Long Life Concrete Pavement Joint Performance

Drainage of PCC Pavement
#jointsworkshop

National Concrete Pavement Technology Center

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Why Do We Discuss Drainage in a Workshop on Joints?

- Concrete is failing at joints because it is saturated
- Where is the water coming from?
- How do we ensure it can get it away?

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Causes of Joint Saturation

- Joint not cracked below saw cut
- Seal failure
- No outlet through the foundation layers
  - – High water table
  - – Poor subbase drainage
  - – Poor subgrade drainage

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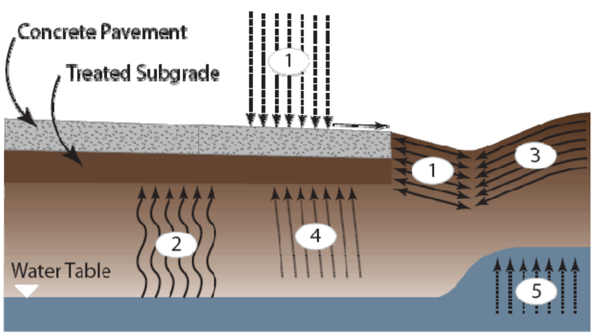
Water Sources



1. Precipitation/Entry from the pavement edge
2. Capillary suction from the water table
3. Drainage from natural high ground
4. Vapor movement through the soil
5. Water table rise in elevation

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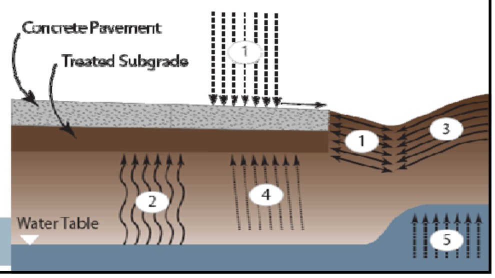
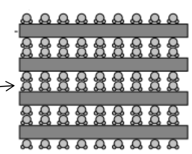
Drainage

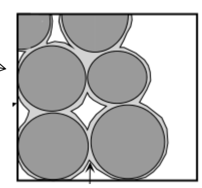
- Addressed by proper design *and* construction:
  - Subbase (and associated drain system) affects *top down* water (1, 3)
  - Subgrade (and associated drain system) affects *bottom up* water (2, 4, 5) and water passing the subbase
  - System (e.g., raise the grade above the water table

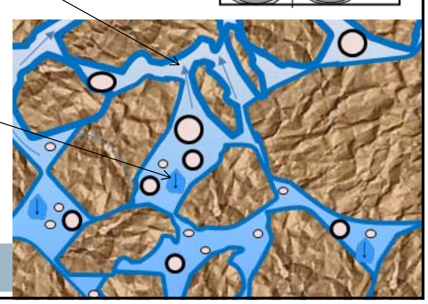


Water in Soil

- Adsorbed water – held by electrostatic force, binds clays, immobile
- Surface water – held by surface tension– binds silts, relatively immobile
- Capillary Water – in small spaces, does not respond to gravity, will move upward, surface tension effect
- Free Water – moves through the soil under gravity

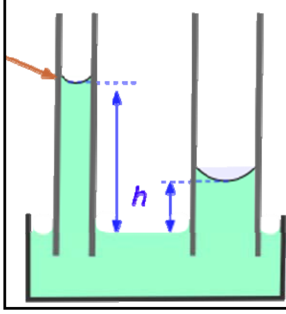


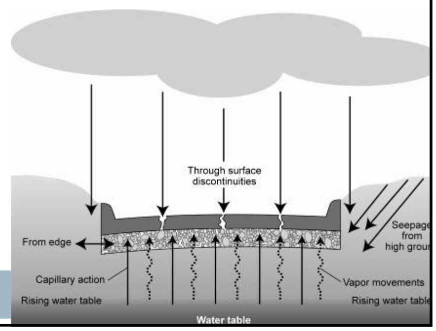




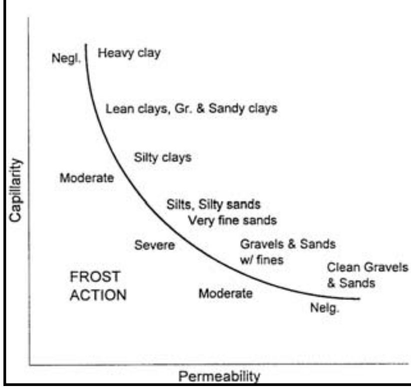
Bottom Up Water

- High water table in contact with slab
- Water table high enough to provide a source for capillary suction
- Water vapor rises when material below slab is cooler than the soil.





Soil Pore Systems



Size	Material	Height of Capillary Rise (feet)
> 4.75mm	Gravel	0.1 to 0.4
4.75 to 0.075 mm	Sand	0.5 to 3
0.075 to 0.002 mm	Silt	3 to 30
< 0.002 mm	Clay	30 – 90

AASHTO Soil Classification System

AASHTO Soil Classification System (from AASHTO M145)											
General Classification	Granular Materials 35% or less passing the No. 200 (75 µm) sieve							Silt-Clay Materials >35% passing the No. 200 (75 µm) sieve			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis, % passing											
No. 10 (2.00 mm)	50 max	—	—	—	—	—	—	—	—	—	—
No. 40 (0.425 mm)	30 max	50 max	51 max	—	—	—	—	—	—	—	—
No. 200 (75 µm)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing No. 40 (0.425 mm)											
Liquid Limit	—		—	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity Index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min*
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as a subgrade	Excellent to Good							Fair to Poor			

* Plasticity Index of the A-7-5 subgroup is equal to or less than LL minus 30. Plasticity Index of the A-7-6 subgroup is greater than LL minus 30.

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Subgrade Considerations

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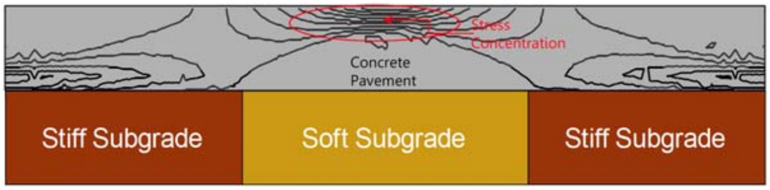
Stability of the Subgrade

- Subgrade does not require substantial strength
- Subgrade does require uniformity for stability



  - No abrupt changes :
    - Water
    - Material types
      - Erosion resistant
      - Control movement

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Permeability of the Subgrade

- A stable subgrade requires sufficient permeability to control the subgrade moisture content
- Design considerations
  - Permeable enough to move the water out
  - Strong enough to provide stability and support
  - Maintains uniformity and stability under conditions of water movement

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Other Subgrade Considerations

- Compaction
- Clay Content
- Fines Movement
- Damage during construction

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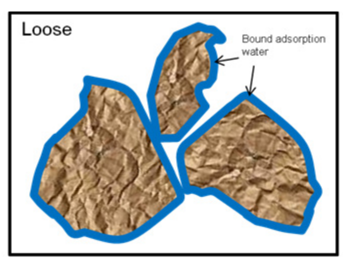
Compaction and Water Content

- The degree of compaction affects the saturation of a soil.
- When the soil particles close in on each other during compaction the bound water becomes free.



- Compaction reduces the subgrade's ability to transport water away.

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Clay Content

- Proper compaction of clay soils is important to provide uniform support
- Can result in a low permeability system under pavement
  - Tight and small pores
  - Complicated pore system
- Can be expansive as they imbibe water

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Clay Soils Treatment

- Expansive soils can be mitigated by
  - Compacting the subgrade at the proper moisture content
  - Selectively grading the subgrade material
  - Chemically modifying the subgrade

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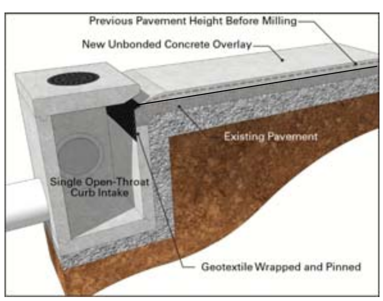
Capillary Cut off Layer

- Need to prevent water from sitting in soil
- Cut off layer of coarse granular or geosynthetic below subbase may be needed
- Requires drainable outlet

Geotextile Drainage Layer

Example:

- Thickness (mil/mm) – 280/7.1 to 300/7.6
- Drainage rate gpm/ft2 – 90 to 110



Fines Movement

- A geosynthetic or dense graded separator layer is required between the OGDC and subbase to keep fines (-200 mesh) material from migrating into and clogging the OGDC

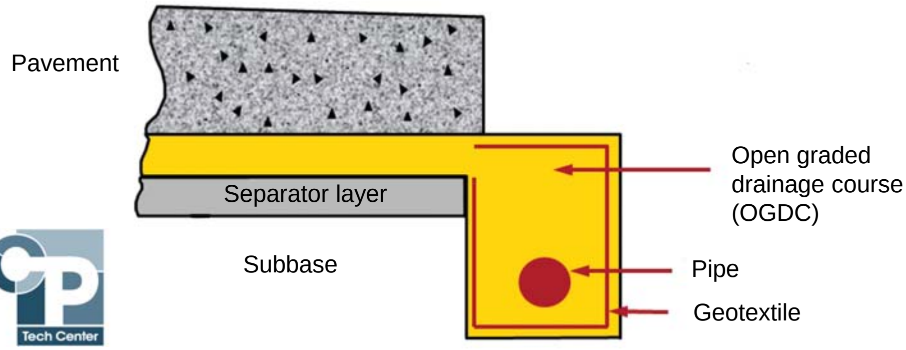
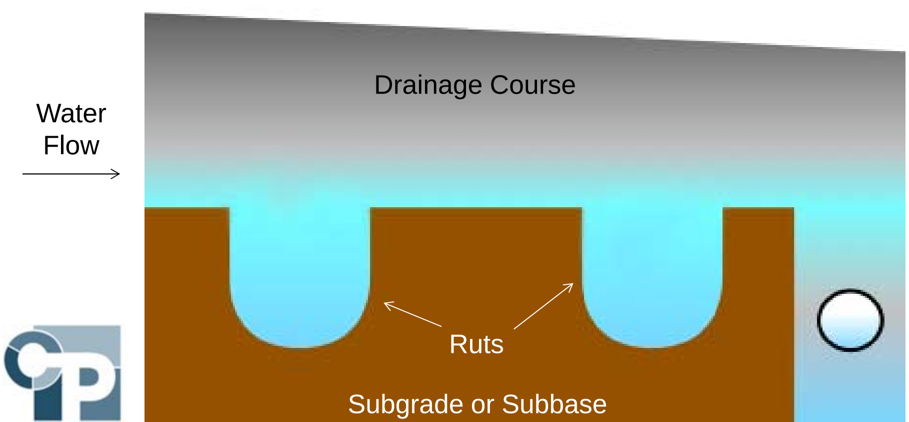


Figure adopted from NIH 131008

Damage During Construction

Rutting of the subgrade will trap water and prevent drainage



Ways to Remove Excessive Moisture in Soils – New Construction

1. Raise grade where possible to keep out of pockets of high moisture
2. Replace high moisture soil with borrow material
3. Disk the subgrade
4. Use modification such as with fly ash, lime or cement
5. Provide drainage via granular subbases or geosynthetics, trenches or toe drains at the lowest point(s)

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Subbase Considerations

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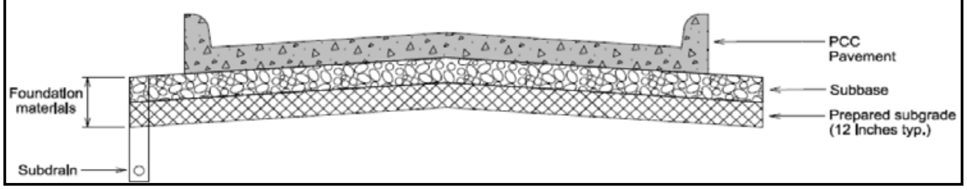
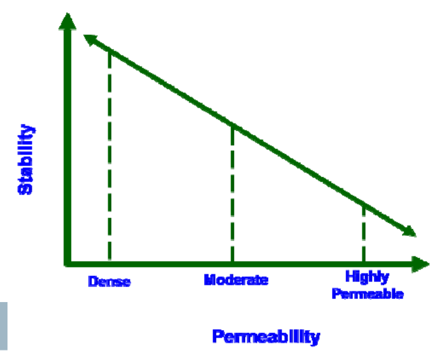
Purpose of Subbases Under Concrete Pavements

- Maintain uniform support
- Protect subgrade from deformation from traffic loading
- Provide stable construction and drainage platform
- Help remove top down & bottom up water



The Challenge

- Properties required in a good pavement subgrade are inversely related (within limits)
  - *Stability* – ability to carry load and resist movement
  - *Permeability* – ability of fluids to move



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Drainable Subbase

- Wet subgrade requires drainage system between pavement and dense subgrade,

or

- Subbase can be granular or geosynthetic system with subdrain pipe

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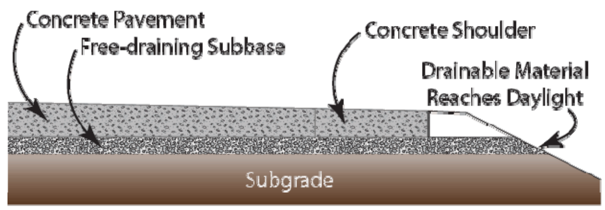
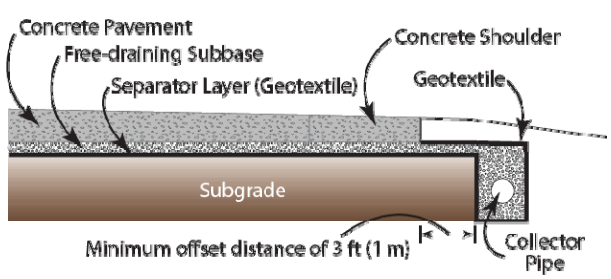
Design Principles

Daylighted



Edge Drain



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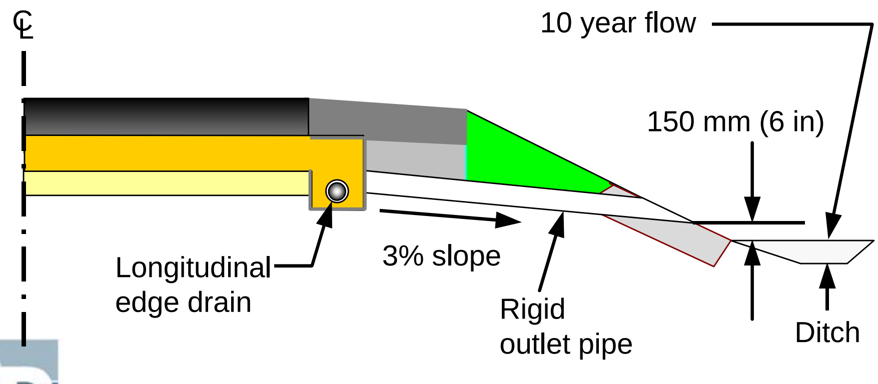
Outlets



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Retrofitted Edge Drains

- Remove surface and infiltration water from beneath pavement
  - Shortens drainage path
  - Gets water out more quickly
- Alleviate moisture problems on older pavements with inadequate drainage
- Delay or slow the development of moisture-related distresses

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Project Selection Considerations

- Characteristics of “good” candidates
  - – Early stages of moisture-related distress
  - – Minimal cracking (<5% slabs cracked)
  - – Young in age (< 10 years)
  - – Acceptable geometrics

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Limitations and Effectiveness

- Not intended to address subsurface drainage conditions (high water tables, lateral seepage) if shallow 2 ft. deep subdrains are used.
- Mixed performance
  - – Pavement too badly deteriorated
  - – Difficulty in improving drainage characteristics
  - – Poor installation
  - – Inadequate maintenance

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Importance of Maintaining Subdrainage Systems

Poorly maintained drains can be worse than having no drains at all!

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Summary

- Water WILL enter the pavement through the joints and if not drained – joint deterioration will occur
- First line of defense is the joint detail
  - If the joint doesn't crack, it won't drain
  - If the seal fails, excess water will enter the joint
  - If the subbase and subgrade are low permeability, the joint won't drain

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Summary

- Seal vs. No Seal
  - – If there is no escape route for the water (eg bath tub or mill and fill) – then seal and maintain
  - – If No Seal, the subbase and subgrade must handle the water for the design life

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Summary

- Elements of a good draining foundation
  - – Good design
  - – Proper materials
  - – Quality construction
  - – Maintenance of the drainage system

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