What is Critical for Long Life Concrete Pavements-That Cost Less

Richard Rogers, P.E.
Executive Director
Cement Council of Texas

1

The Cement Council of Texas Members

2

Disclaimer

The materials and information contained herein are for general guidance and reference purposes only for professionals competent to evaluate the significance and limitations of their content. The materials and information do not constitute a standard, specification, or regulation. Third party materials reflect the views of the authors, who are responsible for the accuracy of the facts, data, opinions, findings, and conclusions presented therein. The contents do not necessarily reflect the official views or policies of the Cement Council of Texas.

3

Outline

- Why Do Concrete Pavements Fail & What is Important for Long-Life Concrete Pavement Design?
- Comparing 3D Finite Element, Elastic Layered Theory & Westergaard
- Traffic Loadings
- State DOT's Experience with Concrete Pavements and Stabilized Soils
  - TxDOT
  - Other States
- Better Performance & Less Cost
- Questions

Cement Council of Texas

4

4

Why Do Concrete Pavements Fail & What is Important for Long-Life Concrete Pavement Design?

5

General Concrete Pavement Characteristics

- Strength
- The Mix
- Thickness
- Uniform Support
- Edge Loading
- Drainage
- Durability of the Concrete & Pavement Layers
- Excessive Stresses/Strains in Supporting Layers
- Construction Issues

Cement Council of Texas

6

6

Specific Concrete Pavement Characteristics

- **Continuously Reinforced Concrete Pavements (CRCP)**
  - Crack Width
  - Punchouts
- **Jointed Concrete Pavement (JCP)**
  - Joint Spacing
  - Joint Maintenance

Strength

- The most sensitive input
- You must be careful when you increase the strength because **durability is more important**. Why?
  - Increasing the cement content results in:
    - The need to add more water &
    - Higher heat of hydration
    - Which causes **greater shrinkage**
- **More cement costs more and increases the COTE and Elastic Modulus**

The Mix

A well graded or optimized gradation can:

- Improved durability because:
  - Less cement-**cost less!**
  - Less effort to consolidate
  - Harder to over consolidate
  - Less shrinkage
  - Lower heat of hydration
- Provide an incentive for optimized gradation to gain supplier acceptance.

9

Thickness

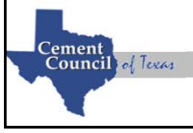
- Very important as pavements have failed because the pavement structure was insufficient.
- The pavement layer thickness should be optimized by increasing the support, which is:
  - Less expensive
  - Helps to reduce the carbon footprint
  - Stabilization helps to maximize the use of local materials

10

Uniform Support

Stated in all the books, but

- How long is the support uniform?
- The designer needs to take steps to make sure that it stays uniform for the design life, but how?



Uniform Support (cont.)

What else is important for the Base & Subgrade Layer?

- Long lasting/Durable
  - What is the best stabilizer & what is the right amount?
- Optimize the Design by adding structure by cement treatment
  - To reduce costs
  - Reduce the carbon footprint
  - Reduce strains in the subgrade
- Stair-stepping each pavement layer to
  - Reduce strains in the subgrade
  - Protect the subgrade from moisture changes

Edge Loading

- Produces significantly higher stresses than an interior load.
- Tied concrete curbs reduce edge loading stresses.
- Concrete shoulders reduce changes in moisture to the trafficked areas and reduce edge loading stresses.
- It is also important to construct each foundation layer at least two-feet narrower than the layer below.
  - This will reduce edge loading and, by spreading the foundation layers beyond the concrete pavement edge, the changes in moisture to the trafficked areas will be reduced.

13

Drainage

- Water should drain away from the pavement's foundation layers
  - Open ditches should not hold water and need to be lower than moisture sensitive pavement layers
- Asphalt will strip if it is kept saturated
- Flex base is very moisture sensitive

14

Durability of the Concrete & Pavement Layers

- The Concrete Pavement
  - Well cured
  - Max w/c should be 0.42 to reduce permeability
  - Well graded to reduce paste content
  - Max placement temperature of the mix is 90 degrees F
  - Tested for freeze-thaw and wet-dry durability
  - Deicing Salt Resistant

15

Excessive Stresses/Strains in the Supporting Layers

- Currently designs are based on fatigue
- Do you know what the critical loads are?
- Do you know what the legal axle load limits are?
- PCA's old design for years was if the stress at the bottom of the concrete pavement was < 45% of the design strength that it would last forever
- The K-value or modulus of subgrade reaction is a spring value that assumes the subgrade will have an elastic response to traffic loadings, but no test has been established to determine the elastic limits of the subgrade or the pavement layers

16

CRCP – Crack Width & Crack Spacing

- Crack spacing is supposed to be an indicator that the cracks will be wide, but there is not a correlation.
- Wide cracks do mean problems are ahead…what can be done?
  - Unfortunately, it depends on if you use deicing salts or aggregate interlock are an issue

17

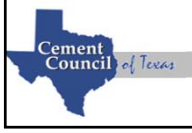
JCP – Joint Spacing

- What happens when you shorten the joint spacing to the width of the joints?
  - They get tighter & provide better load transfer!
- Conversely, what happens when you increase the joint spacing?
  - They get wider & provide less load transfer and it is more important to keep them sealed
- 15-feet is the maximum recommended joint spacing
- Generally, the joint spacing should be no greater than 1.5 times the thickness in inches to get the joint spacing in feet.
- An 8-inch pavement should have a maximum joint spacing of 12-feet.

18

JCP – Joint Maintenance

- What is worse than no joint seal?
  - A poor seal, because it will hold water in the joint
- If the joints are filling with incompressible material, then the joints need to be cleaned and sealed and should be checked every five years



19

Comparing 3-D Finite Element, Elastic Layered Theory & Westergaard

20

Comparison between Different Foundation Quantification Methods

- 3D FE & ELT have similar results for CRCP
  - With tied shoulders and legal traffic loadings
- Westergaard resulted in over design of the concrete layer & neglected excessive critical stresses/strains in supporting layers
- Need to know the elastic limits of supporting layers – Even Westergaard assumes an elastic response
- Concrete strength is the most sensitive input, but …
- Concrete pavements are failing due to failures in the supporting layers or due to durability
- Jointed concrete pavement could be designed with ELT, once the constraints have been identified (i.e. > 95 % load transfer efficiency)

Cement Council of Texas

What Pavement Layer Testing Info is Needed

- Develop Standard Lab Testing Methods To Determine:
  - Supporting layer durability
  - Supporting layer fatigue characteristics
  - Determine the best stabilizer and the proper amount
- Develop Standard Field Testing Methods To Ensure Design Parameters and assumptions have been met.

Cement Council of Texas

Traffic Loadings

23

Current Loading Conditions

- Until the 1990's truck traffic was 5 to 10%
- Now traffic loads can exceed 50%
- On IH35 near Cotulla, over 20% of trucks > double legal limit
- Traffic loads are increasing
  - Super singles
  - Spread tandems
  - Higher tire pressures
- How does your design handle critical loads?

Cement Council of Texas

24

24

State DOT's Experience with Concrete Pavements and Stabilized Soils

25

TxDOT

- In early 1980's ELT was used to design CRCP
  - San Antonio IH 35 → 7-inch CRCP overlay
- Prior to 2002 a crushed stone dense base was used in many districts
  - failed exponentially at 20 years
- Stabilized base
  - at 30 years averaged 1 failure per mile and did not exponentially increase.

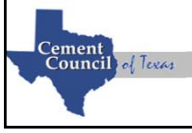
Cement Council of Texas

26

26

Other State Experience

- Florida - Pavement with dowel bars spaced at 12 inches performed significantly longer than pavements with dowel bars only in the wheel path.
- Arizona – Pavement with stabilized base performed significantly longer than the same pavement with aggregate base.



27

Better Performance & Less Cost

28

Recommendations for increased performance while reducing the cost

- Full depth reclamation
  - Durability
  - Reduced pavement thickness
  - Faster
  - Maximizing use of local materials
- Soil stabilization
  - Cement stabilization advantages
    - All weather foundation
    - Faster strength gain
    - Lower carbon footprint

Cement Council of Texas

Recommendations for increased performance while reducing the cost (cont.)

- Add shoulders to:
  - Handle traffic during construction
  - Reduce pavement thickness
- Bonded overlay or Unbonded Overlays
- Stress relieving layer with concrete overlay
- Reverse Oreo
- Innovative relations with affected business

Cement Council of Texas

Questions?

31

The Cement Council of Texas Staff

Richard B. Rogers, P.E.
Executive Director
rrogers@cementx.org
Direct: 512-751-0280

Amy C. Swift
Director of Administration
aswift@cementx.org
Direct: 817-281-6799

Nancy Beltran, Ph.D., EIT.
Regional Program Manager
South/West Texas
nbeltran@cementx.org
Direct: 915-203-0387

Randy Bowers P.E.
Regional Program Manager
North/East Texas
rbowers@cementx.org
Direct: 817-919-5858

Visit our website at http://www.cementx.org/

32