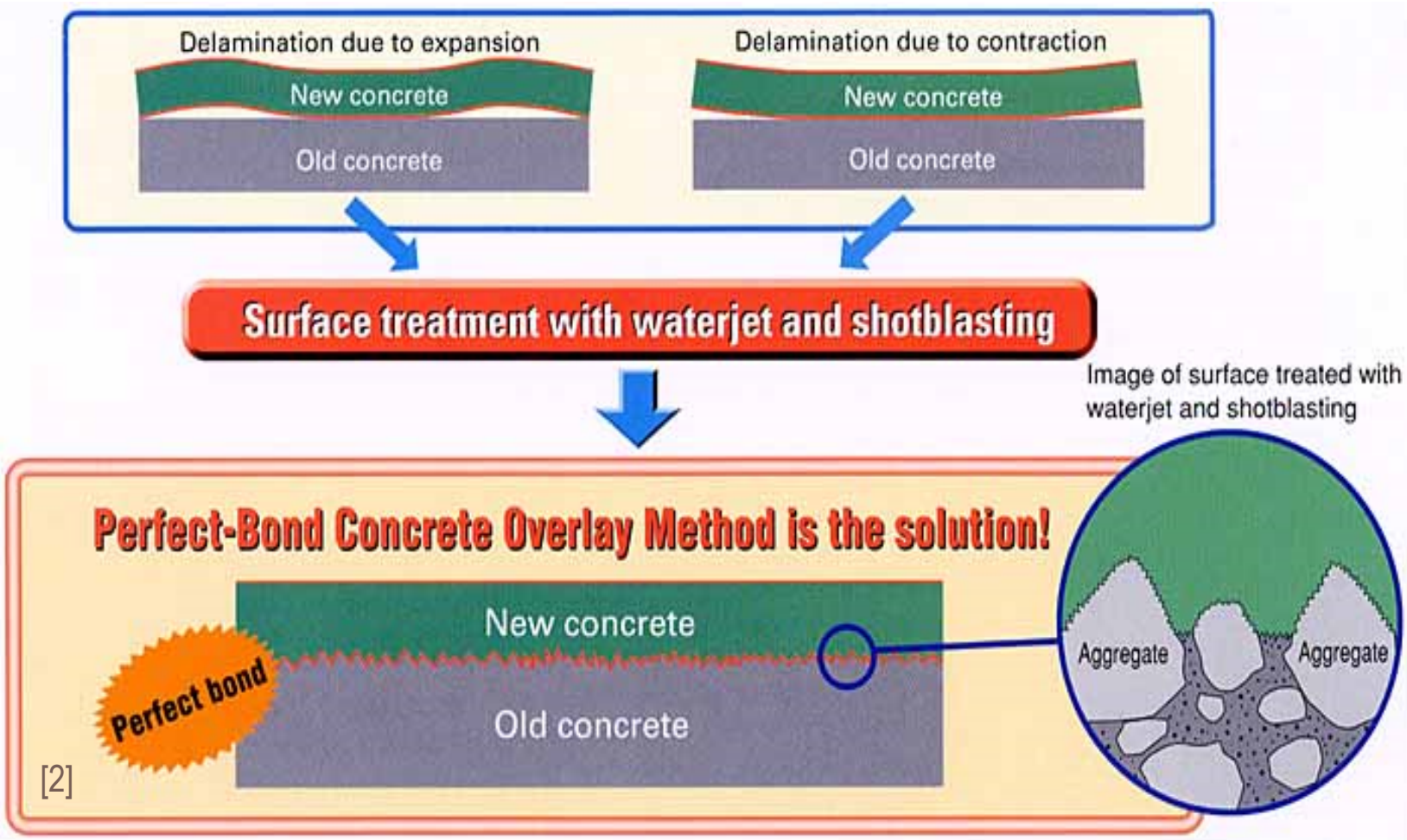
De-Bonded

Stiffness ~ $4^3 + 8^3 = 576$

“Bonded is 3 times stiffer”

Bonded Overlays

- Materials Compatibility
  - Materials used for concrete overlay must be compatible with existing pavement to promote a monolithic pavement
- Surface Preparation
  - Surface must be properly prepared to receive the concrete overlay
  - This will encourage efficient bond at the interface
- Construction
  - Practicing sound construction will maximize benefits of concrete overlays

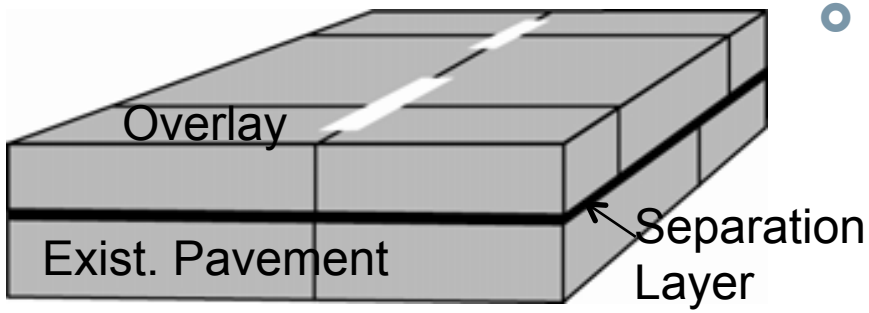


So, good bonding will prevent delamination (de-bonding)!!!

Unbonded Overlays

- Generally greater than 7 inches thick
- Used when existing pavement is in poor structural condition with extensive surface distress
- It is more like a real pavement and not considered monolithic (unbonded condition)
- Existing pavement is considered as a subbase
- Restores or enhances structural capacity, improves surface friction, noise, and rideability

Unbonded Overlays



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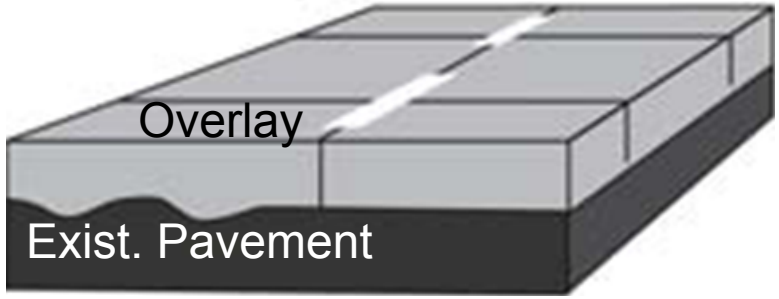
- Unbonded Concrete Overlay on Concrete Pavement (UBCO)
  - A **separation layer** is **ESSENTIAL** in order to deter reflective cracking



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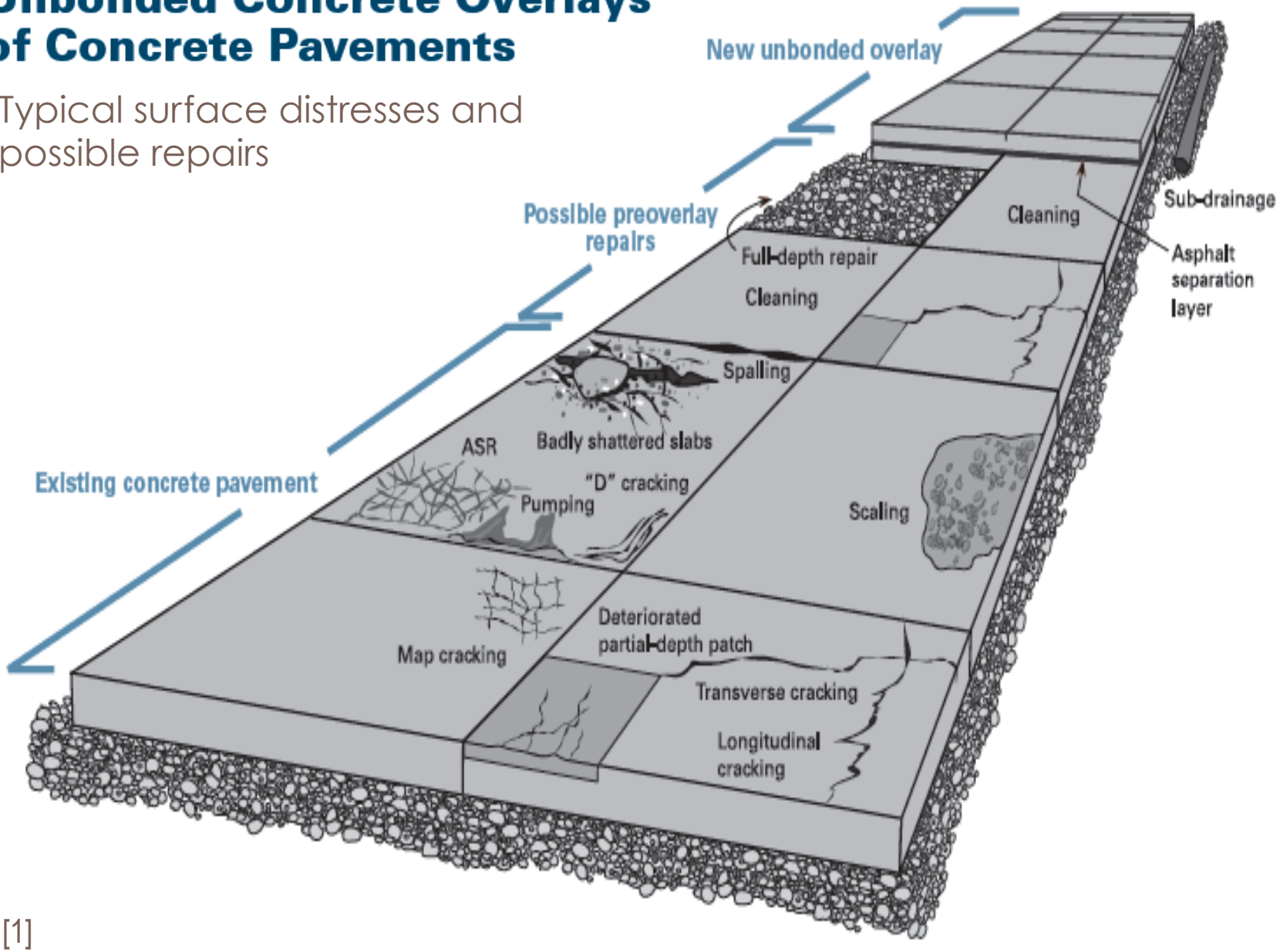
- Unbonded Concrete Overlay on Asphalt Pavement
  - Often called "conventional whitetopping"
  - No separation layer required

Unbonded Concrete Overlays of Concrete Pavements

Typical surface distresses and possible repairs



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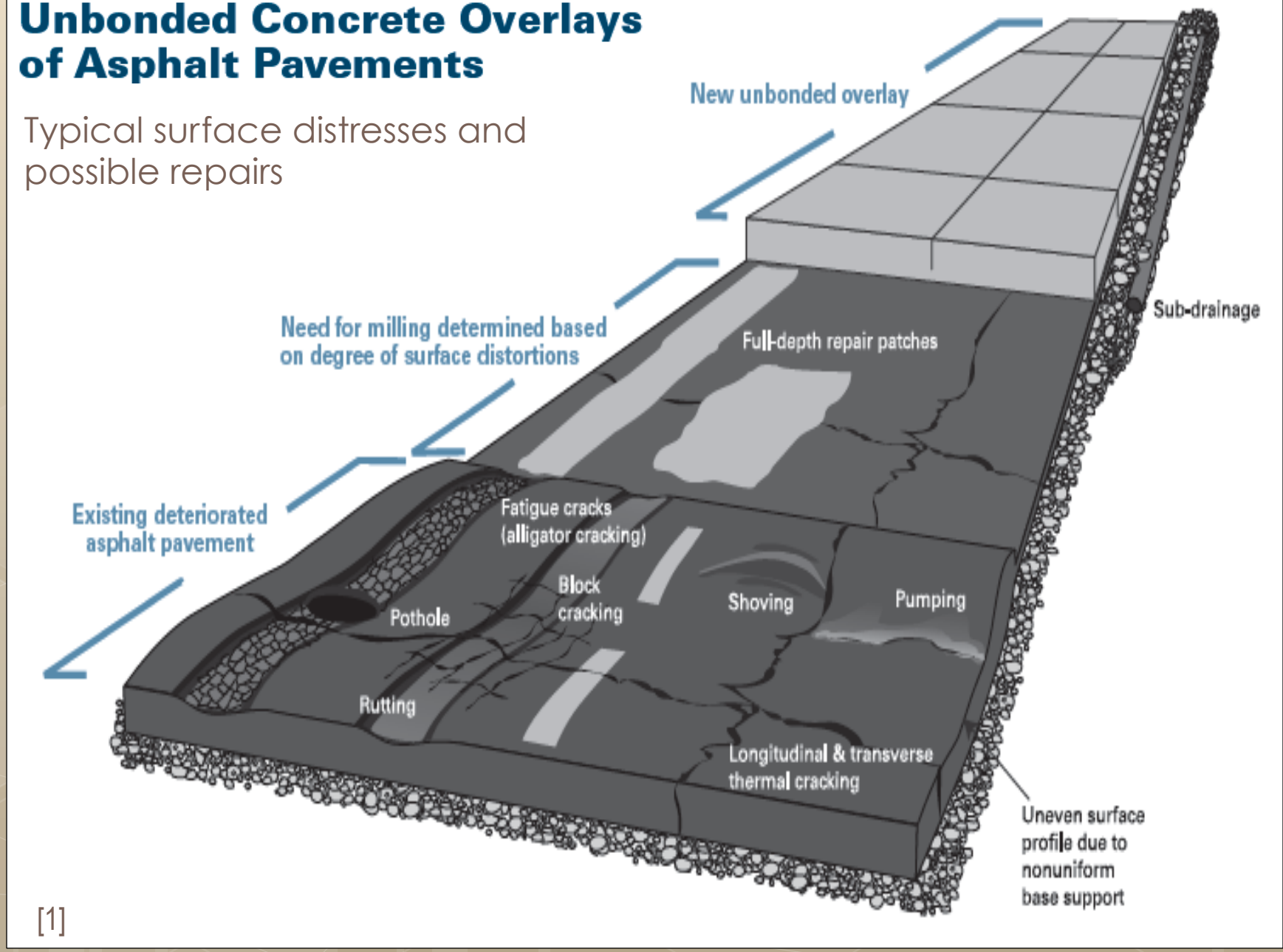
Unbonded Concrete Overlays of Asphalt Pavements

Typical surface distresses and possible repairs



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Unbonded Overlays

- UBCO
  - Must maintain separation with existing pavement
    - Use of separation layer (typically, 1-inch asphalt layer)
  - Two purposes served by the separation layer
    - Provide shear plane that helps prevent cracks from reflecting up from the existing pavement.
    - Prevents bonding between the new and old layer allowing them to move independently (bond breaker)

Factors that Affect Concrete Overlay Performance

Factors that Affect Concrete Overlay Performance

- Performance of concrete overlay depends on the following factors:
  - Materials Compatibility
  - Materials Selection
  - Environmental Considerations
  - Surface Preparation
  - Construction Practice

Materials Compatibility

- **For BCOs only**
- Designed concrete should have thermal and elastic properties similar to or lower than that of existing pavement to minimize stress at bond interface
  - To promote creating a monolithic pavement
  - Coefficient of thermal expansion (CTE) and modulus of elasticity (MOE) of new concrete overlay should be equal or less than that of existing pavement, but no more than 5.5 in/in/°F
  - CTE is determined mainly by the coarse aggregate (CA)

Materials Selection

- Cement type
  - Must consider type of project and environment
    - Normal project
      - A typical pavement construction without any foreseen changes
      - Normal cement can be used
    - Expedited project
      - Shortened construction time and opening to public traffic is crucial
      - Cements with high early strength should be considered

Materials Selection

- Cementitious content
  - Cementitious content for typical concrete pavement mixture designs can be used for unbonded overlays
  - For bonded overlays, cementitious content should be increased to have enough paste available at the interface to form an efficient bond
- Water-to-cementitious materials Ratio (w/cm)
  - A chosen w/cm must provide enough water to create adequate amount of paste but no more than enough to prevent deleterious effects such as shrinkage

Materials Selection

- Aggregates
  - Maximum coarse aggregate (CA) size should be less than one-third of the concrete overlay thickness (but no more than 1 to 1.5 inches)
  - Fine aggregate (FA) should be natural, non-reactive, and have low absorption
  - Generally, the amount of CA should be maximized and FA should be minimized to reduce shrinkage
  - Uniform gradation is recommended to reduce paste requirement

Materials Selection

- Fly Ash
  - Fly ash replacement for cement can:
    - Reduce cost
    - Increase workability
    - Increase protection against deleterious environment
    - Increase setting time
  - However, higher the fly ash replacement the early strength will be lower
    - Will lead to delay in construction and opening to traffic
    - Cold weather (lower temperature) can delay the strength gain even further
  - Replacement rate must be adjusted according to the weather and the project allotted time

Materials Selection

- Admixtures
  - Can be used to increase workability, promote fiber incorporation into concrete mixture, air entrainment, and retard or accelerate concrete reaction
  - Trial batches should be made to see the interaction between the admixtures

Materials Selection

- Fibers
  - May reduce shrinkage and/or increase toughness of concrete
  - May reduce compressive and flexural strength
  - Fibers may help to bridge cracks and keep them tight
  - Typical fiber dosages used in concrete overlay constructions do not alter CTE of the concrete
  - Stronger fibers (such as steel and structural synthetic fibers) can carry load even after concrete cracks
  - However,
    - Fibers decrease workability (can be offset by use of water reducers, increasing cement paste, and/or fly ash)
    - Good fiber dispersion may be difficult to achieve

Materials Selection

- Reinforcement bars or wire mesh
  - Placing reinforcement bars or wire mesh at the bottom of the concrete overlay (near the interface) restricts the movement at the bottom
  - An effective bond will be achieved with less movement near the interface

Materials Selection

- Separation Layer Material for UBCOs
  - Allows the new concrete overlay to act independently on the existing pavement
  - 1-inch thick asphalt layer is typically used
  - Inadequate layer will allow reflective cracking

Environmental Considerations

- Weather conditions during construction of the overlay can be critical
- The following variables must be monitored during construction:
  - Temperature
  - Wind speed
  - Relative humidity
- Using the above variables, the rate of evaporation can be measured and ensure whether to allow or postpone concrete overlay construction
- ConcreteWorks™ program can be used to simulate temperatures

Surface Preparation

- Well prepared surface will promote bond for bonded overlays and prevent reflective cracking for unbonded overlays
- Bonded Overlays
  - Some repair on severely deteriorated areas
  - **BOND** is **CRITICAL!!!**
    - Remove foreign materials that may hinder bond development
    - Surface texturing to increase the efficiency of bond
      - Mean profile depth (MPD) measured by a circular track meter (CTM) should be greater than 0.80
    - Surface cleaning and wetting just before overlay placement
- Unbonded overlays
  - Some repair on severely deteriorated areas
  - **A SEPARATION LAYER** is **CRITICAL!!!**
  - Surface cleaning and wetting before overlay placement

Construction Methods

- There are a numerous steps for concrete overlay construction that defer from typical pavement constructions
  - Placement
    - Bonding agent application (if needed)
    - Reinforcements
    - Consistency
  - Jointing
  - Finishing/Curing
    - Carpet dragging
    - Higher curing agent dosage

Factors that Affect Concrete Overlay Performance

- Guidelines have been developed to help you successfully control the mentioned factors to produce quality concrete overlays
  - Materials selection guideline provides:
    - Selection criteria
    - Flowcharts
  - Construction method guideline provides:
    - A construction process walkthrough

Materials Selection Guidelines

Materials Selection Guidelines

- Materials selected must satisfy both of the following:
  - Performance Based Acceptance Criteria
  - Prescriptive Based Acceptance Criteria
- Flowcharts for project and materials selection
  - Created to assist in project and materials selection through a step-by-step procedure

Performance Based Acceptance Criteria

Candidate materials selected for concrete overlays should meet certain **RECOMMENDED** performance limits which were obtained from 0-6590 project, TxDOT specifications, and literature review

Compressive and Flexural Strength

- Compressive Test (ASTM C39)
  - Measures the compressive strength of concrete
  - Determines if concrete is adequate to resist compressive load induced by traffic
- Flexural Test (ASTM C78)
  - Measures the flexural strength of concrete
  - Determines if concrete is adequate to resist flexural (bending) load induced by traffic

Compressive and Flexural Strength

- Compressive Criteria
  - Minimum: 3500 psi at 7 days or 4400 psi at 28 days
  - Maximum: Must be adjusted so that increased MOE due to high compressive strength is less than the MOE of the existing pavement to reduce interface stress (for BCOs only)
- Flexural Criteria
  - Minimum: 570 psi at 7-day or 680 psi at 28-day
- Obtained from ITEM 360 TxDOT specification 2004

Compressive and Flexural Strength

- To increase the strength:
  - Decrease fly ash replacement
  - Decrease w/cm
  - Use coarse aggregate with higher strength
- The following may lower the strength:
  - Increased fly ash replacement
  - Increase w/cm
  - Fiber addition (only minimal decrease in the performance)

CTE and MOE (applicable to BCOs only)

- Coefficient of Thermal Expansion (CTE)
  - Measures the degree of concrete expansion and contraction due to thermal change
  - CTE compatibility between concrete overlay and the existing pavement is very important to promote a monolithic pavement
- Modulus of Elasticity (MOE)
  - Measures the elasticity of concrete
  - MOE compatibility between concrete overlay and the existing pavement is very important to reduce stress on the concrete overlay

CTE and MOE (applicable to BCOs only)

- CTE and MOE should be equal or lower than that of existing pavement
- CTE is determined by CA
  - Must select CA that will yield concrete with equal or lower CTE than that of the existing pavement, but no more than 5.5 in/in/°F
- To lower MOE:
  - Increase fly ash addition
  - Increase w/cm
  - Add fibers
- The following may increase MOE:
  - Decreased fly ash addition
  - Decrease w/cm

Bond Strength (applicable to BCOs only)

- Bond Strength (ASTM C1583)
  - Measures the bond strength at the interface between concrete overlay and the existing pavement
  - Determines whether adequate bond strength is achieved at the interface that will promote a monolithic pavement

Bond Strength (applicable to BCOs only)

- The recommended minimum strength: 200 psi
  - This criterion comes from AASHTO and is based on numerous past studies that found that bond strength greater than 200 psi resulted in satisfactory concrete overlay performance.
- Bond strength criteria should be included in special specifications in every bonded overlay project.
- Increased bond strength will promote monolithic movement of the concrete overlay and the existing pavement

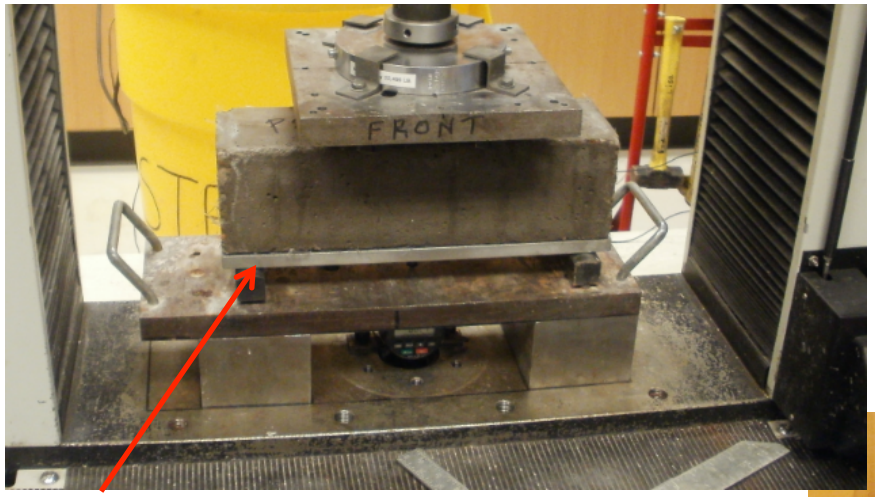
Bond Strength (BCOs only)

- To increase the bond strength:
  - Use of CA with low CTE and MOE
  - Prepare the surface properly
  - Increase cement paste available at the interface
  - Addition of fibers may increase bond strength
- The following may lower the bond strength:
  - Use of CA with high CTE and MOE
  - Lack of proper surface preparation
  - Decreased cement content available at the interface

Average Residual Strength (ARS)

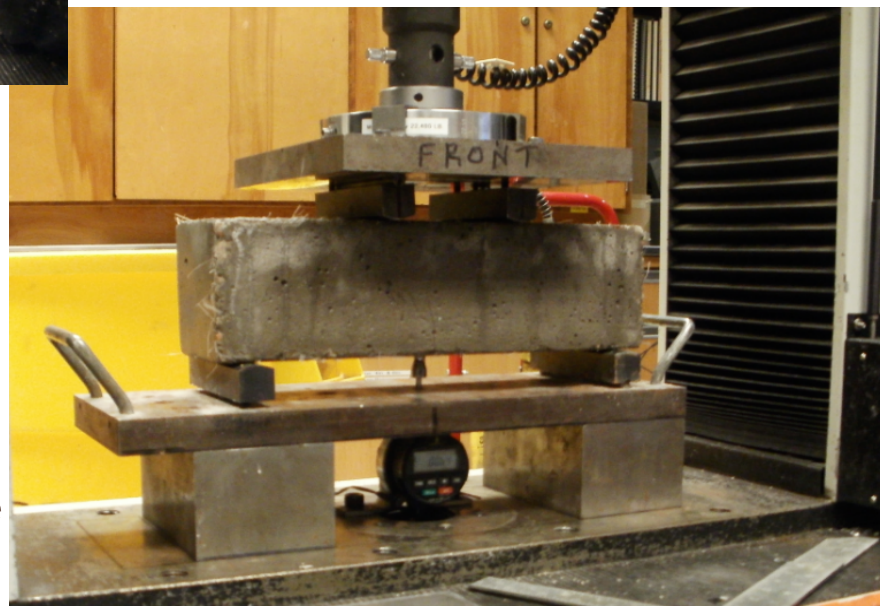
- What is ARS?
  - One of the possible benefits of incorporating fibers into concrete is their ability to bridge and carry load after concrete cracks
  - The distributed fibers act as tension load carrying elements and their averaged quantifiable strength is called "Average Residual Strength."
- Explanation of the test (ASTM C1399)
  - A modified four-point bending test with a steel plate
  - A beam is first loaded until it cracks—plate on bottom prevents complete separation.
  - Plate is removed and load is applied to determine the contribution of the fibers across the crack to carry load.

Average Residual Strength (ARS)



Steel Plate

- Beam (with a steel plate at the bottom) is loaded until the first crack



- The steel plate is removed and reloaded to measure ARS

Average Residual Strength (ARS)

- TxDOT tentatively recommends a minimum of: 115 psi
  - However, there is no direct correlation between ARS results and field performance
  - There are no data to prove that fibers increase concrete overlay performance
- ARS test should be used to evaluate any changes in toughness due to fiber incorporation
  - Fibers act to bridge the cracks providing more toughness to the concrete
- Well dispersed fibers will increase consistency and average maximum ARS
- Better fiber dispersion can be achieved by introducing the fibers early in the mixer

Average Residual Strength (ARS)

- To increase ARS:
  - Use steel or structural synthetic fibers instead of using normal synthetic fibers
  - Increase fiber dosage
  - Use fibers with deformed shape
  - Increase mixing time to improve fiber dispersion
- The following may lower ARS:
  - Minimal fiber dosage
  - Lack of proper fiber dispersion

Drying Shrinkage

- Drying Shrinkage (ASTM C157)
  - Measures the degree of shrinkage of concrete
  - Drying shrinkage should be minimized
- To lower shrinkage:
  - Increase fly ash replacement
  - Decrease w/cm
- The following may increase shrinkage:
  - Increased w/cm
  - Decreased fly ash replacement

Workability (Slump)

- Slump Test (ASTM C143)
  - Provides a measure of concrete workability
- Slump requirement is project specific and depends on
  - Type of project
  - Whether slip-form paving is used or form-work is used
- Material constituents will affect the slump, therefore trial batches should be made
  - Addition of fibers will greatly reduce workability
  - Water reducing agents, fly ash, reduction in fine aggregate content will increase workability

Workability (Slump)

- To increase workability:
  - Increase fly ash replacement
  - Increase w/cm
  - Use water reducer
- The following may decrease workability:
  - Decreased fly ash replacement
  - Decreased w/cm
  - Use of fibers
    - Higher the dosage lower the workability

Prescriptive Based Acceptance Criteria

Candidate materials selected for concrete overlays should satisfy certain **RECOMMENDED** design guidelines which have been obtained from 0-6590 project, TxDOT specifications, and literature review

Cement Type

- Criteria
  - Based on the research project:
    - Type I/II – Adequate for normal concrete overlays
  - Recommendations from literature:
    - For normal concrete overlays
      - Type I or I/II
    - For expedited concrete overlays
      - Type III or more finely ground Type I

Cement Type

- Type I/II
  - A normal cement type that produces adequate performance requirements for typical concrete overlays
- Type III or more finely ground Type I
  - Ideal for expedited constructions because higher early strength can be achieved in less time
  - However, heat of hydration is increased and can cause thermal cracking

Cement Content

- Criteria
  - Based on the research project:
    - 6 – 7 sks/yd³ (564 – 658 lb/yd³)
  - Recommendations from literature:
    - Up to 7.5 sks/yd³ (705 lb/yd³) has been used (for BCOs only)
    - Higher cement content will increase paste availability at the interface and will promote
      - Adequate bond at the interface therefore eliminating the need for a bonding agent
      - Coat aggregates
      - Increased workability
    - However, the cement content should be minimized to reduce the possibility of shrinkage cracking

Cement Content

- Increase in cement content (i.e. decreasing w/cm)

- Benefits
  - Higher compressive strength at early age
  - Higher flexural strength at early age
  - Higher bond strength

- Drawbacks
  - Higher shrinkage
  - Higher MOE

Fly Ash Replacement

- Replacement Criteria
  - In the research, adequate properties were achieved at dosages up to 25%, but compressive and flexural strengths were significantly lowered at 50% dosage
  - Current TxDOT allowable
    - Minimum: 20%
    - Maximum: 35%
- Increased replacement results in lower early compressive, flexural, and bond strength especially in cold weather.
  - When high dosage of fly ash is used in cold weather, the low ambient temperature will slow down or even stop hydration reaction and concrete may never set

Fly Ash Replacement

- Increase in fly ash replacement
  - Benefits
    - Higher workability
    - Lower drying shrinkage
    - Lower MOE
  - Drawbacks
    - Lower compressive strength at early age
    - Lower flexural strength at early age

Water-to-Cementitious Materials Ratio (w/cm)

- Recommendations from literature:
  - For normal placement
    - Minimum: 0.40 (used in the research project)
    - Maximum: 0.45
    - For expedited placement
      - As low as 0.35
- Increasing the w/cm can lead to:
  - Higher workability
  - Lower MOE

Aggregates

- Coarse Aggregate Criteria
  - Coefficient of thermal expansion, CTE (BCOs only)
    - Equal or lower than the CTE of the existing pavement
  - Size
    - Minimum: 0.5 inches
    - Maximum: one-third of the concrete overlay thickness (not to exceed 1 – 1.5 inches)
  - Gradation
    - Maximize CA and minimize FA
    - Uniform gradation reduces paste requirement, thus reducing shrinkage
- Fine Aggregate Criteria
  - Natural, non-reactive, and low absorption
  - Acid insoluble residue greater than 60%

Aggregates Ratio

- Fine aggregate to overall aggregate ratio, FA/(FA+CA) by weight, criteria
  - Based on the research project
    - 0.35 – 0.45
- Aggregate to cement (a/c) ratio by weight criteria
  - Based on the research project
    - 4.7 – 6.0
- Maximize CA and minimize FA
- Both ratios are indirectly proportional to workability

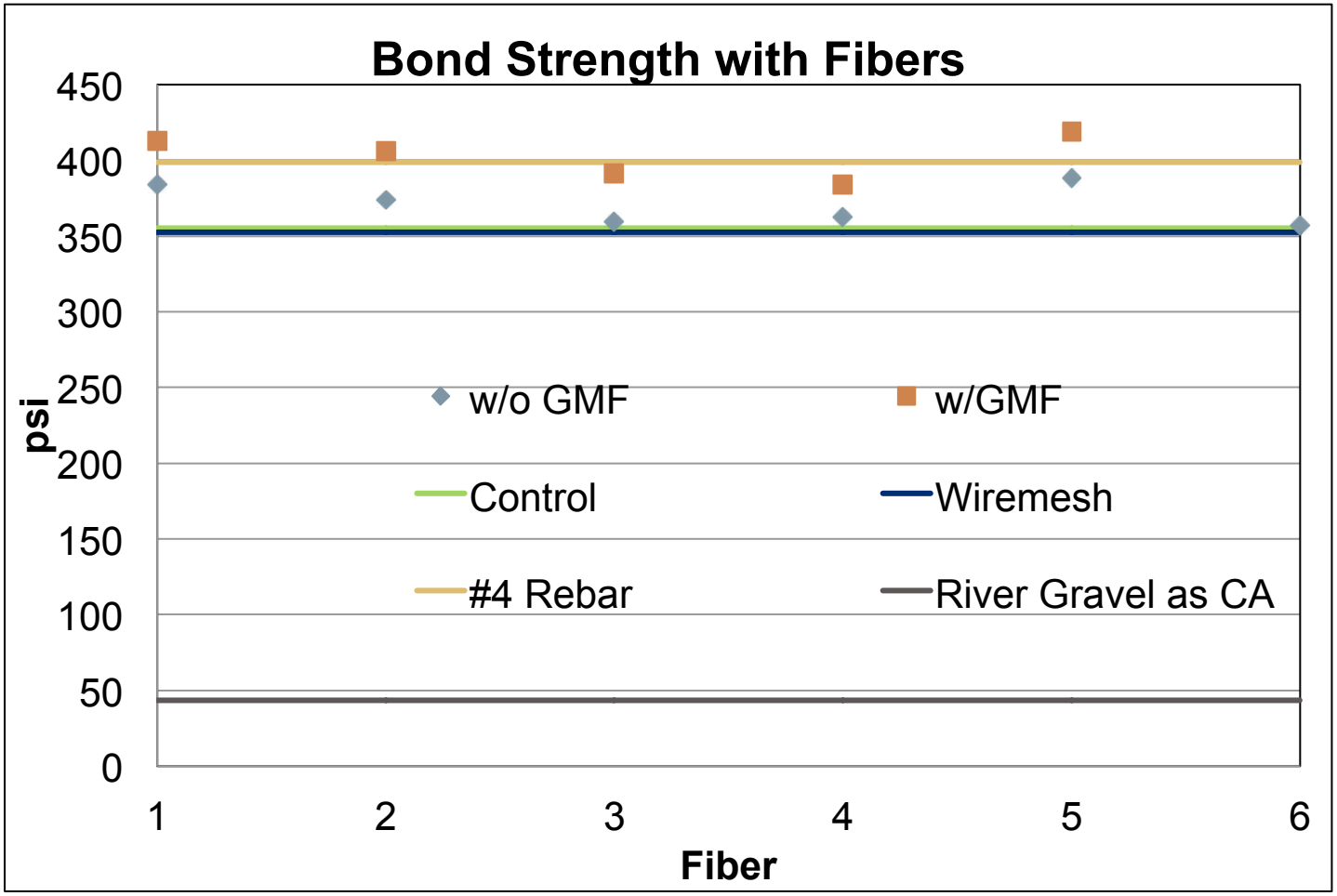
Admixture Selection and Dosage

- Criteria
  - Based on the research project
    - Water reducing agent (ASTM C494 Type A) at the manufacturer's recommended dosage found to be adequate
    - Increased workability and helped to incorporate fibers into the mixture
    - Dosages should be adjusted through trial batches

Fibers

- There is still a lack of proof confirming benefits of using fibers in concrete overlay application
  - One test to measure quantifiable benefit of using fibers available is average residual stress (ARS) test
  - However, there is no direct correlation between ARS test and the field performance
- Fibers may help to reduce shrinkage, increase toughness, and improve bond strength
  - But, not enough information exists on how the actual performance of the overlay will be affected

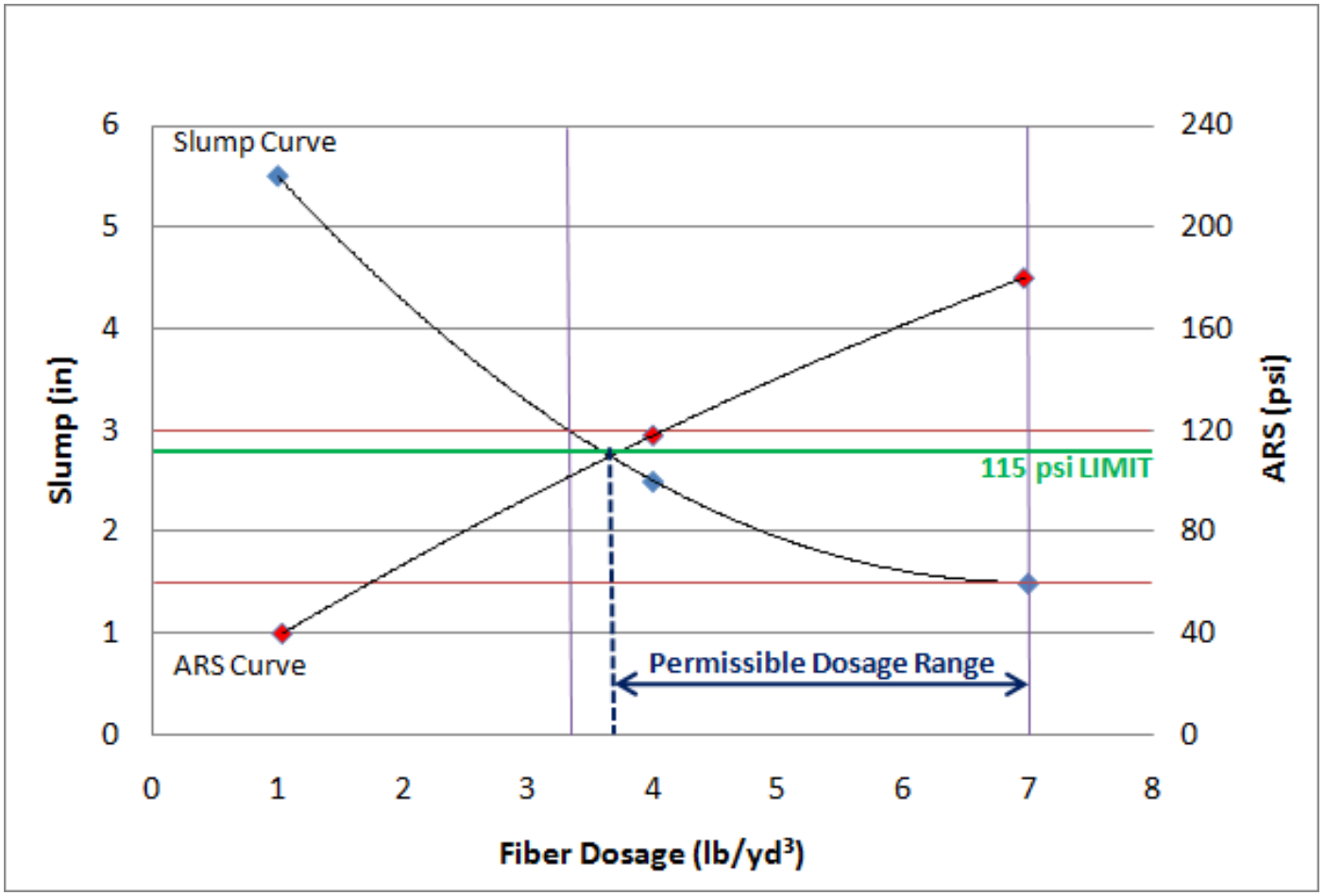
Increase in Bond Strength with Different Reinforcements



Process for Determining permissible fiber content

- Perform trial batches with varying fiber content
- Measure slump
- Determine ARS from concrete beams
- Graph slump and ARS versus fiber content plot
- This plot will provide permissible fiber dosage range that will
  - Satisfy minimum TxDOT ARS value of 115 psi, **and**
  - Meet slump requirement

Example Plot



Fiber Types

- Steel or structural (rigid) synthetic
  - Steel or structural (rigid) synthetic
    - Higher ARS than normal synthetic fibers, therefore increase in toughness
  - Deformed shape can increase ARS

Novocon XR (Steel)

Tuf-Strand SF (Structural Synthetic

Fiber Types

- Normal Synthetic
  - Lower ARS than steel or structural (rigid) synthetic fibers and mainly used for shrinkage control

Performax Fiber

Grace MicroFiber

MAC 470

Fibermesh 300

Fiber Dosage

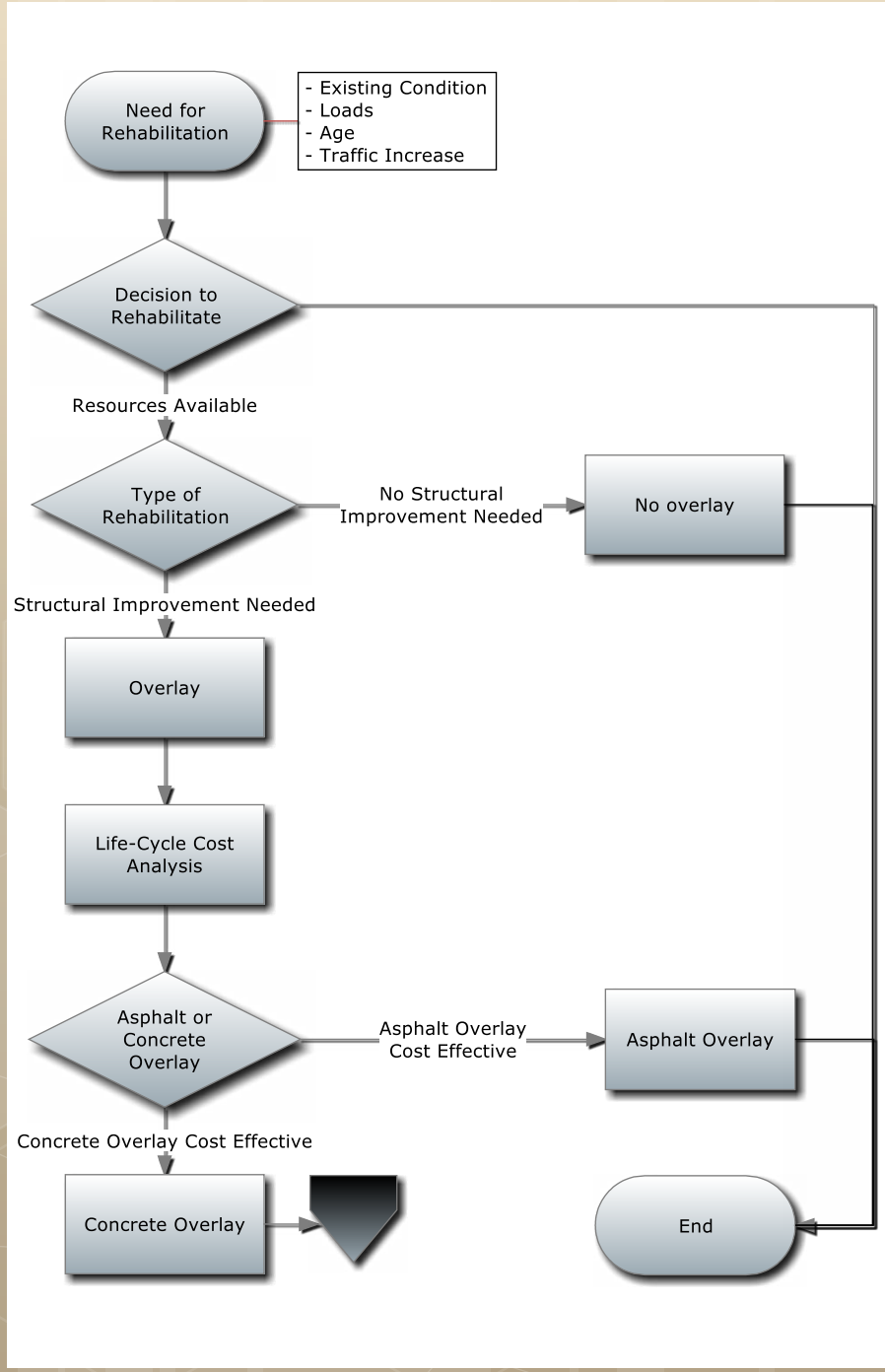
- Use of fibers **COULD** increase bond strength
- Incorporation of fibers at typical concrete overlay dosage did not alter CTE
- Increase in dosage may lead to:
  - Lower workability
  - Slightly lower compressive strength
  - Slightly lower flexural strength
  - Higher ARS
- Decrease in dosage may lead to:
  - Higher workability
  - Lower ARS

Reinforcements

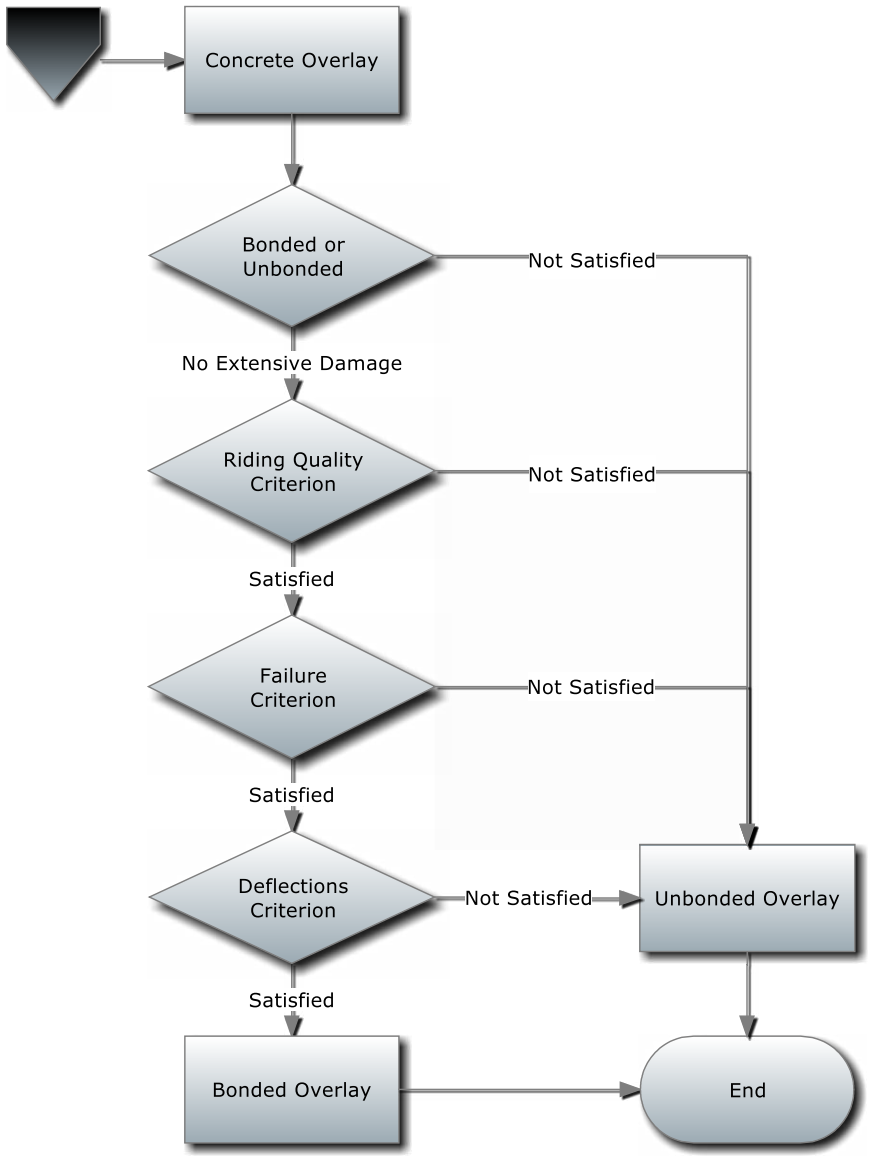
- Reinforcement bars or wire mesh
  - Placing reinforcement bars or wire mesh at the bottom of the concrete overlay (near the interface) restricts the movement of the overlay at the interface
  - Improved bond will be achieved with less movement near the interface

Flowcharts for Project Selection

A conceptual flowchart has been developed for project selection process, which is a series of activities conducive to a successful concrete overlay



A conceptual project selection flowchart



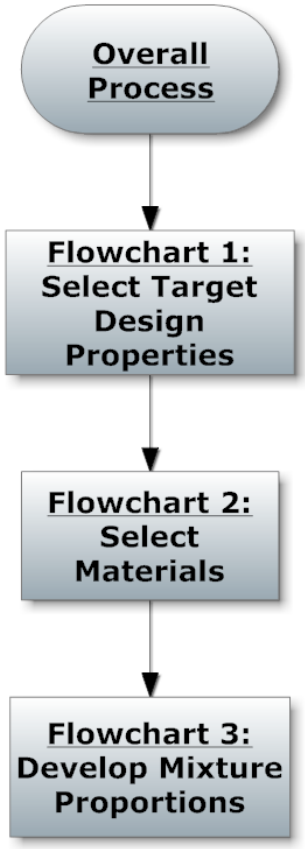
Explanation of each step is provided in 0-6590 training manual

Flowcharts for Materials Selection

A flowchart is provided to assist in selecting proper materials for concrete overlay constructions

Flowcharts for Concrete Overlays Materials Selection

The following flowcharts are a guide to assist in developing concrete overlay mixtures



Flowcharts 1 to 3 are provided in 0-6590 training manual

End of Materials Selection Guidelines

Construction Method Guidelines

Construction Method Guideline

- This guideline explains **RECOMMENDED** methods for each step of concrete overlay construction:
  - Surface preparation
  - Concrete overlay placement
  - Finishing and curing
  - Quality assurance/quality control
- All based on the research results and literature

Surface Preparation

The following steps to achieve a well prepared surface are crucial in promoting successful interface bond or separation between concrete overlay and the existing pavement

Surface Preparation Steps

- Steps for Bonded Overlays
  1. Surface Repair
  2. Bituminous and Foreign Material Removal
  3. Surface Texturing
  4. Surface Cleaning
  5. Wetting the Surface Before Placement

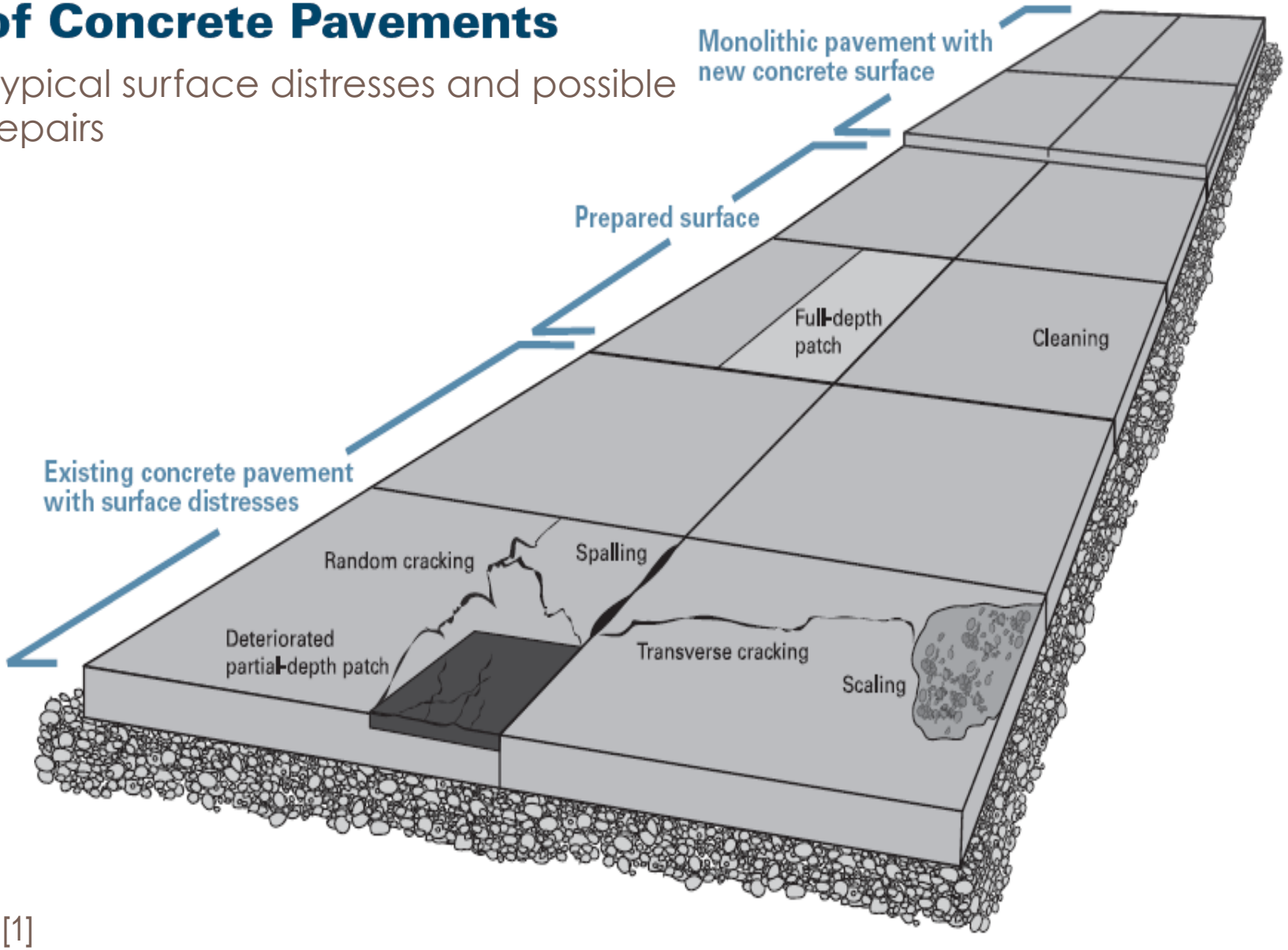
- Steps for Unbonded Overlays
  1. Surface Repair
  2. Separation Layer Placement
  3. Wetting the Surface Before Placement

Surface Preparation for Bonded Overlays

- Surface Repair
  - Typically, bonded type overlays are chosen for existing pavements with minor deterioration that require minimum repair
  - Structural failures (e.g. punchouts) must be repaired
    - Localized areas of structural weakness need to be partial or full depth repaired
    - Requires spot-repairing of severely deteriorated areas
    - Working cracks must be repaired or sawed since they will reflect through the new overlay
  - For existing asphalt pavements, milling can be used to remove rutting to achieve level surface

Bonded Concrete Overlays of Concrete Pavements

Typical surface distresses and possible repairs



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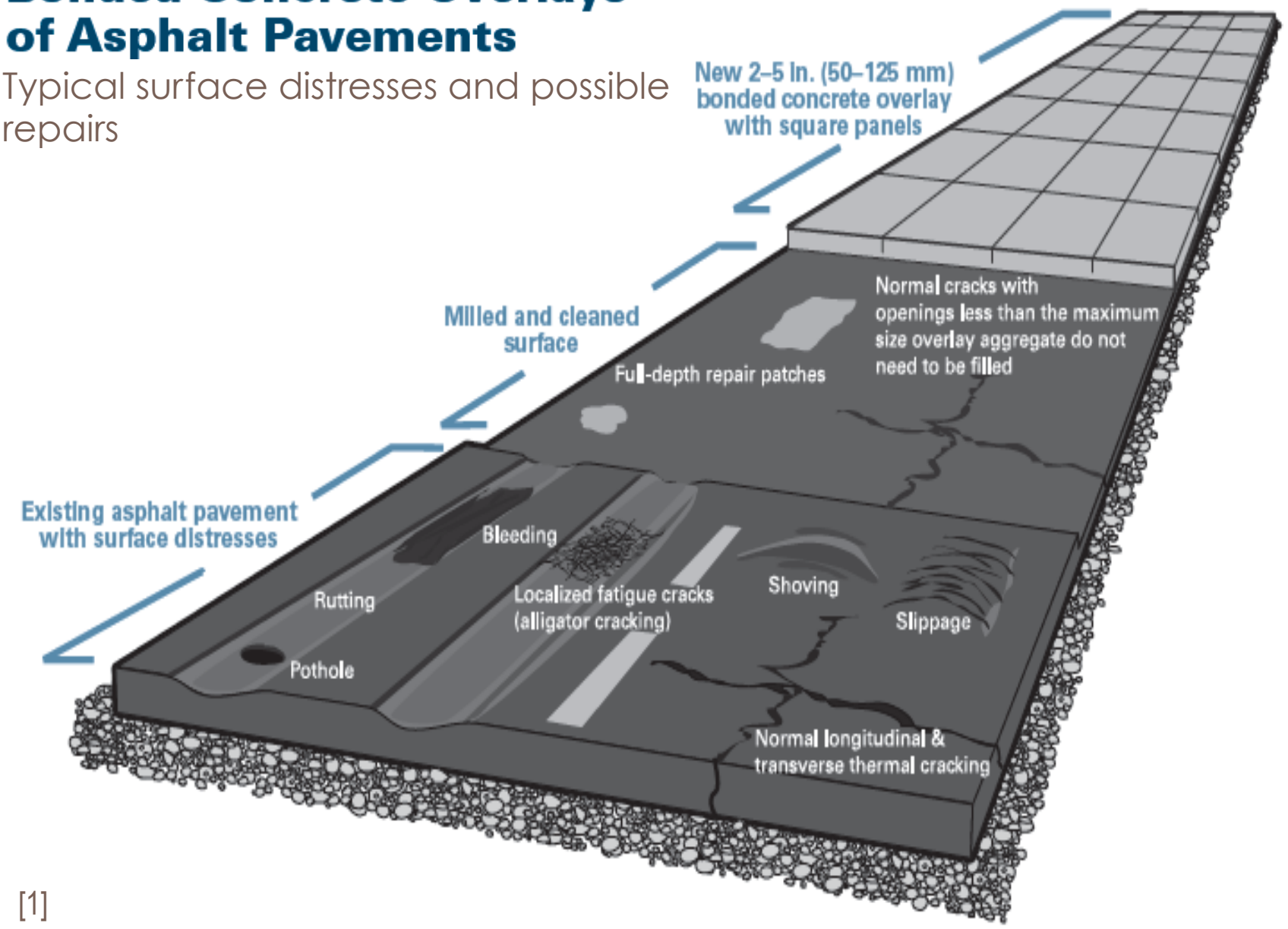
Bonded Concrete Overlays of Asphalt Pavements

Typical surface distresses and possible repairs



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Surface Preparation for Bonded Overlays

- Bituminous and Foreign Material Removal
  - Good bond is the **MOST** important factor that promotes monolithic movement of the two layers
  - Undesirable existing materials that may hinder the bond must be removed
    - If the existing concrete pavement has bituminous patching materials, they must be removed
    - Paint stripes should be removed
    - Existing joint sealants should be removed

Surface Preparation for Bonded Overlays

- Surface Texturing of the existing pavement
  - Well and consistently textured surface is critical in encouraging aggregate interlock that promotes monolithic bonding
  - The idea is to expose the coarse aggregate in the existing pavement
  - Minimum profile depth (MPD) greater than 0.80, measured by a Circular Track Meter (CTM), has been found to give adequate texture
    - But, further research is needed to examine the relationship between bond strength and surface texture
- Shotblasting, grinding, sandblasting, milling, and high pressure (30,000 psi) water jet washing are often used for the operation

Surface Preparation for Bonded Overlays

- Shotblasting
  - Ideal if the existing pavement is concrete
  - Breaks down mortar and leaves the coarse aggregate sound and intact
- Milling
  - Ideal if the existing pavement is asphalt
  - Not recommended for concrete pavements because the operation causes microcracking in the substrate
- High pressure washing
  - Ideal if the existing pavement is concrete
  - Produces no dust; however water needs to be properly disposed since it contains contaminants

Shotblasted Surface

http://overlays.acpa.org/webapps/overlayexplorer/index.html

Surface Preparation for Bonded Overlays

- Surface Cleaning
  - Immediately prior to placing concrete, the prepared and textured surface shall be thoroughly cleaned of all dust and loose particles by vacuum or air blowing
    - **ANY CONTAMINATION** may cause **DEBONDING** and **DELAMINATION** will **OCCUR**
  - Appropriate measures must be taken to prevent any contamination to the cleaned surface if trucks or other equipment will be driving on it
  - This effort is intended to prevent contamination of the prepared surface from foreign materials that may hinder the bond

Cleaning Just Ahead of the Paver

http://overlays.acpa.org/webapps/overlayexplorer/index.html

Surface Preparation for Bonded Overlays

- Wetting the surface before placement
  - The goal is to achieve surface saturated dry (SSD) condition on the surface in order to:
    - Lower the surface temperature
    - Prevent moisture loss through the existing pavement
  - The surface should be adequately wetted (but kept at minimum) **IMMEDIATELY BEFORE** the placement
  - Pooling of water must be avoided since the areas may introduce weak planes at the interface and hinder bond strength

Wetted Surface and Dried Surface

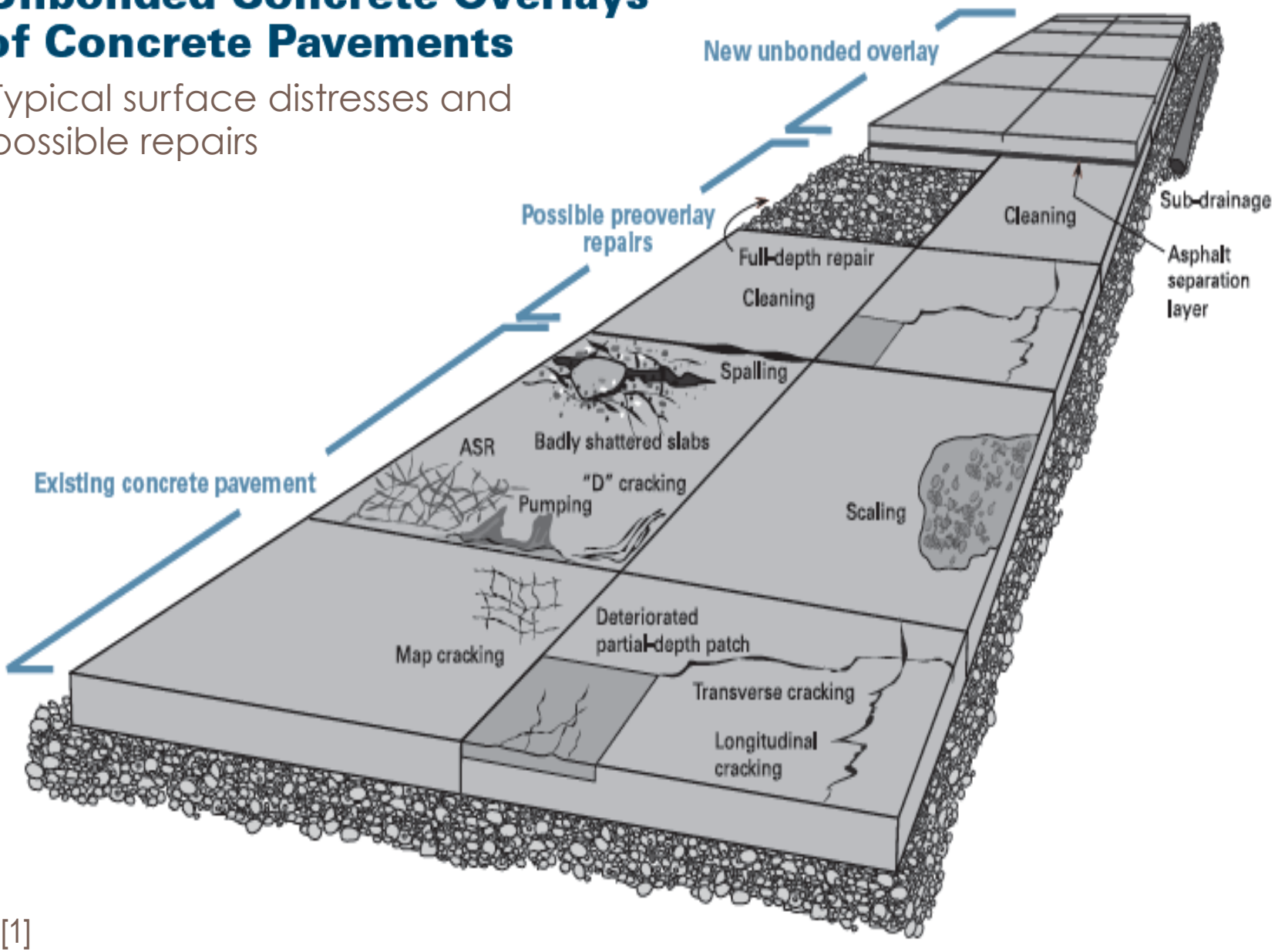
http://overlays.acpa.org/webapps/overlayexplorer/index.html

Surface Preparation for Unbonded Overlays

- Surface Repair
  - Typically, unbonded overlays are chosen for existing pavements with major deterioration
  - The existing pavement acts more as a subbase and must provide a uniform strength platform
  - If not, repair, alteration, and/or removal of questionable areas must be performed
    - Full-depth repairs are required only where structural integrity is lost at isolated spots
    - A **PLANE UNIFORM SURFACE MUST BE ACHIEVED** without any ruts (milling can be used to remove ruts)

Unbonded Concrete Overlays of Concrete Pavements

Typical surface distresses and possible repairs



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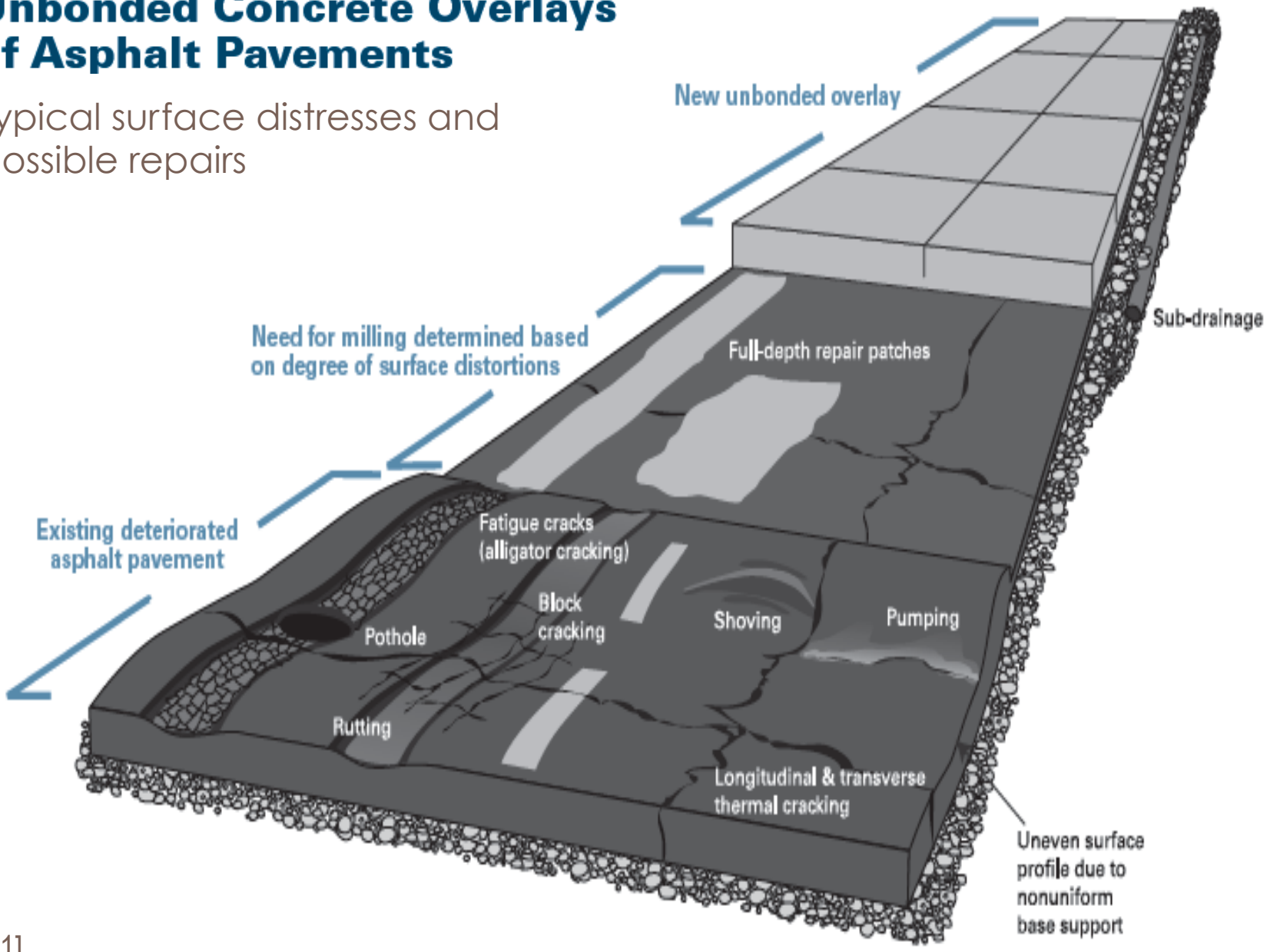
Unbonded Concrete Overlays of Asphalt Pavements

Typical surface distresses and possible repairs



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Surface Preparation for Unbonded Overlays

- Separation Layer Placement for UBCO
  - Separation layer is **ESSENTIAL** to isolate unbonded overlay from existing concrete pavement, minimize reflective cracking, and provide a smooth, level surface
    - Typically 1-inch asphalt layer is placed
    - The asphalt layer acts as a bond breaker
- For unbonded whitetoppings, no separation layer is required
  - However, surface should be plane and provide a uniform strength platform

Grout Mix Filler Used to Provide a Plane Surface

http://overlays.acpa.org/webapps/overlayexplorer/index.html

Existing Pavement, 2-inch Thick Asphalt Separation Layer, and Concrete Overlay Placement

http://overlays.acpa.org/webapps/overlayexplorer/index.html

Surface Preparation for Unbonded Overlays

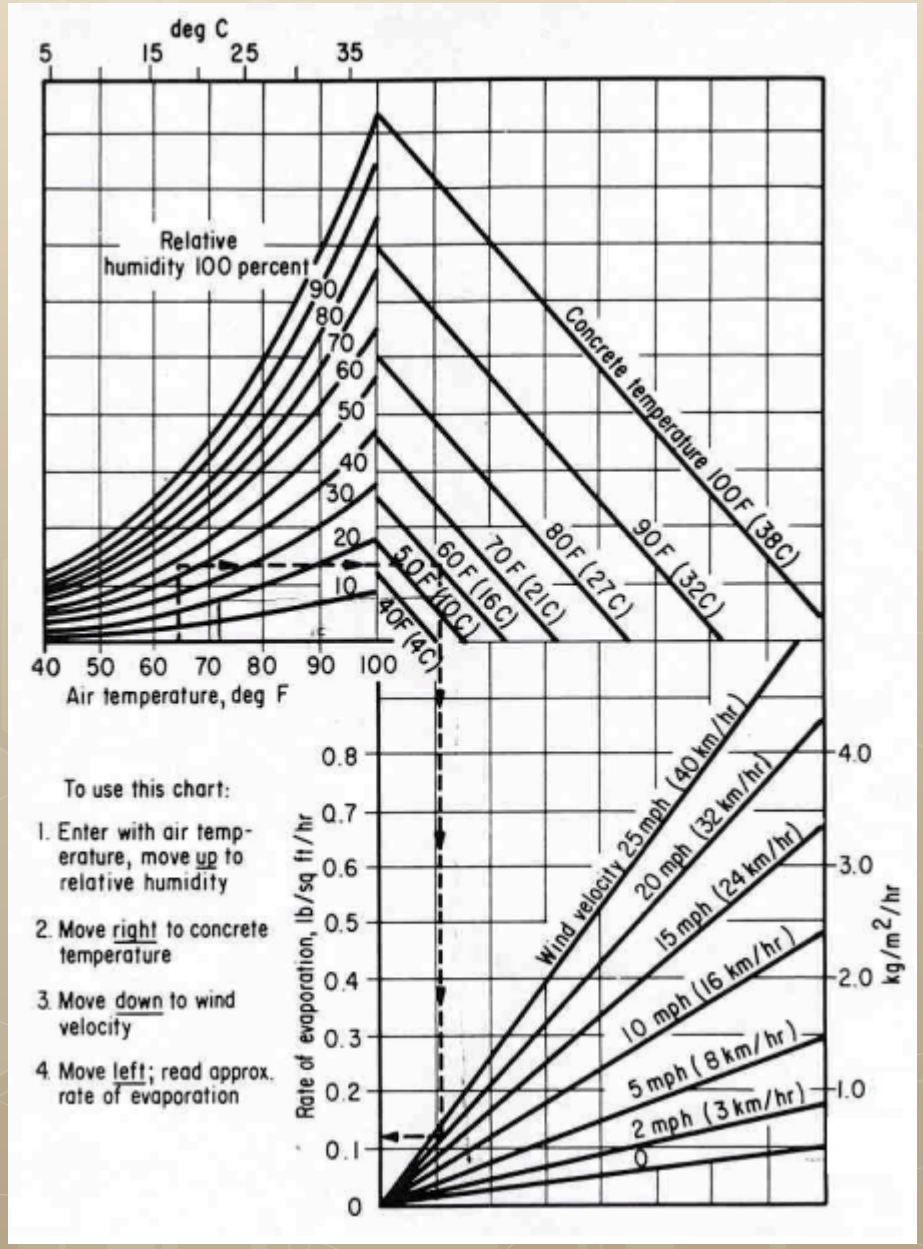
- Wetting the surface before placement
  - The goal is to achieve SSD condition on the surface in order to:
    - Lower the surface temperature
    - Prevent moisture loss through the existing pavement
  - The surface should be adequately wetted (but kept and minimum) **IMMEDIATELY BEFORE** the placement

Concrete Overlay Placement

The following procedures are recommended for proper concrete overlay placement

Environmental Considerations

- Must follow Item 360 in TxDOT specification
- Additional recommended considerations:
  - Temperature
    - Temperature of concrete mixture should not exceed 95 °F immediately before placement
    - emperature differential within 24 hours after the placement must be less than 25 °F
    - Temperature of the air or the existing pavement surface should be considered
  - Wind speed
  - Relative humidity
  - Rate of evaporation – ACI nomograph
    - A condition where water evaporation rates exceeding 0.2 lb/ft²/hr based on the nomograph must be avoided



Evaporation nomograph

Environmental Considerations

- Future weather conditions can be forecasted using ConcreteWorks™ program
- If adverse environmental conditions occur or are predicted during placement of concrete, placement should be postponed unless the conditions can be offset by such measures as:
  - Cooling the aggregates or concrete
  - Special curing methods or increased application
  - Use of fly ash as cement replacement to lower the heat of hydration

Bonding Agent Application

- Using bonding agent to promote bond at the interface is **NOT** recommended or encouraged
- Placing bonding agent is cumbersome and, if not done right, bonding agents may act as a bond breaker causing more problems
- If, for some reason, lack of bond strength is predicted, bonding agents (such as grout or epoxy) may be used
  - Bonding agents should be applied as a thin, even coat onto the cleaned dry surface just ahead of the paver
  - If applied too early, the bonding agents will harden and can act as a bond breaker

Consistency of the Placement

- Must follow Item 360 in TxDOT specification
- Slump and air contents should be measured at regular intervals for consistency
- The minimum thickness of the overlay should be regularly checked
  - Sections that do not meet the minimum thickness will act origination sites for crack formation and propagation

Reinforcements

- Reinforcement Bars
  - Must be wetted immediately before concrete placement
  - Can be placed directly on top of existing pavement (BCOs only)
- Fibers
  - Fiber balling or uncoated fibers must be prevented
  - Special mixing procedures to increase fiber dispersion are necessary, such as:
    - Introducing fibers into the mixture sooner
    - Increasing mixing time
    - Slightly reducing batch size
- Dowels at Construction Joints
  - There should be enough coverage over the dowels
    - If not, spalling over the dowel bars likely will occur
  - For thinner overlays, use of dowels can be eliminated

Finishing and Curing

The following items will ensure proper finishing and curing

Finishing

- Must follow Item 360 in TxDOT specification
- Unweighted carpet drag
  - Use of burlap drag is not recommended when fibers are used because the fibers can be entangled in the burlap leading to other fibers and coarse aggregates being pulled out from concrete
  - An unweighted carpet drag can be an alternative option to provide a satisfactory finish
- Tining
  - In between the completion of hand finishing and immediately before application of curing compound, transverse tining should be performed

Carpet Dragged Surface

http://overlays.acpa.org/webapps/overlayexplorer/index.html

Curing

- Must follow Item 360 in TxDOT specification
- Typically, curing compound is applied at a much higher rate than the standard pavement curing
  - Thinner the overlay, higher the curing compound is necessary
  - Past studies have utilized 1.5 – 2 times the normal application rate
- Blankets or mats are also very effective
  - They must be light in color and must not take the place of a curing compound
  - Temperature under the blanket shall not exceed 160 °F
  - Blankets shall not be removed until the temperature under the blanket is within 40 °F

Curing

Recommended curing for BCOs

Condition	Recommendation
Evaporation below 0.1 lb/sq.ft/hr	Membrane curing
Evaporation above 0.2 lb/sq.ft/hr but below 0.2 lb/sq.ft/hr	Membrane curing, plus evaporation retardant or fogging or wet mats, in place for 12 hours
Evaporation over 0.2 lb/sq.ft/hr	Membrane curing, plus wet mat curing or fogging or other approved methods, in place 36 hours
Temperature drop in next 24 hours less than 25° F below temperature at time of paving	Membrane curing
Temperature drop in next 24 hours more than 25° F below temperature at time of paving	Membrane curing plus wet mats for 36 hours, or other approved methods

Jointing

- Must follow Item 360 in TxDOT specification
- Joints should not be placed along the wheel path
  - Concentrated wheel loads at will accelerate failure at the panel edges
- Saw cutting
  - Should be used before internal concrete stresses could build up and cause cracking
  - No cracking should be observed prior to or following the saw operation
- Matching the joints (BCOs only)
  - Depending on the type of design, joints can be placed in the new overlay
  - Joints in the overlay and the existing pavement should match to promote monolithic movement
  - A reliable method should be used to identify the locations of the joints in the existing pavement

Failed Joints in the Wheel Path

Quality Assurance/Quality Control

The following procedures helps to insure producing cost-effective and serviceable concrete overlays

Recommended QA/QC Procedures

- Must follow Item 360 in TxDOT specification
- Other complementary procedures include:
  - **Bond Strength Testing (should be included in special specifications in every bonded overlay project**)
  - Materials Evaluations
    - Compressive
    - Flexural
    - Maturity testing
  - Statistical Survey – Visual monitoring of signs of distress
  - Condition Survey – Locating delaminations
    - Chain dragging or sounding test
  - FWD Testing

End of Construction Method Guidelines

End of Training

Thank you so much for your attention and please refer to 0-6590 report: "Materials Selection for Concrete Overlays" for further details

References

1. Harrington, D., “Guide to Concrete Overlays,” National Concrete Pavement Technology Center, 2nd Edition, Sep. 2008.
2. http://www.nipponroad.co.jp/english/images2/ptoto34_01.jpg