Concrete Pavement Basics

Andy Johnson, Ph.D., P.E.
Pavement Design Engineer
Southeast Cement Promotion Association

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What is a pavement supposed to do?

- Functional aspects:
  - Noise
  - Ride
  - Friction
  - Rutting
What is a pavement supposed to do?

• Structural aspects:
  - Protect the subgrade from permanent deformation
  - Have sufficient fatigue resistance and stability to withstand repeated loading
Design Principles

- Asphalt pavements are flexible
- Distribution of loads depends largely on pavement thickness
- Load on subgrade is more concentrated
- Deflections are much higher
- Subgrade strength/stiffness is very important
Granular solid force chain
Design Principles

- PCC pavements are rigid
- Vehicle loads are distributed over large areas (beam strength) (15-20 ft)
- Minor deflections
- Low subgrade pressures
- Subgrade uniformity is as important as strength
Structural Pavement Aspects

• Resist fatigue damage from repeated traffic loading

Critical Stress/Strain
Pavement Design

• For most pavements consisting of bound materials, fatigue damage is the controlling factor.
• The larger the stress or strain at the critical point, the fewer load repetitions to failure.
• The relationship between material response and damage is referred to as a transfer function.
Pavement Design

- At one extreme, a pavement can fail in one load repetition. This is a consideration for airfield pavement, but not so much for highways.
- At the other extreme, the load-induced response in the pavement can be so low that the fatigue life is “infinite”. 
For asphalt, the “infinite” condition is determined by the endurance limit and expressed in microstrain. Researchers differ somewhat on what the endurance limit is, but the range is generally 70 to 200 microstrain and depends on the mix design.
Pavement Design

• For concrete and cement-treated bases, the fatigue life is generally expressed as the ratio of horizontal tensile stress to the modulus of rupture.

• It is often assumed that if the ratio is less than 0.45 to 0.40, the fatigue life is also infinite.
Why do concrete pavements need joints?

• Portland cement undergoes a chemical reaction when mixed with water.

• After the reaction, the volume of the finished product is less than the ingredients. The volume of the hardened concrete is less than the green concrete.
Why do concrete pavements need joints?

• Imagine you have a very long slab of concrete sitting on a subbase.
• As it cures, the concrete slab shrinks and would become shorter if it were floating.
• But, friction between the subbase and concrete is greater than 1.0 and restrains the concrete from moving.
• This has the effect of stretching the concrete, which is much stronger in compression than tension.
Why do concrete pavements need joints?

No stress at ends

Max stress in center
Why do concrete pavements need joints?
Why do concrete pavements need joints?

100 psi

8” slab

Pressure ~3 to 7 psi

+/- 20 ft
Why do concrete pavements need joints?

• Joints must be able to transfer load across the joint.
• Joints that have lost load transfer can fault and deteriorate.
• In all older pavements and some light-duty JPCP, the rough face under the sawed joint was the means to transfer load.
• High volumes of traffic will cause the aggregate at the joint to shear away after some time.
Jointing details are critical for concrete pavement.

A. Isolation joints
B. Longitudinal construction joints
C. Longitudinal contraction joints
D. Transverse contraction joint
E. Planned transverse construction joint
F. Emergency transverse construction joint
So what can go wrong?

• Pumping
So what can go wrong?
Pumping
Why do concrete pavements need joints?

- Problem has been largely solved by the use of smooth steel dowels with bond breakers placed across the joint.
- Bars take the stress off of the aggregate face.
- These bars are intended to limit vertical joint motion but allow horizontal motion.
- Can be placed on the subbase in chairs or inserted through paver.
- Also need to lightly reinforce the centerline joint with deformed bars to prevent it from opening over time.
Why do concrete pavements need joints?
A concrete pavement structure typically consists of a concrete surface and subbase(s) placed upon a prepared subgrade.
Bases/Subbases

• A “base” is part of an asphalt pavement structure, while a subbase is an optional element of a concrete pavement structure.
Why the difference in terminology?

• **Pressures** imposed on a **base** (under asphalt) are dramatically **different** than those imposed on a **subbase** (under concrete) due to differences in moduli (stiffness) of the surface layer.

• Material requirements for a subbase may be different when compared to a base.
• Roadbeds for a concrete pavement structure should:
  - Be free from abrupt changes in character of the materials (should be uniform and constructed of a material that will provide requisite stability over the life of the pavement)
  - Resist erosion
**Case 1:** The foundation is perfectly rigid.

- Applied Load
- **\( E_{\text{material}} = \infty \)**
- Due to the perfectly rigid foundation, no deflections or flexural stresses develop.
- Loss of support results in high stresses in the concrete slab upon loading.
- **\( E_{\text{material}} = \infty \)**
- During environmental loading, the foundation does not conform to the slab and support is lost.

**Case 2:** The foundation is very flexible.

- Applied Load
- **\( E_{\text{material}} = 1 \text{ psi (0.007 MPa)} \)**
- Due to the lack of support, the concrete slab is free to deflect and high flexural stresses develop.
- **\( E_{\text{material}} = 1 \text{ psi (0.007 MPa)} \)**
- During environmental loading, the foundation conforms to slab, maintaining support.
Thank you!

Andy Johnson, Ph.D., PE
Pavement Design Engineer
ajohnson@secement.org
803-556-2889