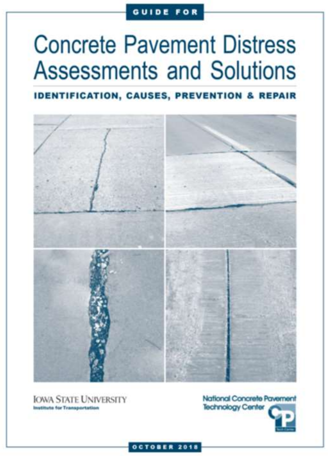
National Concrete Pavement Technology Center

IOWA STATE UNIVERSITY
Institute for Transportation

2019 Municipal Streets Seminar

Concrete Pavement Preservation

Distressed Concrete Pavements
- Causes
- Prevention
- Preservation
- Treatment



Purpose

- Please remember that the purpose of this manual is to help improve design and construction of concrete pavements by:
  - ✓ Identifying preventable pavement distress
  - ✓ Understanding the causes of the distress
  - ✓ How to prevent the distress
  - ✓ Rehabilitation methodologies

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Who was this Guide developed for?

- Pavement Inspectors/Design Engineers
- Project Design Engineers
- Construction and Maintenance Staff
- Asset & Pavement Management Engineers
- Consulting Engineers

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Guide Development

- Published: October 2018
- Pages: 470
- E-pubs Version
- 8 Authors
- 16 Technical Advisory Committee Members
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Chapters

1. **Division I** Introduction to Full Depth Pavement
2. Surface defects
3. Surface Delamination
4. Materials Related cracks
5. Transverse and Diagonal Cracks
6. Longitudinal Cracks
7. Corners Cracks
8. Spalling
9. Faulting
10. Slab Warping and Curling
11. Blowups
12. Subgrades and base Support
13. CRCP
14. **Division II** Introduction
15. Bonded Concrete Over Asphalt Overlays
16. Bonded Concrete over Concrete Overlays
17. Unbonded Concrete Over Asphalt Overlays
18. Unbonded Concrete Over Concrete Overlays
19. **Division III** Laboratory and Field Testing

68% Division I - **Full Depth Pavement**

26% Division II **Concrete Overlays**

6% Division III **Testing**

Typical Chapter Content

Items Covered

1. Description
2. Severity
3. Testing
4. Identification of Causes
5. Evaluation/Prevention
6. Treatment and Repairs
7. References

Division I – Full Depth Pavement

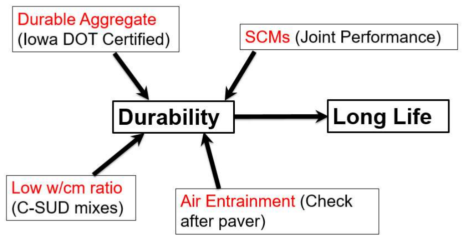
Summary

What is Essential for Long Life Concrete Pavements?

Materials
- **Low Permeability (Use SCMs)**
- **Aggregate Durability and Gradation**
- **Air Entrainment**

Design
- **Thickness**
- **Drainage**
- **Proper jointing**

Construction
- **Proper Air**
- **Proper Curing**
- **Proper Sawing**



(IMCP Manual)

Facts

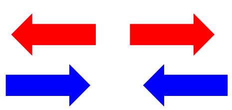
Fresh concrete shrinks. This shrinkage leads to cracking. Cracking is necessary to relieve stress but must be controlled under the joint sawcut. A number of factors affect early age cracking:

- Volume changes and restraint
- Curling and warping
- Strength gain during the stages of hydration
- Subgrade support
- Early loading

(IMCP Manual)

Primary Factors of Early-Age Cracking

- Concrete expands as **temperature** rises and contracts as **temperature** falls



- Concrete expands as **moisture** increases and contracts as **moisture** decreases

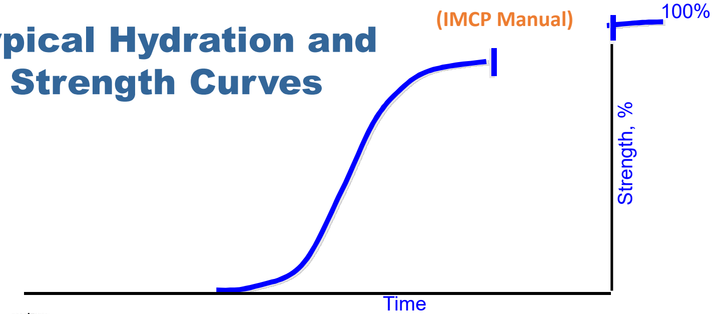
(IMCP Manual)

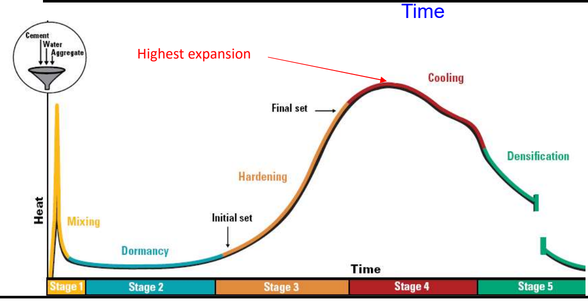
Strength and Stiffness

Strength: The greater the concrete strength, the greater stress it can withstand.
- Early-age concrete has not gained all its potential strength
- Stresses in early-age concrete can surpass the concrete's strength

Typical Hydration and Strength Curves

(IMCP Manual)



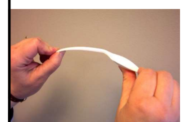


(IMCP Manual)

Strength and Stiffness

Stiffness: The stiffer the concrete (as indicated by modules of elasticity), the greater the stresses resulting from volume change.

- Unfortunately, stiffness increases faster than strength for the first few hours after setting
- First few hours
  - Minimize temperature & moisture change
  - Minimize the build up of stresses when the concrete has not gained sufficient strength

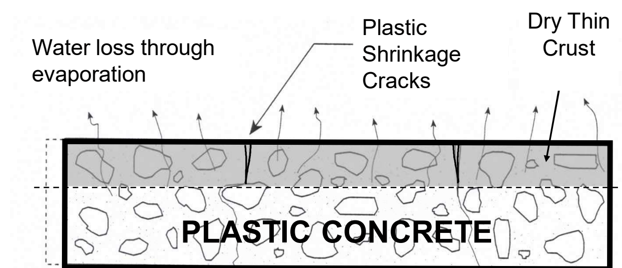


Chapter 2. Surface Defects

- Map cracking
- Plastic shrinkage cracks
- Scaling
- Surface polishing & wear
- Popouts & mortar flaking

Causes
- Poor Curing practices
- High w/cm ratio
- High amounts of cement
- Low abrasive resistant aggregates
- Chemical deicers
- Overworking the surface

Example of Plastic Shrinkage



Rapid loss of water through evaporation causes concrete to shrink. If shrinkage is restrained, tension develops, which may cause cracking.

Surface Defects
Prevention, Treatment and Repairs

Prevention:

- **Do not over work surface**
- **Low W/CM ratio**
- **Design concrete mixes for low permeability**
- **Use proper abrasion resistance aggregates**
- **Proper curing**

Treatment and Repairs:

- **Full-depth repairs (Including slab replacement) (*can be expensive*)**
- **Diamond grinding**
- **Unbonded concrete overlay (*depends on vertical restrictions)***

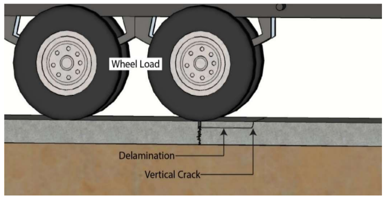
Chapter 3. Surface Delamination

Causes

- Differential Consolidation
- Differential Moist Gradient throughout slab depth
- Trapped bleed water
- Over Working Surface
- Inadequate or Late Curing
- Compression Shear
- Horizontal Plane of Weakness

Chapter 3. Surface Delamination

Traffic loading leads to slab deflections that may result in delamination if a horizontal plane of weakness already exists in the concrete. Loading only exacerbates a pre-existing condition (such as planes of weakness, poor placement or finishing operations, improper curing, etc.) and would not result in delamination by itself.



Delamination
Prevention, Treatment and Repairs

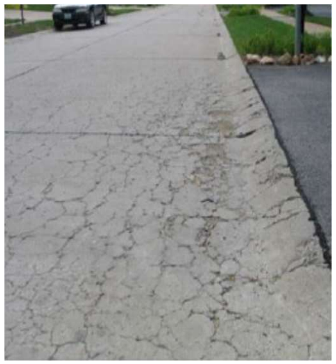
Prevention:

- Do not over work surface
- Low W/CM Ratio
- Design concrete mixes for low permeability
- Do not seal in bleed water
- Use proper abrasion resistance aggregates
- Proper curing (no excessive evaporation, can also use evaporation retarder)

Treatment and Repairs

- Full-depth repairs (including slab replacement) (can be expensive)
- Partial-depth repairs at joint
- Milling and diamond grinding (depends on depth of delamination)
- Concrete overlay (depends on vertical restrictions)

Chapter 4. Material-Related Cracks



Common MRD

- **D-cracking**
- **Alkali–silica reactivity (ASR)**
- **Alkali-carbonate reactivity (ACR)**

"D" Cracking

Causes

"D" cracking is the deterioration of critically saturated, susceptible coarse aggregates in a concrete mixture caused by freeze-thaw cycles. Coarse aggregates such a certain limestone, dolomitic rock and chert which have higher total porosity, in which the pores can absorb moisture but does not readily release the moisture. The entrapped moisture expands when frozen causing cracking of the aggregate and harden paste. The cracks are closely spaced and normally start at joints.

Three factors are needed for D cracking to develop:

1. Coarse aggregates that are susceptible to D cracking in sufficient quantity and size.
2. Concrete that is exposed to moisture.
3. Concrete goes through repeated cycles of Freezing-thawing

Alkali–Silica Reactivity-ASR

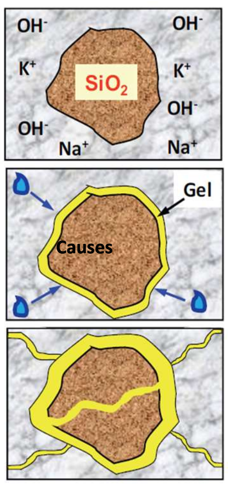
Causes

For ASR to occur, the concrete must have the following:

1. A sufficient concentration of alkali hydroxides in the pore solution of the concrete. The main source of alkalis in concrete is portland cement

2. A sufficient quantity of unstable silica in the aggregate such as quartzite, gneiss, shale and others.

3. A sufficient supply of moisture in the concrete. The ASR reaction ceases below a relative humidity of 80 percent but increases in intensity as the relative humidity within the concrete increases from 80 to 100 percent.



Reaction between the alkali hydroxides (Na, K & OH) from the cement and unstable silica, SiO_2, in some types of aggregate.

The reaction produces an alkali-silica gel.

The gel absorbs water from the surrounding paste …

… and expands.

The internal expansion eventually leads to cracking of the surrounding concrete.

"D" cracking & ASR

Prevention, Treatment and Repairs

Prevention:

- Proper selection of coarse aggregates
- Low W/CM Ratio
- Design concrete mixes for low permeability
- Adequate Drainage of Pavement
- Adequate jointing
- Proper curing

Treatment and Repairs

- Surface Treatments
  - *Surface Sealers used to help prevent ingress of moisture*
  - *Lithium compounds-Lithium Nitrate*
- Partial-Depth Repairs at the joint
- Full-Depth Repairs (Including Slab Replacement) (can be expenses)
- Retrofitted Edge Drains (depends on drainability of base materials)
- Unbonded Concrete Overlay (depends on vertical restrictions)

Chapter 5. Transverse and Diagonal Cracking

Causes

- Temperature, humidity, joint lockup)
- Improper joint spacing and layout, inadequate thickness
- Timing/depth of joint sawing, curing, restraint cracks from adjacent lanes, utilities
- Traffic loading
- Mix proportioning, high shrinkage
- Poor foundation support

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Transverse and Diagonal Cracking Prevention, Treatment and Repairs

Prevention

- **Drainable Subbase**
- **Uniform and compacted subgrades**
- **Sealed Joints**
- **Adequate load transfer & proper sawing operations (eliminate sympathy cracks)**
- **Avoid high shrinkage mixtures**
- **Employ hot and cold weather paving practices**
- **Insure proper joint spacings**

Treatment and Repairs

- **Full-depth repairs (Including slab replacement)**
- **Dowel bar retrofit with diamond grinding**
- **Joint and crack sealing**

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Chapter 6. Longitudinal Cracking

Causes

- Subgrade support
- Base erodibility
- Late sawing
- Excessive panel widths
- Traffic loadings
- Poor joint layouts
- Over tied lanes
- Tied shoulders with vertical movements
- Sympathy cracks

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Longitudinal Cracking Prevention, Treatment and Repairs

Prevention

- Drainable subbase
- Uniform and compacted subgrades
- Sealed joints
- Adequate load transfer & proper sawing operations (eliminate sympathy cracks, shallow saw cuts, late sawing, too wide longitudinal joints)
- Avoid high shrinkage mixtures
- Employ hot and cold weather paving practices
- Do not over-tie longitudinal joints

Treatment and Repairs

- Joint and crack sealing
- Cross-stitching and/or slot stitching
- Full-depth repairs (Including slab replacement)

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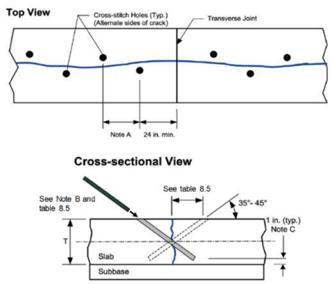
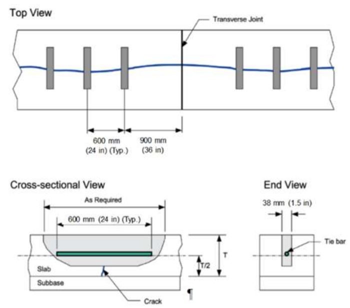
Longitudinal Cracks Treatment and Repairs

Full-Depth Repair

Cross-Stitching



Slot Stitching



Chapter 7. Corner Cracking

Causes

- **Heavy loads in wheel path and slab corners**
- **Poor load transfer and edge support**
- **Loss of foundation support due to pumping, erosion, slab curling**
- **Volume changes subgrade soil**
- **Poor jointing practices**

Corner Cracking Treatment and Repairs

Prevention:

- Adequate edge support
- Proper load transfer
- Minimize subgrade volume changes
- Proper jointing (no acute angles)
- Low shrinkage mixes to reduce curling and warping
- Timing of tied slabs placement so mainline is not moving one direction and tied lane in different direction

Treatment and Repairs

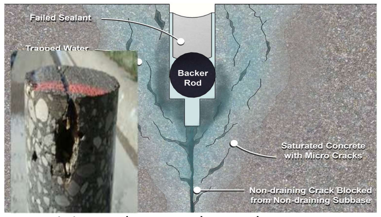
- Full-depth repairs (including slab replacement)
- Slab stabilization
- Tied shoulders
- Edge drains
- Joint sealants

Chapter 8. Joint Spalling

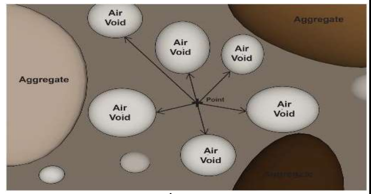
Causes

- Infiltration of incompressibles
- Improper air entrainment- freeze-thaw damage to the paste of the concrete
- Saturation of the joint
- Use of calcium and magnesium chlorides and lack of use of fly ash
- Poor soundness and durability of the aggregate
- Compression shear from deflection

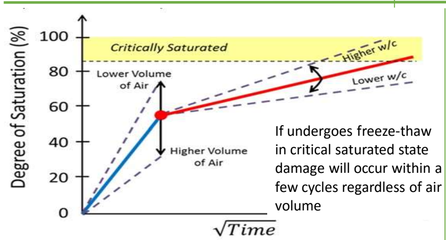
Major Causes of Joint Spalling



Poor joint sealant –Backer Rod



Freeze-Thaw Damage
(Lack of Air Entrainment)

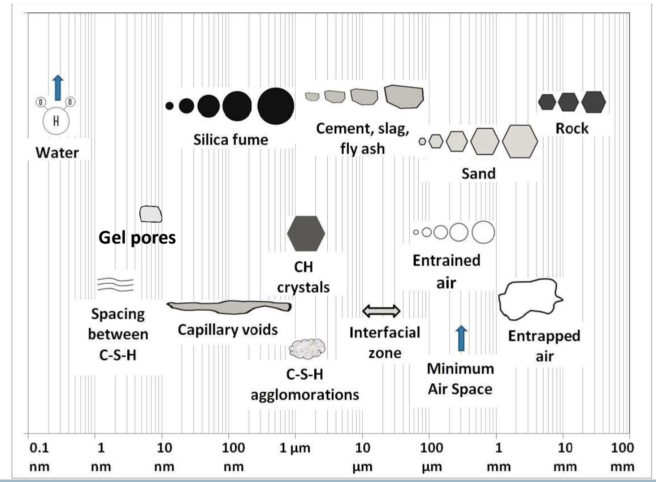


Magnesium & calcium chlorides in deicing salts can react with calcium chlorides in concrete resulting in the formation of **calcium oxychloride** which results in flaking (expansion) of the hardened paste causing significant damage particularly in joints.

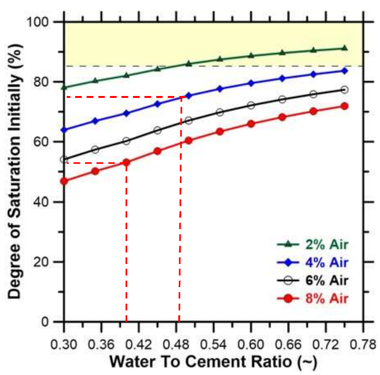
Oxychloride expansion can be 3 times greater than freeze-thaw expansion.

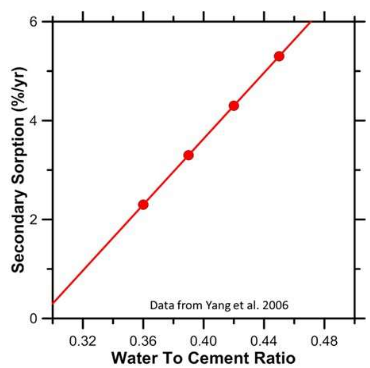
Deicing Salts

Sizes of Concrete Components



Critical Saturation Rates





Weiss 2014

Joint Spalling Prevention, Treatment and Repairs

Prevention

- Drainable Subbase and prevent saturated concrete
- Sealed Joints (to prevent incompressibles)
- Adequate load transfer & proper sawing operations
- Eliminate backer rod
- Proper air entrainment (check air behind paver at least twice daily)
- Use of SCM to lower permeability & reduce oxychloride reaction
- High quality curling compounds
- Use w/cm of 0.42 to reduce shrinkage & corrosion (with proper cover)

Treatment and Repairs

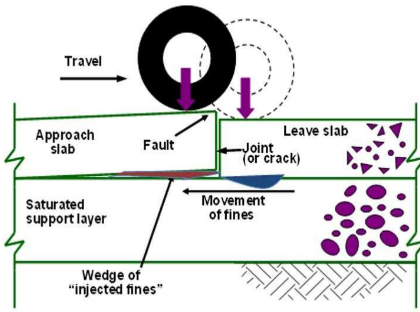
- Partial-depth repairs
- Full-depth repairs (including slab replacement) (*can be expensive*)
- Minimize use of deicing chemical magnesium and calcium chlorides. Use sodium chlorides where possible.
- Retrofitted edge drains (*depends on drainability of base materials*)
- Unbonded concrete overlay (*depends on vertical restrictions*
- Surface sealants (*research is ongoing in Iowa)*
- Joint sealing

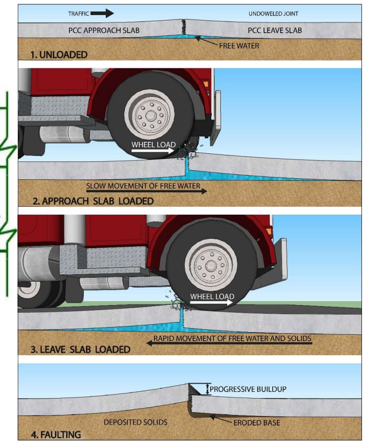
Chapter 9. Faulting

Causes

- Loss of load transfer
- Failure of aggregate interlock
- Water intrusion under the joint
- Ejection of water/soil beneath the joint

Causes of Faulting





Faulting Prevention, Treatment and Repairs

Prevention

- Proper aggregate Interlock or load transfer.
- Drainable and low deformation prosperities of subbase.
- Geotextile under subbase where subgrade prone to migration of granular subbase settlement.
- Uniform subgrade material and compaction.
- Subgrade chemical subgrade treatment when justified with wet & unstable subgrade soils.
- Sealed joints

Treatment and Repairs

- Slab jacking with milling/ diamond grinding
- Full-depth repairs (*including slab replacement and subbase and subgrade repair).*
- Retrofit edge drains (*depends on drain-ability of base materials*
- Joint and crack sealing
- Proper maintenance of subdrain systems

Chapter 10. Curling and Warping

Causes

- Temperature/moisture gradient changes throughout the day (curling)
- High CTE (curling)
- Dry shrinkage and moisture characteristics (warping)

Curling and Warping Prevention, Treatment and Repairs

Prevention

- Proper joint spacing, load transfer and base restraint.
- Low CTE for aggregates
- Do not pave just prior to predicted temperature and significant temperature changes
- Low shrinkage mixes where possible.
- Ensure free drainage and do not trap water beneath the slab.
- Minimize evaporation from surface after pavement is poured.
- Where feasible consider Internal Curing

Treatment and Repairs

- Retrofit edge drains (depends on drain-ability of base materials
- Full-depth repairs (including slab replacement and subbase and subgrade repair).
- Joint and crack sealing
- Proper maintenance of subdrain systems

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Chapter 11. Blowups

Causes

- Blowups are often associated with heat waves- increasing expansion following rainfall
- Filling transverse joints with incompressible
- Combination of heat, entrapped water and high CTE
- Poor pavement drainage
- Unsound aggregates

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Blowups Prevention, Treatment and Repairs

Prevention

- Low CTE of aggregates
- Minimize where possible spring and fall paving in cold weather. If not possible shorten transverse joint spacing.
- Proper joint sealing to minimize incompressibles in joints.
- Well drained subgrades and subbases

Treatment and Repairs

- Full-depth repairs (including slab Replacement-can be expenses)
- Edge drain retrofit (depends on drain-ability of base materials)
- Joint resealing

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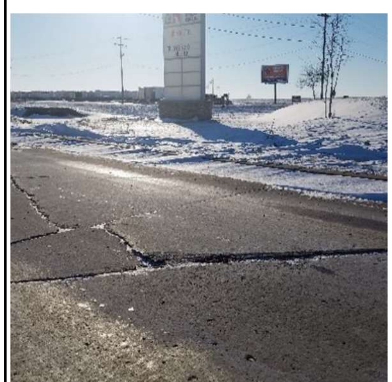
Chapter 12. Subgrade and Base Support Conditions



Causes

- Soils prone to volume change as a function of moisture/density variations
- Poor drainage of the subgrade
- Contamination of the base layer
- Inadequate compaction
- Nonuniform subgrade soils have different absorptions, shrinkage characteristics, etc.
- Lack of base or subbase

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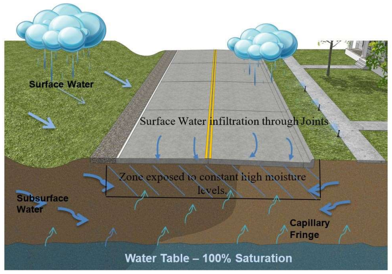
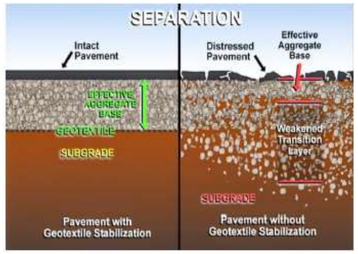
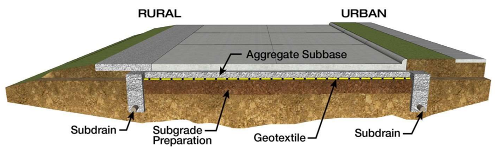
Subgrade and Base Support Conditions



Concrete pavement exposed to surface and subsurface moisture conditions



Prevention of fines into granular unstabilized subbase



Typical subsurface drainage system

Subgrade Prevention, Treatment and Repairs

Prevention:

- **Drainable and stable granular subbase (less than 10% fines).**
- **Geotextile under subbase where subgrade prone to migration of granular subbase material.**
- **Adequate compaction of subgrade, particularly of subdrain trenches.**
- **Uniform subgrade material and compaction.**
- **Subgrade chemical subgrade treatment when justified with wet and unstable subgrade soils**
- **Seal joints**

Treatment and Repairs

- **Retrofit edge drains (*depends on drain-ability of base materials***
- **Full-depth repairs (*including slab replacement)***
- **Slab jacking with diamond grinding of spot settlement areas**
- **Joint and crack sealing**
- **Proper maintenance of subdrain systems**

Chapter 13. Continuously Reinforced Concrete Pavement (CRPC)

- Poor base material
- Insufficient longitudinal steel content
- Variable concrete strength
- High level of friction between slab and base
- Inefficient depth of cover of steel
- Poor consolidation around embedded steel

Coming Out Soon!

Concrete Pavement Preservation

Web- Based Training Modules

NHI-134207 Rigid Pavements
1. Partial-Depth Patching
2. Full-Depth Repairs
3. Diamond Grinding and Grooving
4. Dowel Bar Retrofit and Cross-Stitching
5. Joint Sealing