Diamond Grinding

August 29th 2012
Nashville, TN

Matt Ross P.E.
Penhall Company
Diamond Grinding

• Purpose
  – Smooth the surface
  – Reestablish skid resistance
  – Correct cross-slope

• Used for:
  – Faulted joints
  – Wheel track wear
  – Drainage slope improvements
  – Polished pavement
What is Diamond Grinding?

Removal of thin surface layer of hardened PCC using closely spaced diamond saw blades
Diamond Grinding

- Uses closely-spaced, diamond saw blades mounted on a rotating drum
- Removes weathered concrete
- Corrects surface irregularities
- Provides smooth riding surface
Diamond Grinding – Candidate Distresses

- Faulting at joints and cracks
- Built-in or construction roughness
- Wheel path rutting caused by studded tires
- Polished concrete surface
- Unacceptable noise level
- Permanent upward slab warping
- Inadequate transverse slope
Useful Information

• Year the pavement was built
• Pavement type (plain, reinforced)
• Transverse joint spacing
• Aggregate sources
• Aggregate hardness
Useful Information (cont.)

• Aggregate/sand quantity/abrasiveness
• Aggregate size and exposure
• Existing pavement profile (California Profilograph)
• Faulting index or average faulting
• Studded tire rut depth
• Amount of warping
Diamond Grinding of Roadways Was Invented in California

- Diamond grinding was first used in California in 1965 on a 19-year old section of I-10 to eliminate significant faulting (Neal and Woodstrom 1976).

- In 1983, CPP was conducted on this same pavement section, including the use of additional grinding to restore the rideability and skid resistance of the surface. In 1997, the process was repeated.

- Since its first use in 1965, the use of diamond grinding has grown to become a major element of PCC pavement preservation.
Effectiveness of Diamond Grinding
CALTRANS

- CALTRANS has determined that the average life of a diamond ground pavement surface is 17 years and that a pavement can be ground at least three times without affecting pavement structurally. See ACPA-SW for full report.
$F = m \times a$

Dynamic Load > Static Load
Rough Pavement

Profile

wavelength

amplitude

Wheel Load

27+ kips

18 kips

Distance
Smooth Profile

Profile

Wheel Load

27+ kips

18 kips

Distance
Basic Components

- Grindling Machine Frame
- Grinding Head
- Hydraulic Cylinder
- Leading Bogies
- Subframe
- Trailing Bogies
- Depth-Control Wheels
Tracing Profile Only Gives Uniform Depth Cut

Should Remove High Spots
Selecting Saw Blades

- Choose blades with appropriate:
  - Bond hardness
  - Diamond concentration
- Optimize grinding head cutting life
- Even appearance of final surface
Blades and Spacers
Setting up Grinding Head

• Select blade spacing based on aggregate hardness
  – Hard (close spacing)
  – Soft (wide spacing)
• Do not line up blade segments
  – avoids vibration
Operating Grinding Machine

Important Aspects of Operation:

• Grinding head blade setup
• Grinding head power
• Machine speed
• Steering
# Aggregate Hardness

<table>
<thead>
<tr>
<th>SOFT</th>
<th>MEDIUM</th>
<th>HARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone</td>
<td>River Gravel</td>
<td>Granite</td>
</tr>
<tr>
<td>Dolomite</td>
<td>Trap Rock</td>
<td>Flint</td>
</tr>
<tr>
<td>Coral</td>
<td>Granite</td>
<td>Chert</td>
</tr>
<tr>
<td>River Gravel</td>
<td></td>
<td>Quartz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>River Gravel</td>
</tr>
<tr>
<td>Range</td>
<td>Hard Aggregate</td>
<td>Soft Aggregate</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Grooves</td>
<td>0.1”-0.15”</td>
<td>0.1”-0.15”</td>
</tr>
<tr>
<td>Land Area</td>
<td>0.06”-0.13”</td>
<td>0.08”</td>
</tr>
<tr>
<td>Height</td>
<td>0.06”</td>
<td>0.06”</td>
</tr>
<tr>
<td>Grooves/ft</td>
<td>50-60</td>
<td>53-60</td>
</tr>
</tbody>
</table>

**Land Area**

**Height**

**Groove**
Bond Hardness

Bond Too Low

Bond Too High

Diamonds Break Free

Diamonds Polish Before Metal Segments
Holidays

- Result from unground areas
- Lower grinding head to avoid
- Specifications allow up to about 5% of area
- Do not adjust head for holidays less than 2.5 ft$^2$
Cutting Through Bumps

- Machine weight is ballast
- To cut bumps must control:
  - Forward speed
  - Grinding head depth
  - Down pressure
- To verify check for:
  - Variation in cut depth along longitudinal cut line
  - Vertical cut depth match from pass to pass
Diamond Grinding Removes Significant Curling and Warping
Checking Vertical Match of Passes

< 1/8 in/10 ft

10 ft straight edge

Pass 1  Pass 2  Pass 3  Pass 4

Poor Match Between Passes
Dogtails

- Result from no horizontal overlap
- Requires steady steering of grinder
- Attempt to maintain 1-2 in (25-50 mm) horizontal overlap
Poor Overlap Between Passes

Dogtail in ground surface
Improper Blade Spacing
60 Blades vs 52 Blades per Foot
Result of Grinding

Longitudinal texture with desirable friction characteristics
Friction
Key Elements for Success

• Understand the pavement conditions
• Set up the grinding head properly
• Operate the grinding machine properly
• Monitor the operation
Evaluate Ride Quality

- California Profilograph (or similar)
- Take traces before and after grinding
- Should be able to provide 65% improvement over pre-grind profile
- Verify profile index against specification requirement
Slurry Removal

- Inert material
- Vacuum systems remove most slurry
- Deposit along shoulder (rural)
- Deposit into trucks for disposal (urban)
Slurry Removal

• Slurry is a byproduct of diamond grinding
• Slurry can be recycled in a very simple process
• By separating the solids from the water we create two products

  Fine Inert dirt. This can be used for many different things. Fill, re-used in new concrete products or other applications.

  The water is re-used during the diamond grinding process, thus eliminating the need for large quantities of water

• And can be treated to meet environmental requirements for discharge upon completion of the work.
Diamond Grinder Collecting Slurry
Small Projects Collecting Slurry
Brandt System

- This process is very cost effective and can be performed very simply by using a shaker, a centrifuge and a vertical clarifier.
- This system has been used by all the diamond grinding contractors for the last 8 years.

Mechanical method of separating Solids from Water
Mobil Dewatering Plant
Diamond Grinding Trigger Values

Table 9.1. Trigger values for diamond grinding (Correa and Wong 2001).

<table>
<thead>
<tr>
<th></th>
<th>JPCP (High)</th>
<th>JPCP (Med)</th>
<th>JPCP (Low)</th>
<th>JRCP (High)</th>
<th>JRCP (Med)</th>
<th>JRCP (Low)</th>
<th>CRCP (High)</th>
<th>CRCP (Med)</th>
<th>CRCP (Low)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Volumes$^1$</td>
<td>2.0 (0.08)</td>
<td>2.0 (0.08)</td>
<td>2.0 (0.08)</td>
<td>4.0 (0.16)</td>
<td>4.0 (0.16)</td>
<td>4.0 (0.16)</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faulting, mm avg (in avg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skid Resistance</td>
<td></td>
<td></td>
<td></td>
<td>Minimum Local Acceptable Levels</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSR$^2$</td>
<td>3.8</td>
<td>3.6</td>
<td>3.4</td>
<td>3.8</td>
<td>3.6</td>
<td>3.4</td>
<td>3.8</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>IRI, m/km (in/mi)</td>
<td>1.0 (63)</td>
<td>1.2 (76)</td>
<td>1.4 (90)</td>
<td>1.0 (63)</td>
<td>1.2 (76)</td>
<td>1.4 (90)</td>
<td>1.0 (63)</td>
<td>1.2 (76)</td>
<td>1.4 (90)</td>
</tr>
</tbody>
</table>

Notes:
1. Volumes: High ADT>10,000; Med 3,000<ADT<10,000; Low ADT<3,000.
2. PSR = Present serviceability rating.
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Trigger (National)</th>
<th>Climate Region(^1)</th>
<th>Traffic ADT</th>
<th>Life of Treatment (Year)</th>
<th>Estimated Cost ($)(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crack Resealing</td>
<td>&gt;1/4 inch</td>
<td>&gt;1/4</td>
<td>&gt;1/4</td>
<td>&gt;1/4</td>
<td>4 - 7</td>
</tr>
<tr>
<td>Diamond Grinding</td>
<td>Faulting &gt; 1/4 inch; Ride 95 in/mile</td>
<td>&gt;1/4</td>
<td>&gt;1/4</td>
<td>&gt;1/4</td>
<td>10 - 18</td>
</tr>
<tr>
<td>Partial Slab Repair</td>
<td>Surface distress - Patches &lt; 1.2 yd(^2)</td>
<td>&lt;1.2</td>
<td>&lt;1.2</td>
<td>&lt;2.4</td>
<td>8 - 12</td>
</tr>
<tr>
<td>Isolated Slab Replacement</td>
<td>3rd stage cracking or unstable slabs</td>
<td>Same Trigger Value. For desert, mountain, or ADT &lt; 5000, District makes decision to repair.</td>
<td>8 - 12</td>
<td>$4000 - $8000/slab</td>
<td></td>
</tr>
<tr>
<td>Dowel Bar Retrofit</td>
<td>LTE &lt; 60%, Faulting &gt; 1/4 inch, Max 10% Cracking</td>
<td>&lt;40</td>
<td>&gt;70</td>
<td>&lt;70</td>
<td>8 - 17</td>
</tr>
</tbody>
</table>

\(^1\) Climate Regions: Desert, Valley, Coastal, Mountain

\(^2\) Estimated Cost: $27.7k - 42.4 k/ln mi for Crack Resealing; $30.0k - 80.1 k/ln mi for Diamond Grinding; $135 - 270/yd\(^3\) for Partial Slab Repair; $4000 - $8000/slab for Isolated Slab Replacement; $141k - 177k/ln mi for Dowel Bar Retrofit.
### Table 1

<table>
<thead>
<tr>
<th>International Roughness Index Inches Per Mile</th>
<th>Percent of Contract Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 or less</td>
<td>105</td>
</tr>
<tr>
<td>40.1 - 54</td>
<td>103</td>
</tr>
<tr>
<td>54.1 - 80</td>
<td>100</td>
</tr>
<tr>
<td>80.1 or greater</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>After correction to 80 inches per mile or less

### Table 2

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<thead>
<tr>
<th>International Roughness Index Inches Per Mile</th>
<th>Percent of Contract Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>67 or less</td>
<td>103</td>
</tr>
<tr>
<td>67.1 - 134</td>
<td>100</td>
</tr>
<tr>
<td>134.1 or greater</td>
<td>100&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>b</sup>After correction to 134 inches per mile or less
Profile Testing Equipment
Development of the Next Generation Low Maintenance Concrete Surface
The Process

• Development Work-TPTA

• Proof of Concept- MnROADs Low Volume Roads Test Sections

• Full Scale Test Section with Production Grinders
NGCS Compared to CDG
What’s Different about NGCS

1/8” Blade

1/8” Spacer

Conventional Diamond Grind Stacking

Space Provides Cooling and Debris Removal
Equipment Head Differences

NGCS Head

Conventional Diamond Grinding Head
Single or Two Pass Construction

Flush Grind

Grooved
TPTA NGCS Research

• Effect of Groove Spacing, Width, Depth, Insert

- Groove Spacing: 3/8”-3/4”
- Groove Width: 1/8”-1/4”
- NGCS: 1/8”
- Spacing: 1/2” - 5/8”
Concrete Texture Types

Transverse Tine

- 103-110 dBA

Longitudinal Tine

- 101-106 dBA

Conventional Diamond Grinding

- 100-104 dBA

Next Generation Concrete Surface

- 99-101 dBA

Twice as Loud

Traffic Twice as Loud
Conventional Diamond Grind vs Next Generation Concrete Surface
QUESTIONS OR COMMENTS

International Grooving and Grinding Association
IGGA.net

American Concrete Pavement Association ACPA.org

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