How important is strength REALLY?

24th and Stange Road
Ames, Iowa
Constructed 1982

My Maple Tree
What should we really be focused on?

When we are only worried about opening strength…. 

...we miss what's important: **DURABILITY!**
Presentation Overview

- **Focus**
  - Full depth patches
  - 2 lane roadway
  - Daylight hours closure
  - Normally ~6 foot long

- **Think outside the box**
  - Discuss old paradigms
  - Look at why we do what we do
  - Rethink how we approach patching
Presentation Overview

- Goal of the recommendations
  - Reduce the time to construct the patch
  - Utilize reduced opening strength
  - Reduce the cost
  - Provide a durable, long life patch with equal or better performance than those constructed with conventional techniques
Why do we patch?

- Loss of support
- Heavy Loads
- Construction Issues
How long must a patch last?

- **Pavement design**
  - Thickness based on the design loadings for the life of the pavement

- **If we patch a 15 -20 year old pavement…**
  - At least 50%± of the design loadings likely have already occurred?
  - In theory, patch could be thinner!

- **It only has to last as long as the remaining life of the pavement!**
What makes for a long life patch?

- **Opening Strength**
  - Carry the loadings of the first few hours

- **Modulus of elasticity**
  - Similar to the existing pavement or less

- **Coefficient of thermal expansion**
  - Similar to the existing pavement or less

- **Thickness sufficient to carry the loads at the time of opening**
  - Works together with strength
What opening strength is needed?

- Many use the same strength requirement as new pavement
  - Established years ago when we didn’t have the technology to measure in situ pavement strength
  - Includes a large factor of safety
  - Based on ultimate strength

Patches do not need to be the same thickness as the pavement!

Thicker patches need less opening strength!
Extra thickness-longer life patch at no extra cost?

- Build patches thicker than the existing pavement
  - Lower stresses in the pavement
  - Utilize a lower opening strength
  - Extra concrete may not cost more
  - Number of patches placed per day may increase

Why?
What we do today

- Remove the bad stuff
- Handwork clean up
- Hand compact the soil
- Place granular base
- Hand compact the granular
- Place the concrete
Only Put **Concrete** Back in the Hole

- Remove the bad stuff
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Could extra concrete actually save money?

- **Thicker patch**
  - Assume an extra 4” thickness
  - 4” X 6’ X 12’ < 1 cubic yard of concrete
  - Only the cost of extra concrete!

- **Savings compared to the current practice**
  - Hand compact the subgrade
  - Granular backfill material
  - Hand compact the granular backfill
  - **TIME SAVED**
    - For extra patches placed each day
    - For extra curing time
High early strength-
Are we shooting ourselves in the foot?

- **Calcium Chloride effects**
  - Reduces long term strength
  - High heat leading to an enormous amount of temperature shrinkage
  - High risk of corrosion
High early strength—Are we shooting ourselves in the foot?

- High cement content mixture
  - May not provide extra strength
  - Increased drying shrinkage
  - Increased heat generated and thereby thermal shrinkage
  - Increased cracking potential
What opening strength is needed?

- Construction sequence
  - Critical patch is the last one
  - Lag time
    - Time to remove the covering and insulation
    - Time to remove the barricades and cones

- Project specific conditions determine time to reach opening strength
  - Time of the year / weather
  - Concrete mixtures
  - Curing methods
The thicker the patch-the lower the needed opening strength

- Extra thickness allows lower opening strength

<table>
<thead>
<tr>
<th>Slab Thickness (inches)</th>
<th>Minimum Slab Flexural Strength (psi)</th>
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<tr>
<td>7</td>
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<tr>
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<td>9</td>
<td>275</td>
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<td>10</td>
<td>200</td>
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Davis and Darter (1989)
Research by Okamoto

- 10” pavement and 1000 psi compressive
  - Less than 200 psi flexural
  - Interior loading
  - No fatigue damage after 10,000 cycles

- Bearing stresses produced by the dowels often the controlling factor

Other Research

- Cable, J. K., et al
  - *Portland Cement Concrete Patching Techniques vs. Performance and Traffic Delays*, 2004
  - Increased patch depth enhanced strength gain
  - No performance difference
    - Concrete mixtures- with and without CaCl
    - Opening times
    - Patch depths
  - Construction time equal to or less
Other Research

- Buch, et al
  - *Evaluation of high early strength PCC mixtures used in full depth repairs*, 2008
  - Use of Type III cement and high range water reducer together often negatively influenced the air void system
  - Worse when CaCl$_2$ was used
ACPA Recommendations

- Guidelines for Full Depth Repair-TB002.02P
  
  Either minimum strength or minimum time

- Minimum strength of 250 psi for 10” or thicker
When are we REALLY going to open the highway?

- Beams broke weak
- No lighting
- No reflective clothing
- Road has to be open at dark
Recommendations

- Use a conventional concrete mixture with no calcium chloride
- Make the patches thicker and eliminate granular backfill
  - At least 12” thick
- Use larger dowel bars
- Use age as the only criteria for opening, along with certain curing and temperature requirements
  - Base time requirements on 200 psi minimum strength
Change Can Be Good!