



Equipment Grinders and Mills

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Penhall Company

National Concrete Consortium

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Indianapolis, Indiana



making life a little smoother

Grinders & Groovers



What is Diamond Grinding?

- Removal of thin surface layer of hardened PCC using closely spaced diamond saw blades
- Results in smooth, level pavement surface
- Longitudinal texture with desirable friction and low noise characteristics
- Frequently performed in conjunction with other CPR techniques, such as full-depth repair, dowel bar retrofit, and joint resealing
- Comprehensive part of any PCC Pavement Preservation program

Benefits of Diamond Grinding

- Costs considerably less than a HMA overlay or thin-lift AC treatment
- Diamond ground PCC surfaces can provide increased fuel economy
- Increases friction and reduces hydroplaning
- Can be constructed with short lane closures without encroaching into adjacent lanes
- Grinding of one lane does not require grinding of the adjacent lane
- Does not affect overhead clearances underneath bridges and signs – requires no side slope or guard rail modifications
- Provides a low noise surface texture!

Pavement Problems Addressed

- Faulting at joints and cracks
- Built-in or construction roughness
- Polished concrete surface
- Wheel-path rutting
- Permanent upward slab warping and curling
- Inadequate transverse slope
- Unacceptable *noise level*

Safety, Surface Texture and Friction

- Increased macrotexture of diamond ground pavement surface provides for improved drainage of water at tire-pavement interface
- Longitudinal texture provides directional stability and reduces hydroplaning (side-force friction)
- In Wisconsin, overall accident rates for ground surfaces were 40% less than for un-ground surfaces over a 6-year period, 57% in wet weather conditions

Diamond Grinding Trigger Values

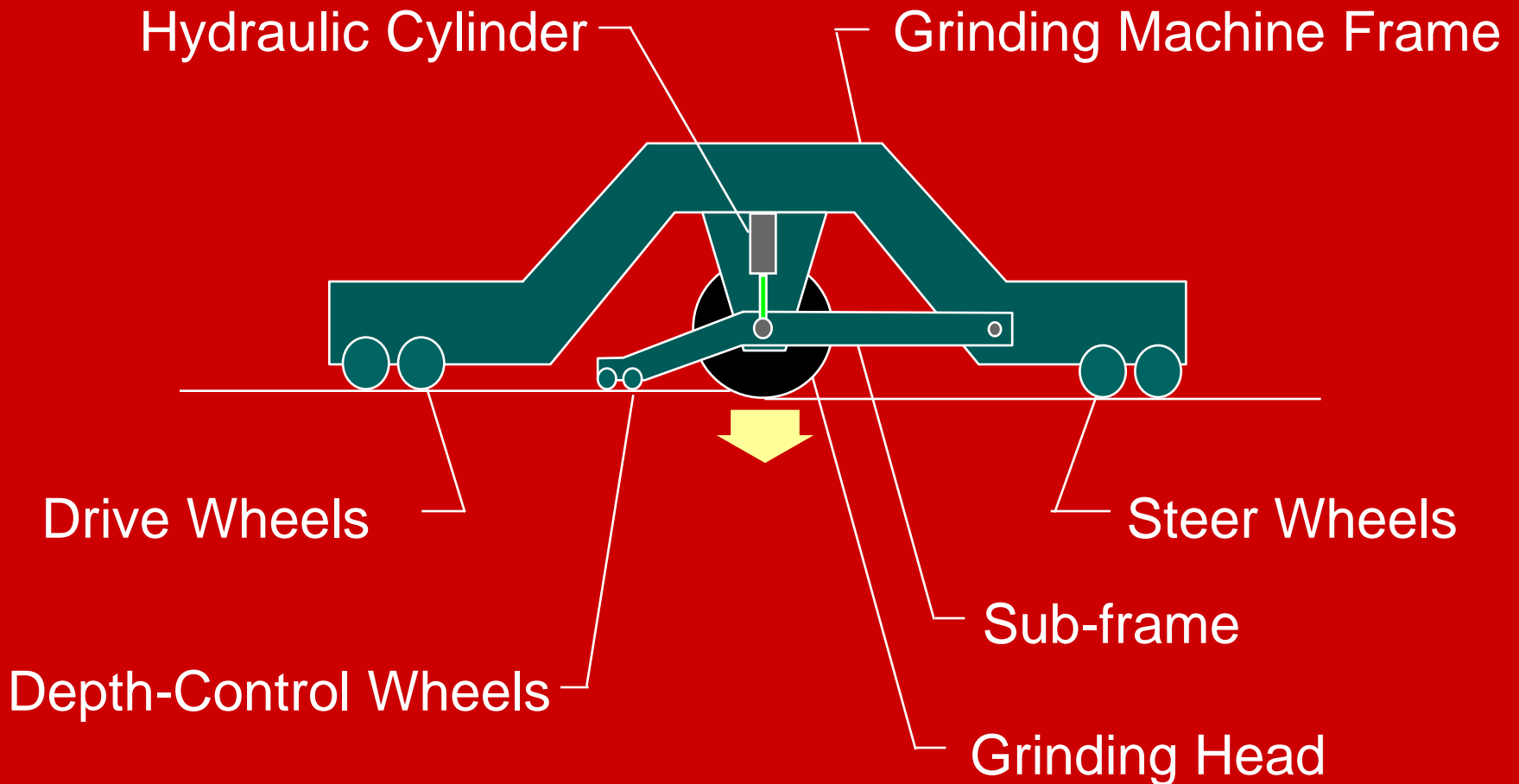
Table 9.1. Trigger values for diamond grinding (Correa and Wong 2001).

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

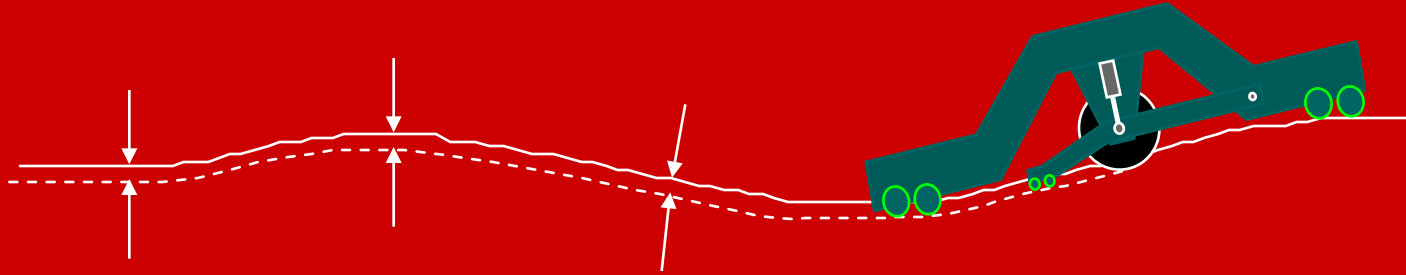
Notes:

1. Volumes: High ADT>10,000; Med 3,000<ADT<10,000; Low ADT<3,000.
2. PSR = Present serviceability rating.

Basic Components



Basic Components



Tracing Profile Only Gives Uniform Depth Cut (Texture Grind)



Should Remove High Spots

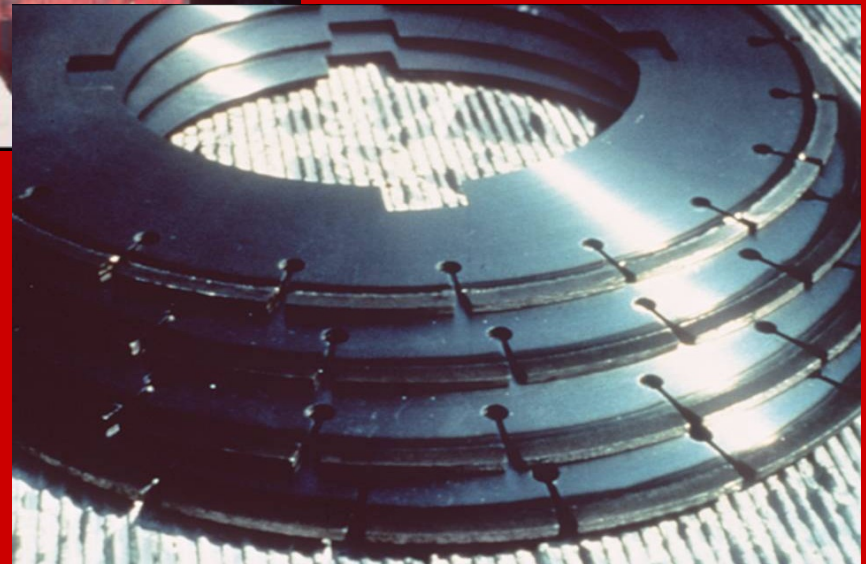
Cutting Through Bumps

- 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

Key Elements for Success

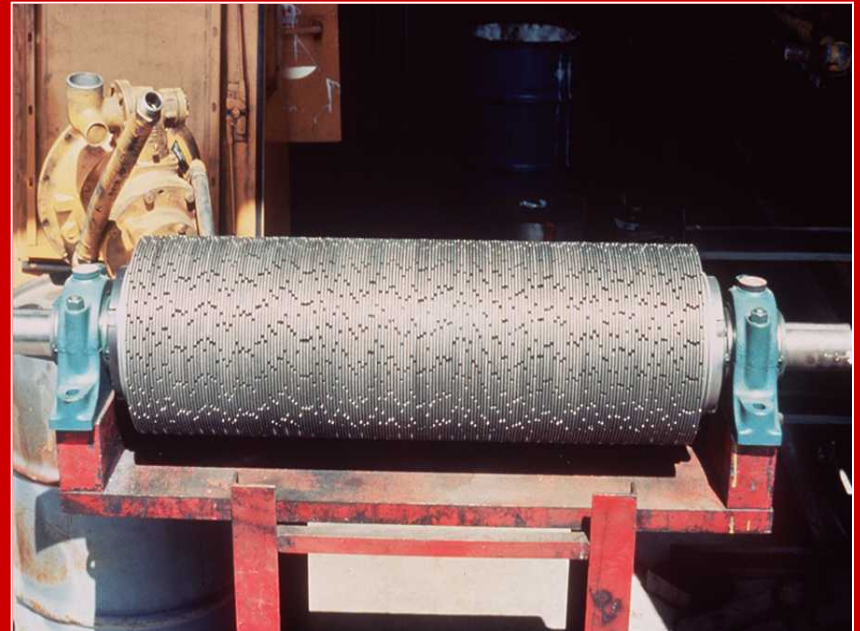
- Understand the pavement conditions
- Set up the grinding head properly
- Operate the grinding machine properly
- Monitor the operation

Diamond Grinding Cutting Head

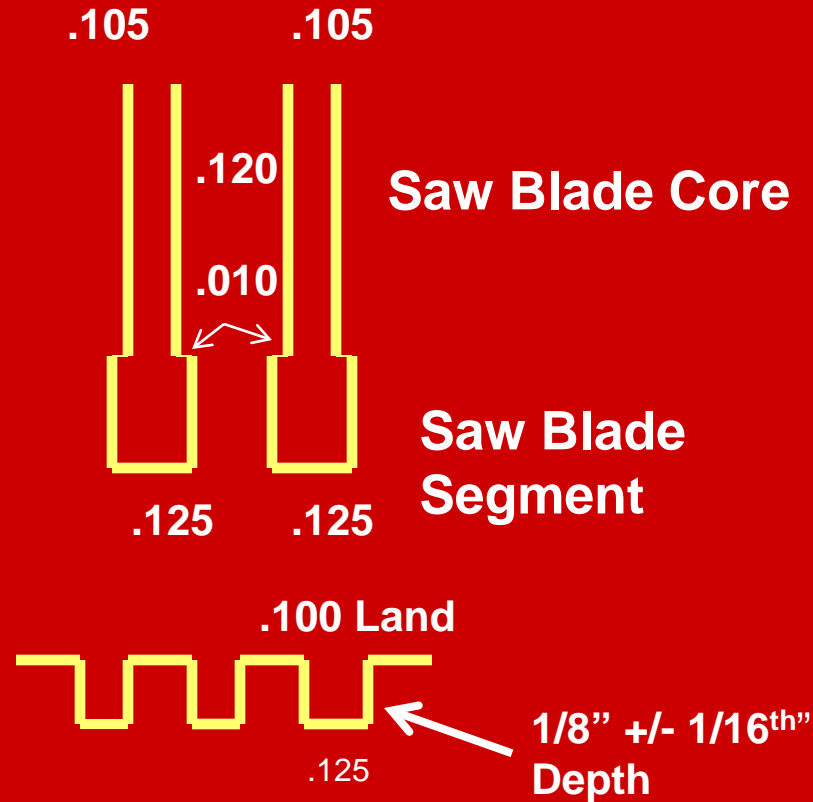


Setting up Grinding Head

- Select blade spacing based on aggregate hardness
 - Hard (close spacing)
 - Soft (wide spacing)
- Do not line up blade segments
 - avoids vibration

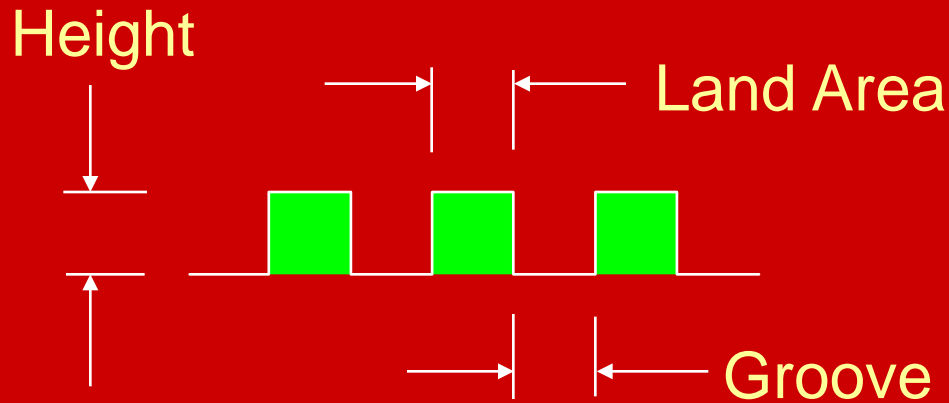


Saw Blade Spacing



105-120 Spacers Normal

110-120 Industry Standard



	Range	Hard Aggregate	Soft Aggregate
Grooves	0.1"-0.15"	0.1"-0.15"	0.1"-0.15"
Land Area	0.06"-0.13"	0.08"	0.1"
Height	0.06"	0.06"	0.06"
Grooves/ft	50-60	53-60	50-54

Aggregate Hardness

SOFT

Limestone

Dolomite

Coral

River Gravel

MEDIUM

River Gravel

Trap Rock

Granite

HARD

Granite

Flint

Chert

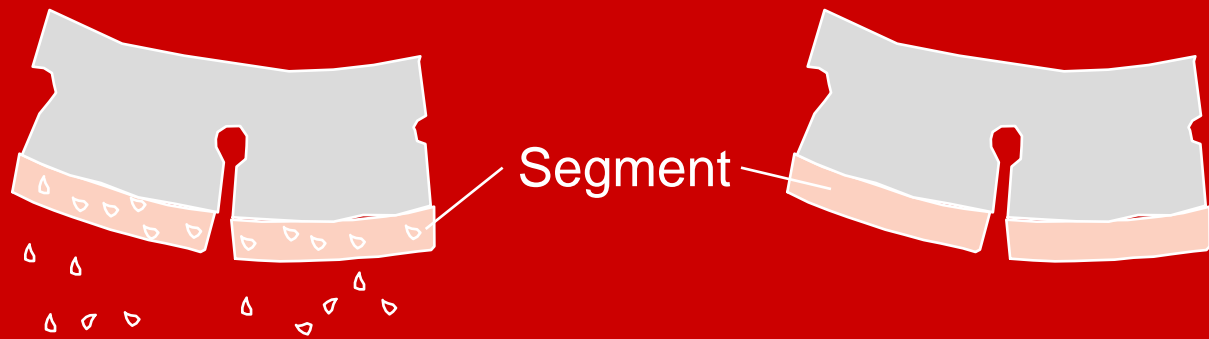
Quartz

River Gravel

Bond Hardness

Bond
Too Low

Bond
Too High



Diamonds Break Free

Diamonds Polish Before
Metal Segments

Blade Spacing Affects Fin Height



60 Blades vs 52 Blades per Foot



PC 5000-6000 Diamond Grinder



HP 485 – 650

- 4' Grinding Head
- Wt .53,000 – 62,000 LBS
- Max Wt. on Grinding Head is variable up to 27,000 Lbs
- Production Rate Variable 2'-40' per min
 - Urban 8'-14' per min
 - Rural high speed often up to 30' per min
- New Machine \$700,000 to \$800,000
 - Complete with tractor and tanker
- Grinding Heads \$60,000 to \$80,000

Conventional Diamond Grinding

Has a profile platform that is adjustable based on the pavements joint spacing, to ensure ride specification can be achieved
movement ranges from 10' to 14'



Conventional Diamond Grinding



Conventional Diamond Grinding

Max Wt to Grinding Head
26,560 lbs depth control
foot print 36 sq inch or 737
lbs / sq inch to pavement

Operating wt 79,520 lbs



Fuel 450 gal 3,600 lbs

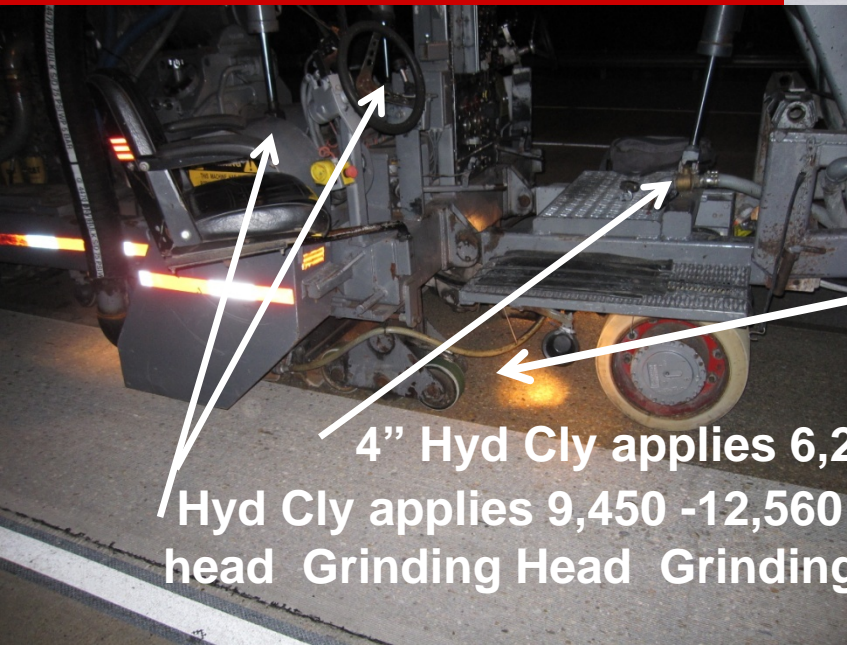
Frame Wt 14,000 lbs

Water 2,850
gal 25,650 lbs

Steering Wheel

Drive Wheels

Depth Control Wheels (Boogie
Wheels)



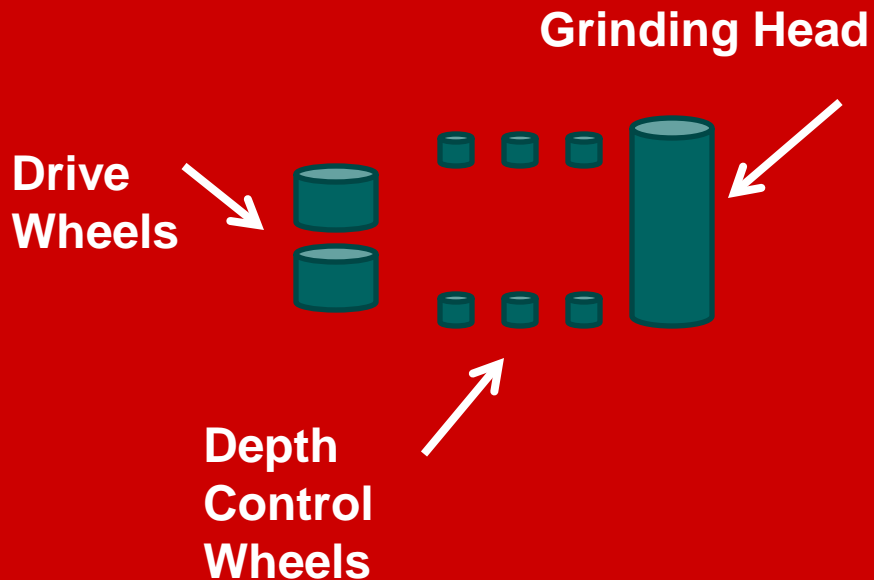
4" Hyd Cly applies 6,280 - 12,560 lbs pressure to drive wheels

Hyd Cly applies 9,450 - 12,560 lbs pressure to grinding
head Grinding Head Grinding head wt est. 5000 lbs

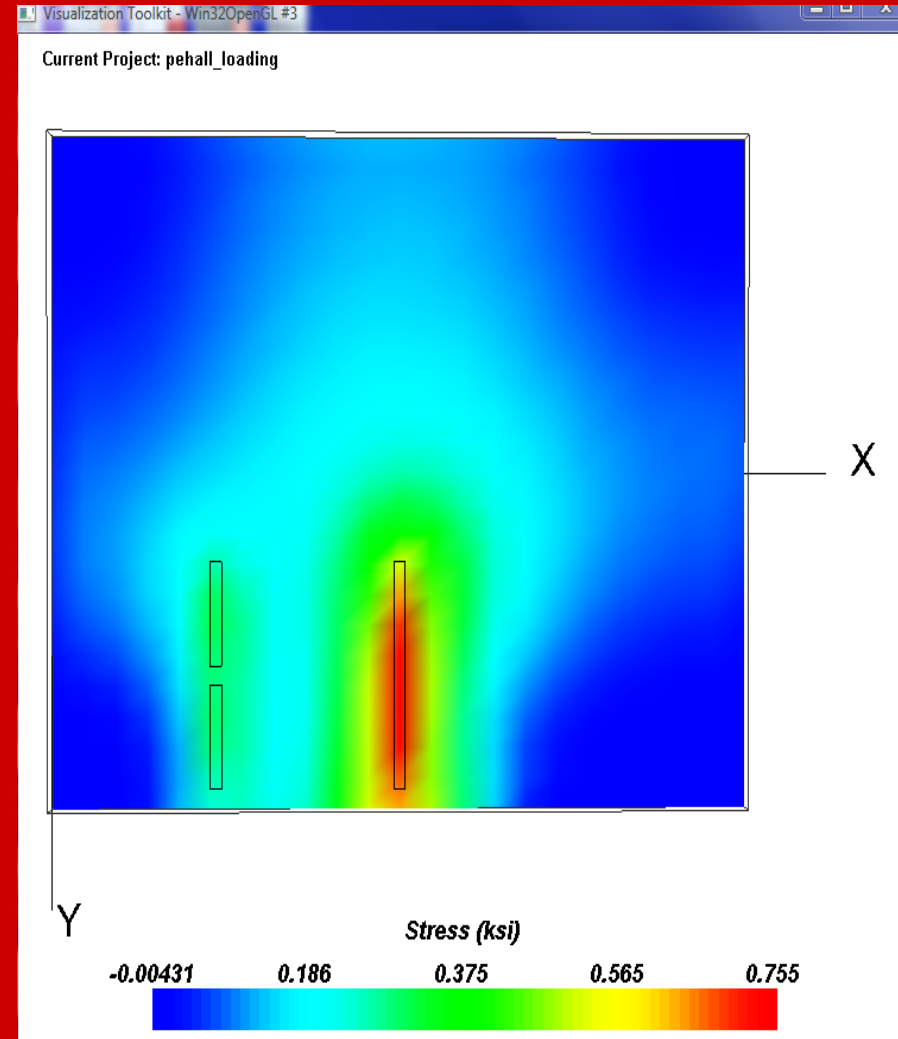
Analysis :

6 inch PCC 650 Psi Flex
12' x 15' Joints

650 psi would be about
740 psi at 28 days
and higher later in life



Ever FE 3D finite-element Analysis tool



PC 5000-6000 Diamond Grinder



- Conventional Diamond Grinder cuts 10'-14' from the wheels behind head to wheels in front
- Clearance normal operations would allow 20"
 - Some modification 12"
 - With attachment 4"

Where do the wheels Ride?

How is drainage effected?

Estimated Grinding Cost

Dependent on Size of Project Aggregate Type
Condition Of Roadway and Wage scale

Square Yard Prices

- \$2.50 - \$5.00 / SqYd
 - Could be as high as \$15.00
 - Rural open highway
- \$4.50 - \$7.50 /Sq Yd
 - Municipal street
- Slurry Disposal
- Traffic Control
- Night Work

Hourly Rates

- Corrective Grinding
- Unencumbered Contracts
- Rates around \$500/ Hr
Grinder \$150/ Hr Tanker
- Plus Mobilization

Target PRM 3804 Grinder



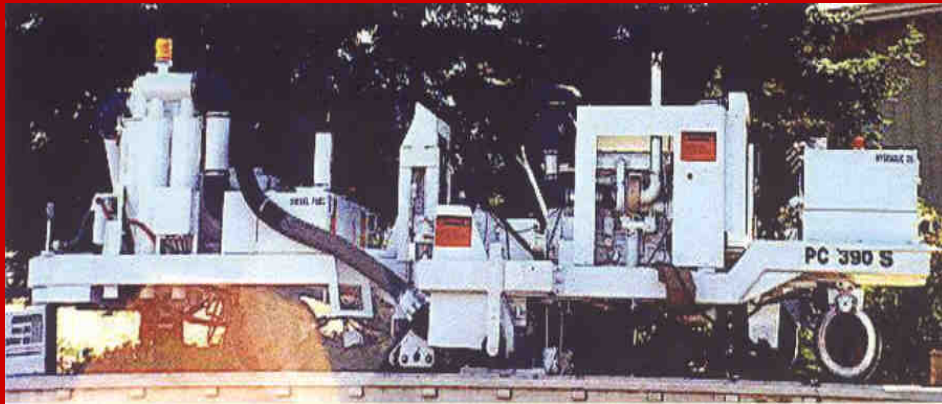
- Wt. Approx. 42,500 lbs
- 250-400 HP
- Originally built with 3' Heads
- Industry remanufactured to 4' heads and 400-700 HP
- No movable Fulcrum
- Production rate up to 25' per Min

G-38 Grinder



- Wt. 35,000 LBS_
- 3 Ft Grinding head
- 2'-20' per min
- Municipal work and small projects
- Min 18" vertical Clearance
- Originally was high production Grinder
Today used as bump grinder and urban city work tight quarters i.e. Race Tracks

PC 390s Bump Grinder & Groover



- Wt. 25,000 lbs
- 3' Head
- Primarily used for bump grinding and city work low production smaller jobs

PC 150 Bump Grinder & Airport Groover



- Wt 17,000 LBS
- 260 HP
- 3' Head
- Can grind within 10"-1" of vertical wall
- Primarily a bump grinder and used in tight places

Home Made min Clearance Grinder



Operating Grinding Machine

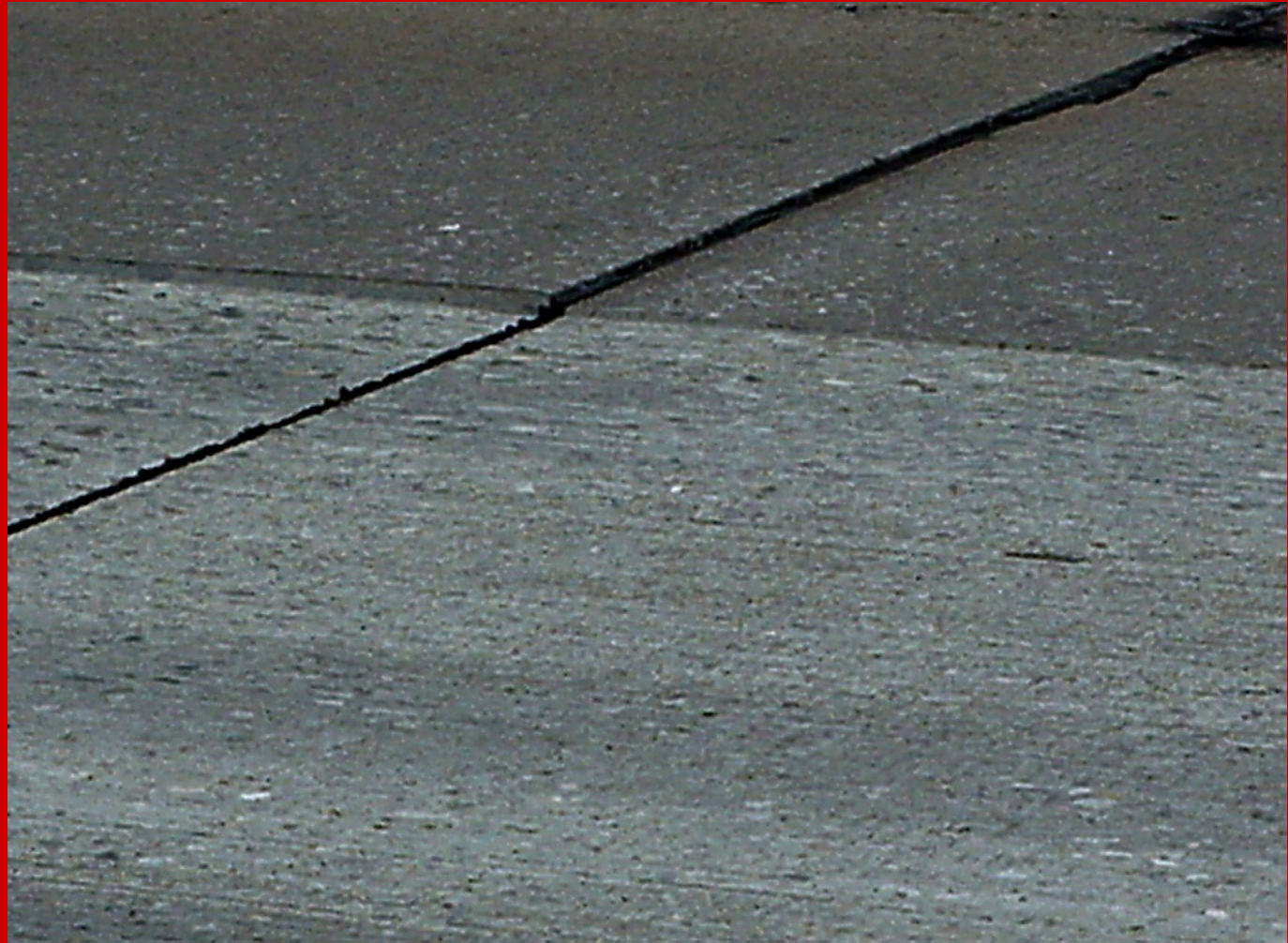
Important Aspects of Operation:

- Grinding head blade setup
- Grinding head power
- Weight of machine
- Machine speed
- Steering

Faulted Joints



Single Pass of Diamond Grinding



Smoothness Enhancement

- Diamond grinding can provide a 60% to 70% improvement over the pre-grind profile on average!



Diamond Grinding Removes Significant Curling and Warping



Curling and Warping is about Gradient Differentials

- Temperature

Curling



Warping

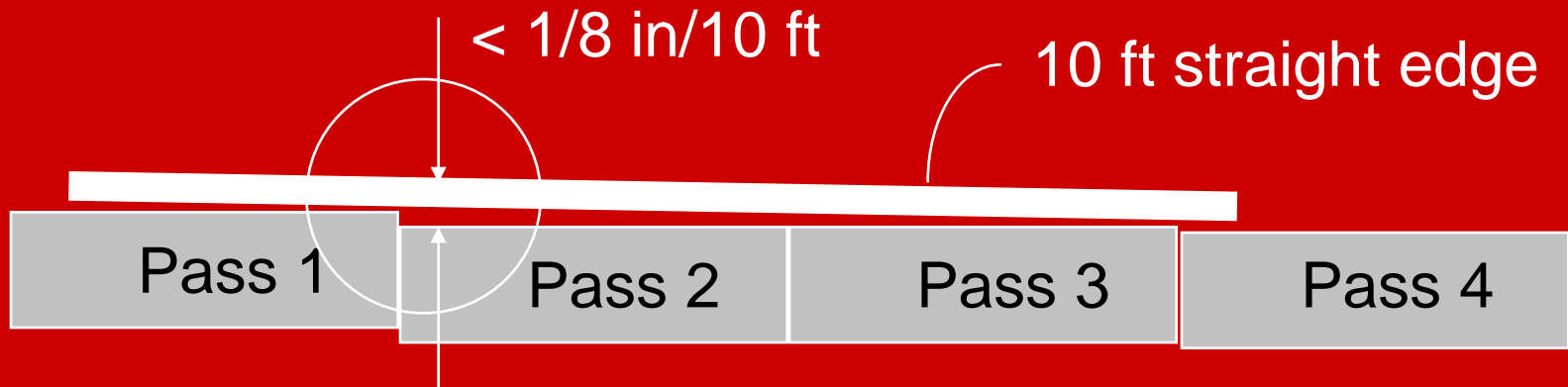
Moisture

Wet

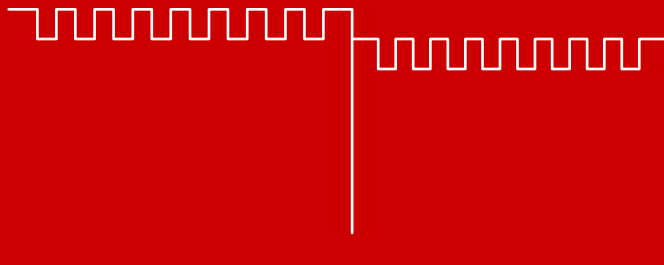
Dry

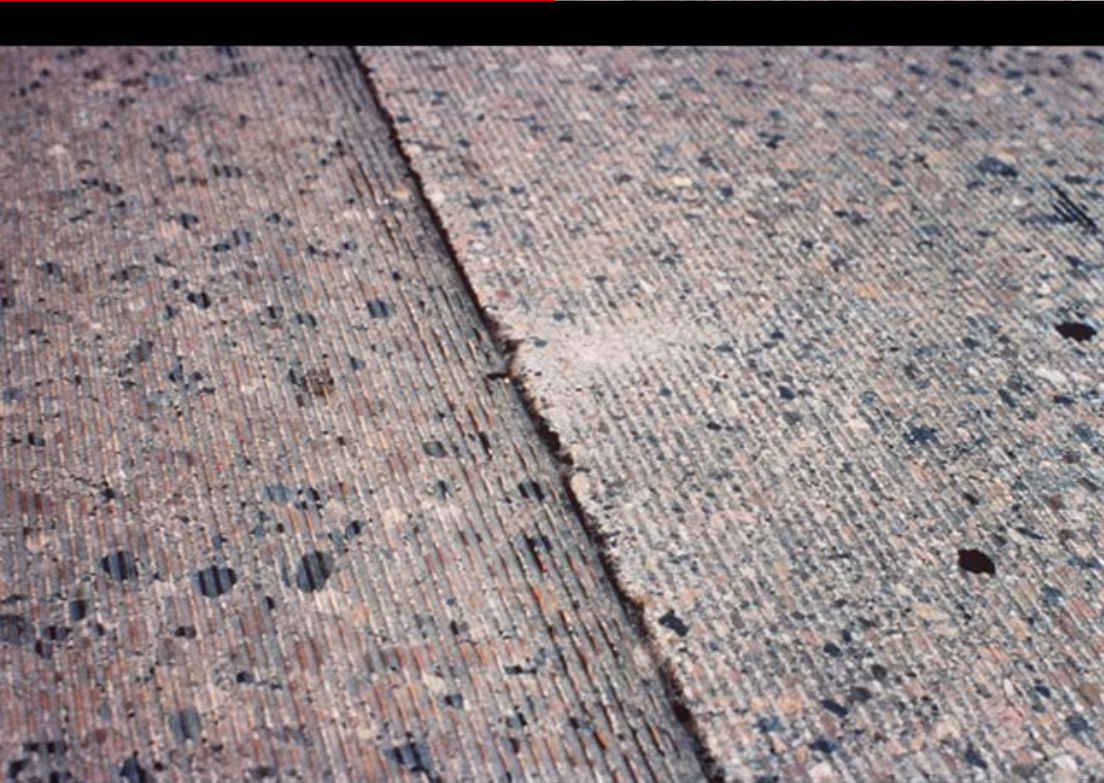


Checking Vertical Match of Passes



Poor Match Between Passes

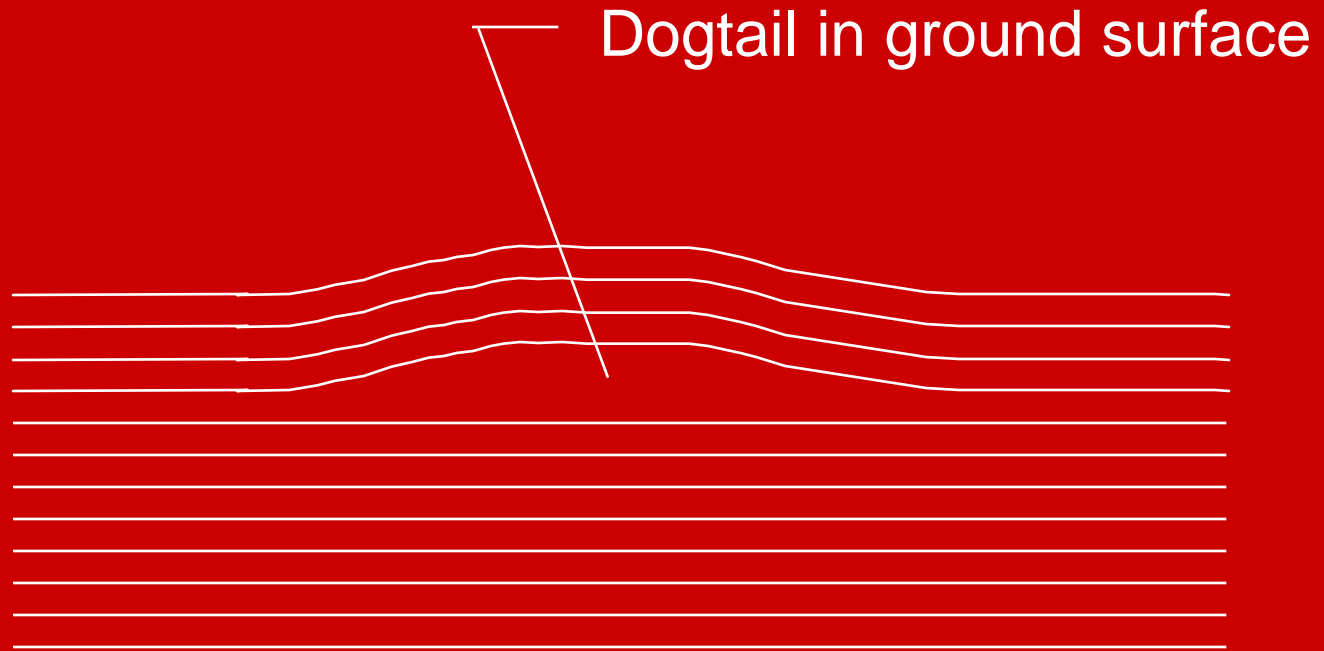




Dogtails

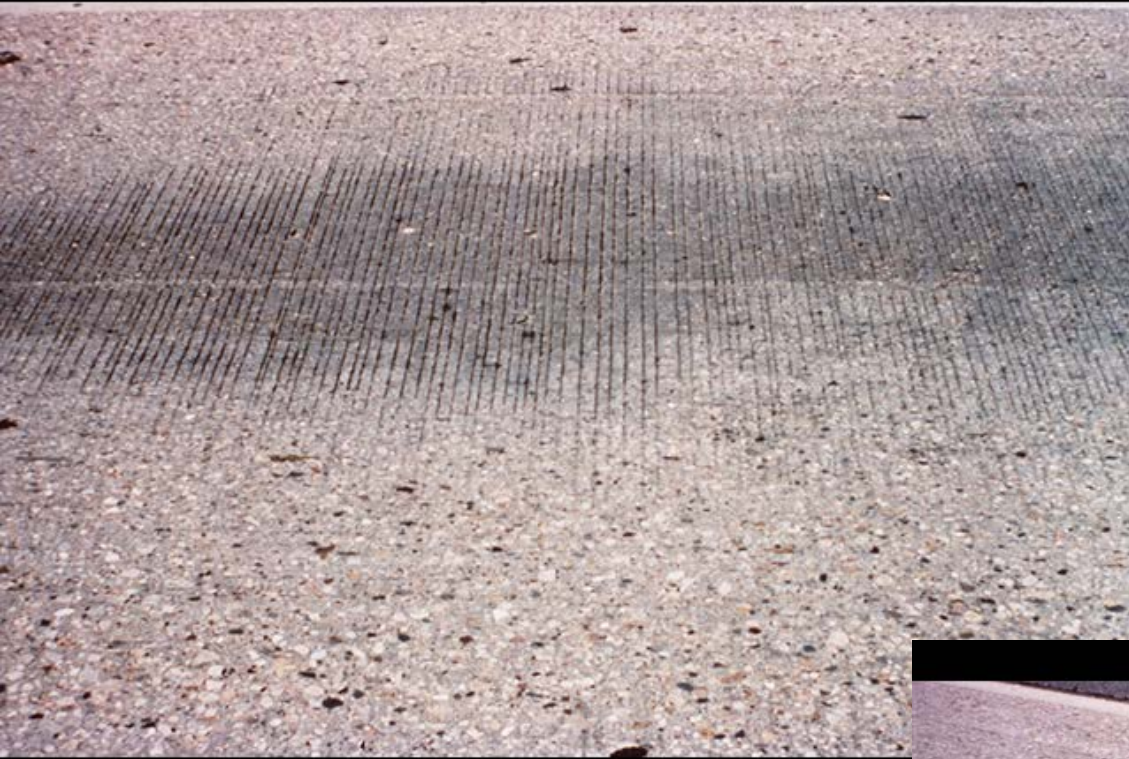
- Result from no horizontal overlap
- Requires steady steering of grinder
- Attempt to maintain 1" to 2" horizontal overlap

Poor Overlap Between Passes



Holidays

- Result from unground areas
- Lower grinding head to avoid
- Specifications should clarify the percent coverage or the percent improvement for ride quality



Evaluate Rideability

- California profilograph or LWP
- What type of specification?
 - Percent improvement
 - Pre determined ride number
- Take traces before and after grinding
- Should be able to provide 60% to 70% improvement over pre-grind profile in most cases
- Verify profile index against specification requirement

Diamond Grinding for City Streets

- Diamond Grinding does not reduce the reservoir capacity of the gutter
- Curb reveal is not reduced
- Man-hole covers and drainage inlets do not require adjustment
- Guide-rails and overhead fixtures do not require adjustment
- Residential driveways do not require expensive tie-in operations

Diamond Grinding for City Streets



Most urban applications require slurry pickup and disposal



Slurry Removal

- Inert material
- Vacuum systems remove most slurry
- Deposit along shoulder (rural)
- Deposit into trucks for disposal (urban)
- Specifications should outline requirements in advance

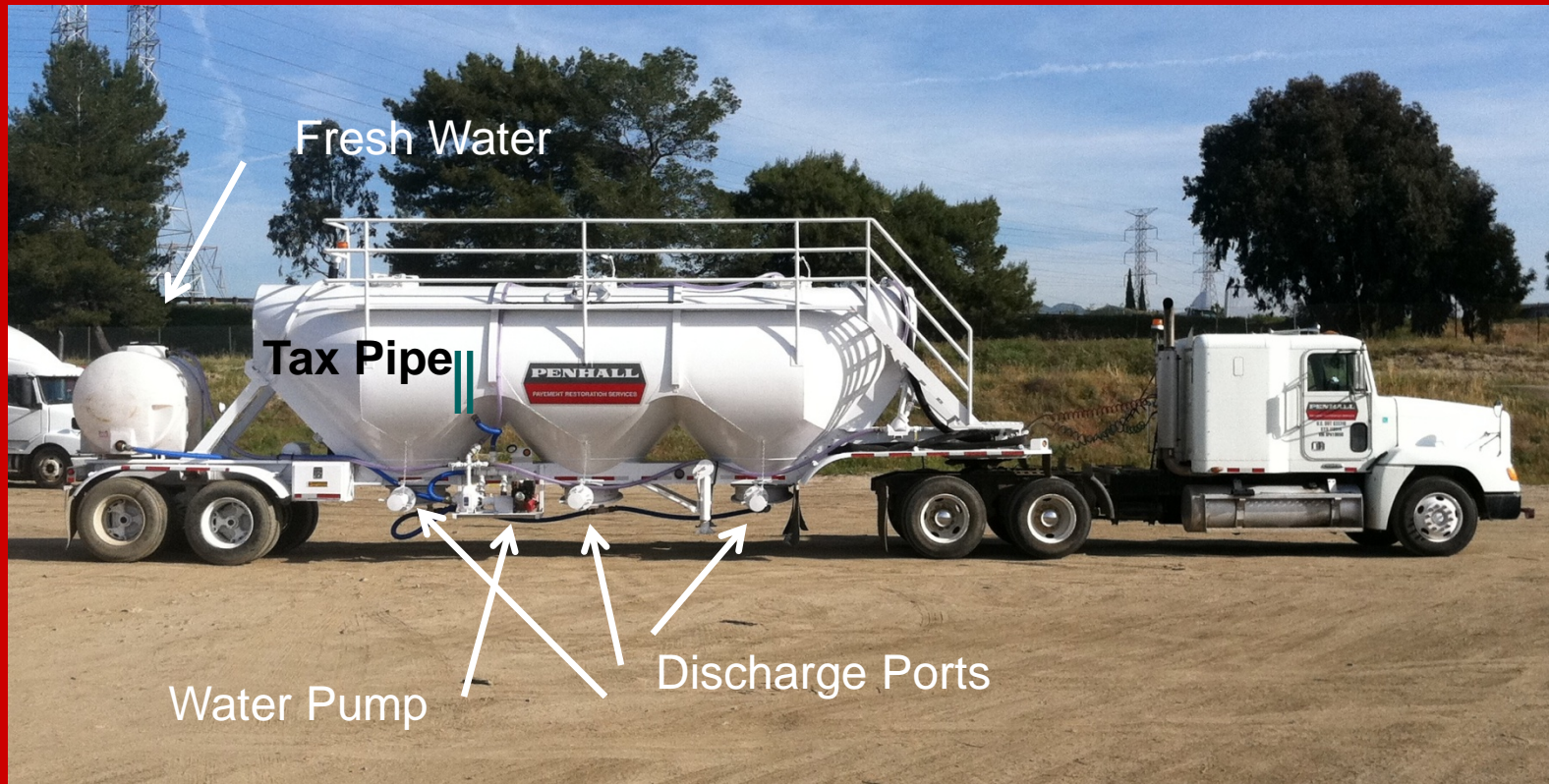


Slurry Collection



5000 Gal Tanker

Recycle Tanker



4000 gal Tanker

Small Projects Collecting Slurry



Slurry Removal

- Slurry is a by product 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.

Dewatering Pond



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



BMP Manual



www.igga.net



diamond grinding **SLURRY** handling

➤ **BEST MANAGEMENT PRACTICES**

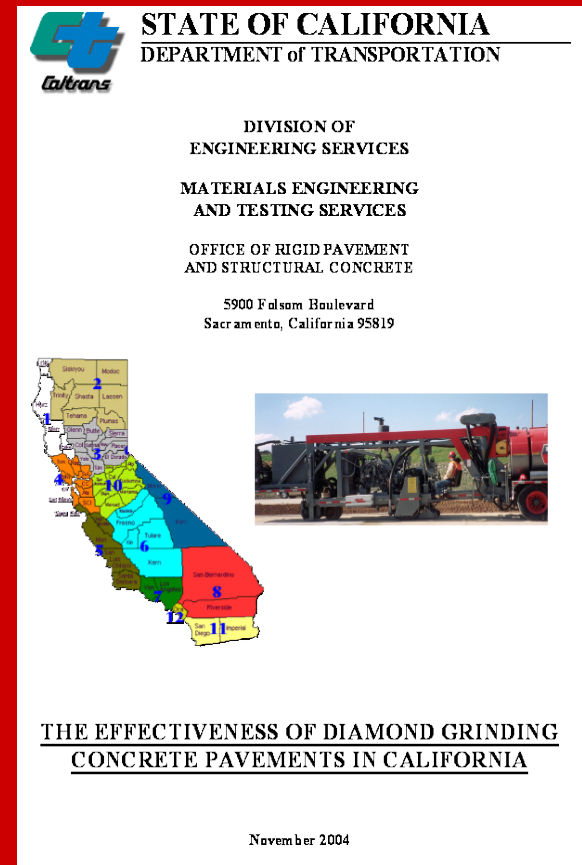


The International Grooving & Grinding Association (IGGA) is a non-profit Trade Association founded in 1972 by a group of dedicated industry professionals committed to the development of the diamond grinding and grinding process for surfaces constructed with Portland cement concrete and asphalt. In 1996, the IGGA joined in affiliation with the American Concrete Pavement Association (ACPA) to represent its newly formed Concrete Pavement Restoration Division. The IGGA / ACPA CPD Division now serves as the technical resource and industry representative in the marketing of optimized pavement surfaces, concrete pavement restoration and pavement preservation around the world. The mission of the IGGA is to serve as the leading promotional and technical resource for acceptance and proper use of diamond grinding and grinding as well as PCC preservation and restoration. For more information, visit www.igga.net.

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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 IGGA.net for full report





STATE OF CALIFORNIA
DEPARTMENT of TRANSPORTATION

**DIVISION OF
ENGINEERING SERVICES**

**MATERIALS ENGINEERING
AND TESTING SERVICES**

**OFFICE OF RIGID PAVEMENT
AND STRUCTURAL CONCRETE**

5900 Folsom Boulevard
Sacramento, California 95819



**THE EFFECTIVENESS OF DIAMOND GRINDING
CONCRETE PAVEMENTS IN CALIFORNIA**

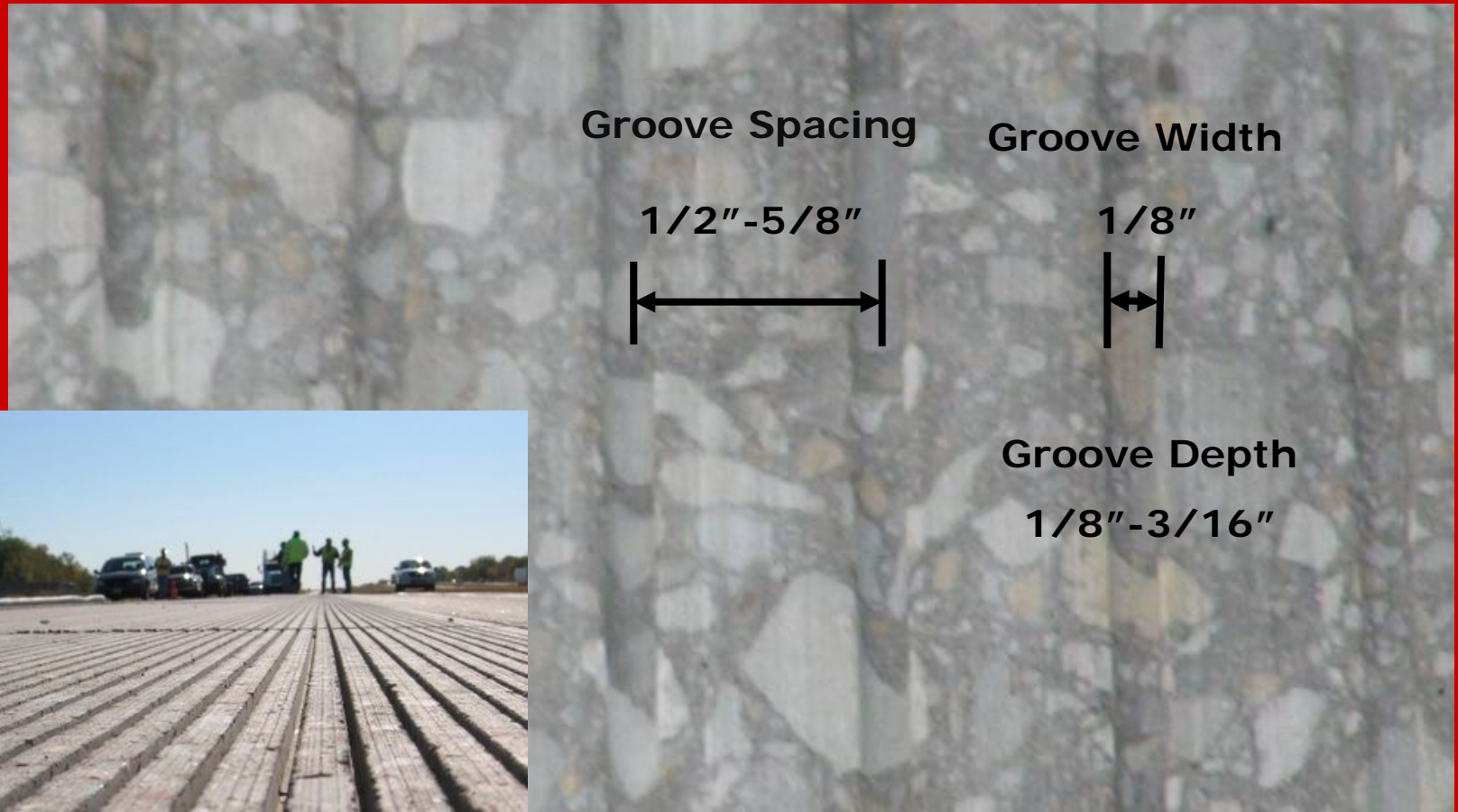
November 2004

NGCS

Development of the Next
Generation Low Maintenance
Concrete Surface

NGCS Research

- Effect of Groove Spacing, Width, Depth



NGCS Compared to CDG

NGCS



CDG



What's Different about NGCS Equipment Head Differences



**NGCS
Head**



**Conventional
Diamond
Grinding
Head**

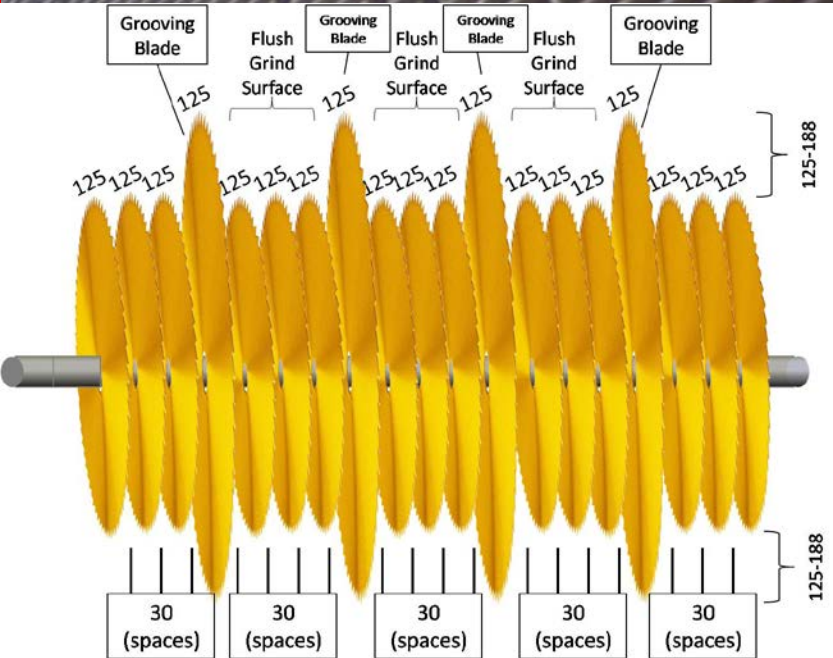
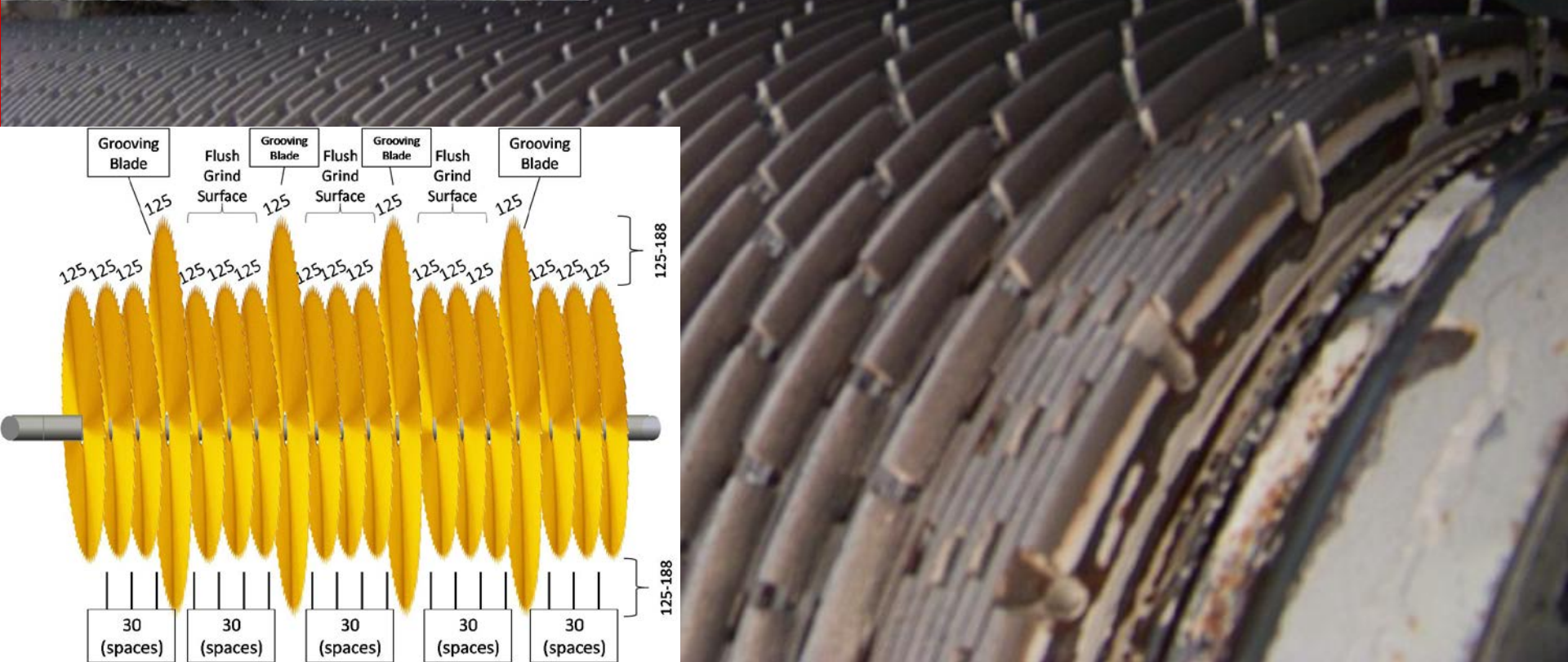


CDG Head

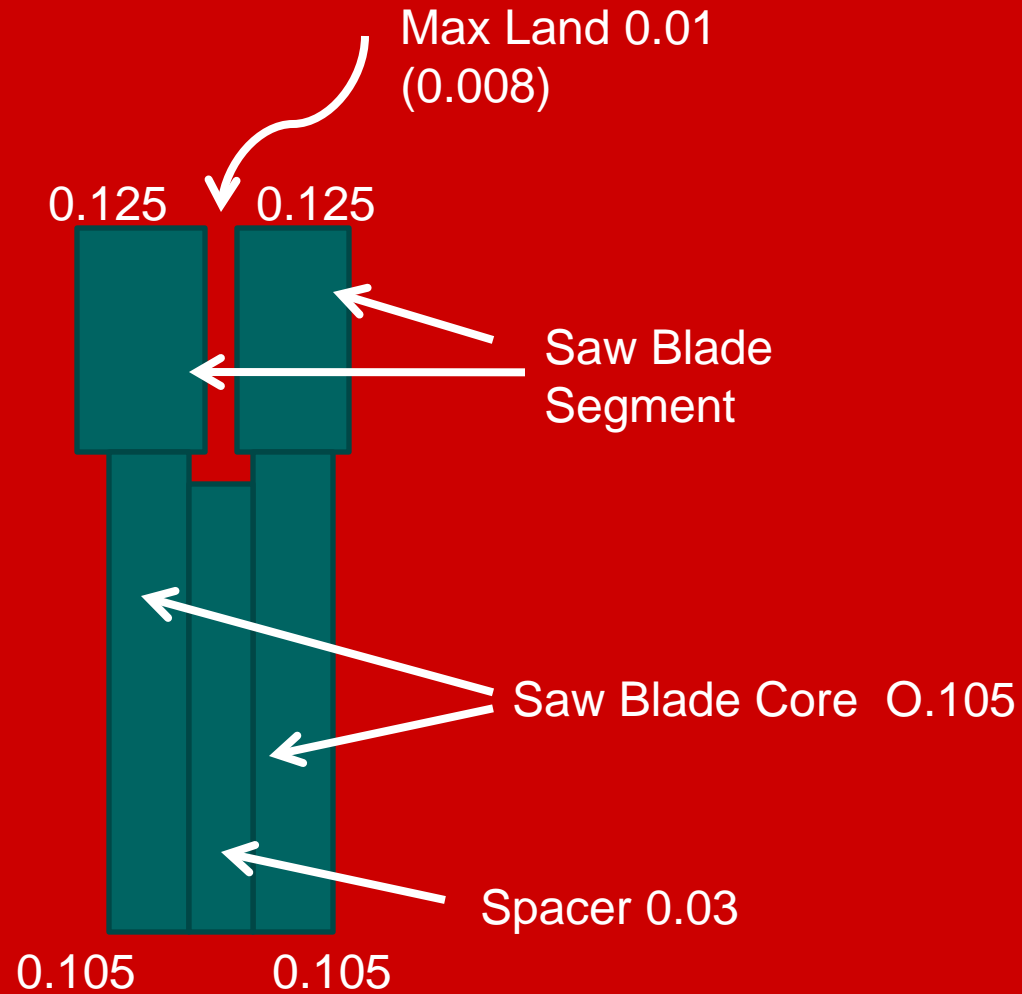




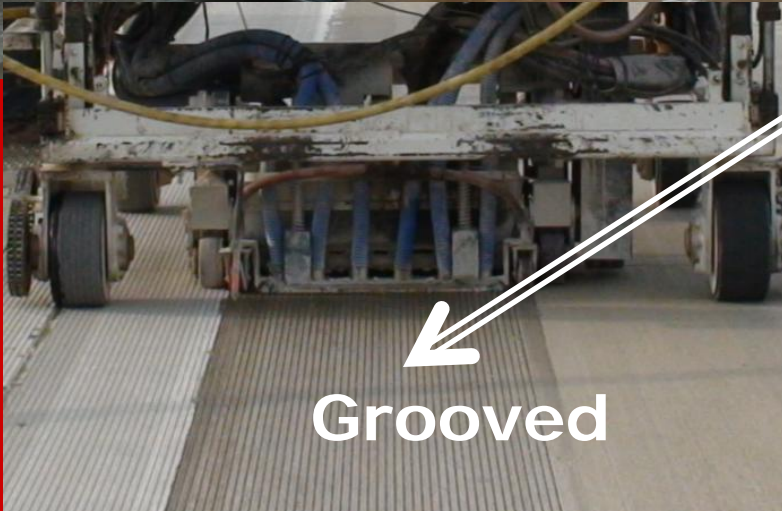
NGCS Head



Saw Blades and Spacers



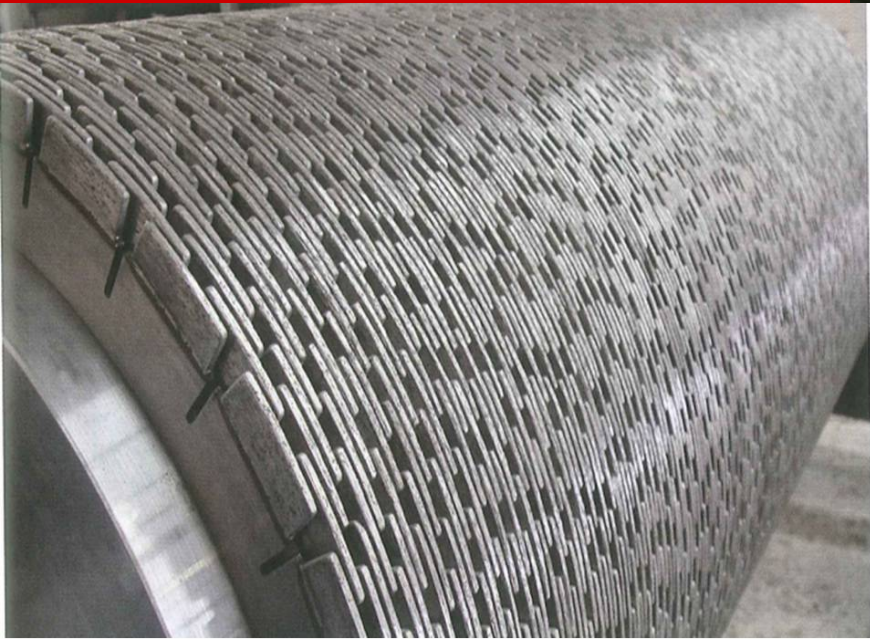
Single or Two Pass Construction



Grooved

Flush Grind

Grooving Head



Concrete Texture Types

Transverse Tine

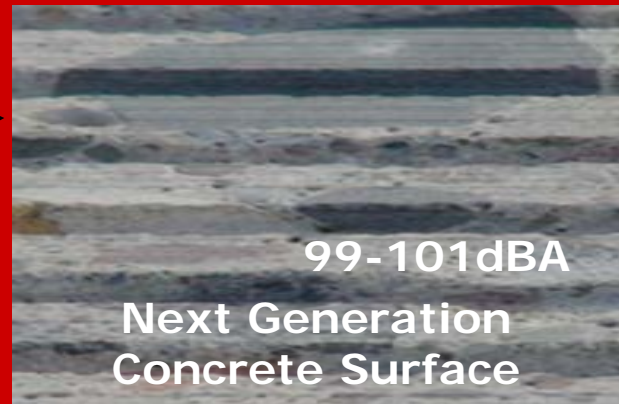


Twice
as
Loud

Conventional
Diamond Grinding



Traffic



NGCS vs Street Safe



Conventional Grind and Conventional Groove



- Used where there maybe or pavement has experienced premature polishing
- Slightly nosier than NGCS as it has positive texture in the land area between grooves
- Higher friction at pavement interface

Groovers

TBG 130 Bridge Deck Groover



- Wt. 20,000
- 160 HP
- 2000 RPM
- 30" Head width
- 12" Blades
- Ave Cost
 - Pavements \$1.50 - \$3.00 /sq yd
 - Bridges \$2.00 - \$4.00 / sq yd

GR-8 8 Foot Airport Groover



- Wt. 44,000 lbs
- 700 HP Detroit Engine
- Three equal width Heads up to 8' wide pass
- Production rate between 600 – 1200 Sq Yd/Hr
- Can groove within 10 ft of the pavement edge

Milling Machines

Milling vs. Grinding

Milling is applying a dynamic load to overcome compressive strength and thereby fracturing concrete.

While Diamond grinding and grooving is sawing the concrete.

Skid Steer Lt. Wt. Mill



- Wt. 8000 lbs
- Cut 2'-3' per min
- Light weight can cause spalling at edges
- Better for small jobs
- Primarily used for spall repairs low volume machine

Keystone Engineering Cutter



- Wt. 12,000 lbs
- Mounts on most larger skid steers and loaders
- Very little dust and spalling of edges
- More controllable still low volume application

Cat 105 2 Milling Machine

- Wt. 12,000 lbs
- 8' per min
- Multiple milling heads front and side
- V shape cut 12" Top 10" bottom 2" deep
- Works well for spall repair
- High Production minimal vibration able to provide constant depth and capable of milling continuous areas



Bart Milling Machine



- Wt. 18,000 lbs
- 150 HP diesel engine
- 15 Ft per min
- Curb Removal \$8 /In
- Mill Transverse Joint
\$1.50 Sq Ft 25'/ min
- Mill Longitudinal Joint
\$1.25 Sq Ft 25-30'/min
- Originally built as a machine for curb removal

7 Foot Vermeer Wheel Saw



- Wt. 24,500 lbs
- 155 HP
- 12" Custom V shaped head

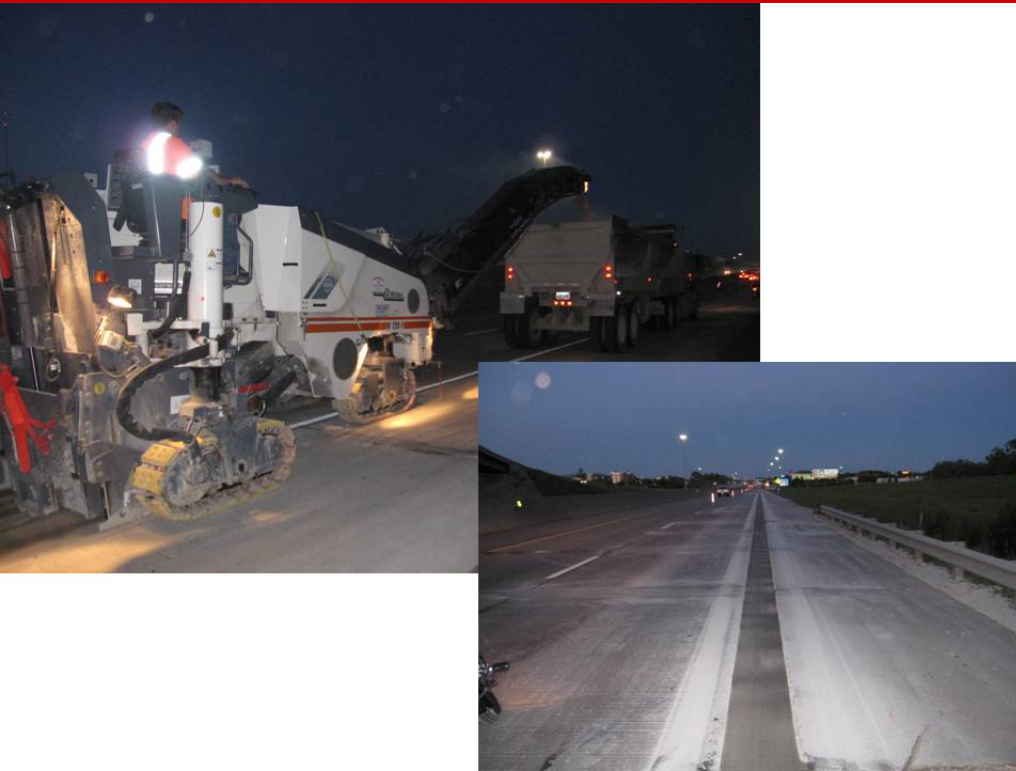


Wirtgen 50 DC Milling Machine



- Wt. 16,973 lbs
- 123 HP
- 20" wide milling Head
Depth up to 8"
- Very versatile
machine

Wirtgen W 120 F Milling Machine



- Wt 40,344 lbs
- 304 HP
- Mill 4' wide 0-13" Deep

Removing 4" Bonded Overlay in one pass on Michigan



**4" mill depth in
one pass
\$2.40 per Sq Yd**



Milling Concrete Full Width Wirtgen

- W50 DL 20" w 8.3"d 123 HP 16,975 lbs
- W60 24" w 12" d 208HP 27,558 lbs
- W120 48" w 13" d 227 HP 40,344 lbs
- W2100 8' w 13"d 700 HP 78,200 lbs
- W2200 12' w 14"d 900 HP 96,342 lbs



Smoothness Specifications IGGA.Net



IGGA Guide Specification: Diamond Grinding for City Streets

Publication Date: May 24, 2010

SCOPE

City streets are defined as roadways with a closed drainage system along with numerous structures such as manholes, wear chutes and catch basins. The grade profile varies to accommodate these structures and intersecting streets. Generally, the posted speed limit is 6 mph or less.

This standard specifies the procedures for operations of continuous diamond grinding Portland cement concrete or asphalt concrete pavement city streets and low speed roadway surfaces to provide desired surface characteristics such as ride, friction and drainage. The standard also provides guidelines for levels of acceptance for the desired surface characteristics. The user of this standard shall be responsible to ensure that all local safety, health and environmental standards are made a part of the project specifications.

Conventional diamond grinding is also utilized to reduce the noise created by the interaction of the tire with the pavement surface in areas of low to moderate noise concern. When grinding solely for noise reduction, it is important to completely remove the existing surface texture such as transverse tining. The profile requirements stated elsewhere in this specification may not apply to grinding solely for noise abatement. In areas of high tire pavement noise concern and speed limits above 45 mph, the pavement should be ground in accordance with the specifications for the Next Generation Concrete Surface (NGCS) grinding.

EQUIPMENT

Grinding shall be performed using diamond blades mounted on a self-propelled machine designed for grinding and texturing pavement. The equipment shall be at a minimum 35,000 pounds (15,875 kilograms), including the grinding head, and of a size that will grind a strip at least 3 feet (0.914 meters) wide. The effective wheel base of the machine shall be no less than 12 feet (3.66 meters).

The equipment shall have positive means of vacuuming the grinding residue from the pavement surface, leaving the surface in a clean, near-dry condition.

Grinding equipment that causes raveling, aggregate fractures or disturbance to the joints shall not be permitted.

The equipment shall be maintained to ensure it is in proper working order, with attention paid to the "roundness" of the match and depth control wheels. Any wheels found to be out of round shall be immediately replaced.

Page 1 of 5 - www.igga.net



IGGA Guide Specification: Diamond Grinding of Asphalt Pavement

Publication Date: November 2010

SCOPE

This standard specifies the procedures for the operations of continuous diamond grinding asphalt pavement to eliminate surface defects such as rutting, roughness and surface deterioration as well as provide desired surface characteristics such as smooth ride, improved friction and drainage. The standard provides guidelines for proper operating procedures along with levels of acceptance for the desired surface characteristics. The user of this standard shall be responsible to ensure that all local safety, health and environmental standards are made a part of the project specifications.

EQUIPMENT

Grinding shall be done using diamond blades mounted on a self-propelled machine designed for grinding and texturing pavement. The equipment shall be at a minimum 35,000 pounds (15,875 kilograms), including grinding head, and of a size that will grind a strip at least 3 feet (0.914 meters) wide. The effective wheel base of the machine shall be no less than 12 feet (3.66 meters).

The equipment shall have positive means of vacuuming the grinding residue from the surface, leaving the surface in a clean, near-dry condition.

Grinding equipment that causes raveling, aggregate fractures or deterioration at joints and cracks shall not be permitted.

The equipment shall be maintained to ensure it is in proper working order, with attention paid to the "roundness" of the match and depth control wheels. Any wheels found to be out of round shall be immediately replaced.

CONSTRUCTION

The construction operator shall proceed in a manner that produces a neat, uniform finished surface. Shoulder auxiliary or ramp lane grinding shall transition from the edge of the machine as required to provide drainage leaving no more than a 3/16-inch (4.8 millimeter) edge and an acceptable riding surface. Any crack sealing required shall be completed subsequent to diamond grinding operations.

Latent drainage shall be achieved by maintaining a constant cross slope between grinding extrudes in each lane. The finished cross slope shall mirror the pregrind cross slope or as shown in the project plans. There shall be no depressions or misalignment of slope greater than 1/4-inch (6.35 millimeter) in 12 feet (3.66 meter) when measured with a 12-foot (3.66

Page 1 of 5 - www.igga.net



IGGA Guide Specification: Diamond Grinding for Pavement Preservation

Publication Date: February 23, 2010

SCOPE

This standard specifies the procedures for operations of continuous diamond grinding Portland cement concrete or asphalt concrete pavement and roadway surfaces to provide desired surface characteristics such as ride, friction and drainage. This standard does not apply to corrective bump grinding. The standard also provides guidelines for levels of acceptance for the desired surface characteristics. The user of this standard shall be responsible to ensure that all local safety, health and environmental standards are made a part of the project specifications.

Conventional diamond grinding is also utilized to reduce the noise created by the interaction of the tire with the pavement surface in areas of low to moderate noise concern. When grinding solely for noise reduction, it is important to completely remove the existing surface texture such as transverse tining. The profile requirements stated elsewhere in this specification may not apply to grinding solely for noise abatement. In areas of high tire pavement noise concern and speed limits above 45 mph, the pavement should be ground in accordance with the specifications for the Next Generation Concrete Surface (NGCS) grinding.

EQUIPMENT

Grinding shall be performed using diamond blades mounted on a self-propelled machine designed for grinding and texturing pavement. The equipment shall be at a minimum 35,000 pounds (15,875 kilograms) including the grinding head, and of a size that will grind a strip at least 3 feet (0.914 meters) wide. The effective wheel base of the machine shall be no less than 12 feet (3.66 meters).

The equipment shall have positive means of vacuuming the grinding residue from the pavement surface, leaving the surface in a clean, near-dry condition.

Grinding equipment that causes raveling, aggregate fractures or disturbance to the joints shall not be permitted.

The equipment shall be maintained to ensure it is in proper working order, with attention paid to the "roundness" of the match and depth control wheels. Any wheels found to be out of round shall be immediately replaced.

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Page 1 of 5 - www.igga.net