



2007 OHIO ASPHALT PAVING CONFERENCE

Pavement Friction Investigation

By

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Jeffrey, S. Kuttesch., "Quantifying the Relationship between Skid Resistance and Wet Weather Accidents for Virginia Data". Thesis (2004)

Skid resistance is statistically significant factor in explaining the wet accident rate.

Skid Number Requirements

Institution	FN	Speed (mph)/Type of Tire
FDOT Safety Improvement Program Manual	<ul style="list-style-type: none"> ■ ≥ 35 ■ ≥ 30 	<ul style="list-style-type: none"> ■ > 45/(Ribbed) ■ < 45/(Ribbed)
FDOT Friction Testing and Action Program	<ul style="list-style-type: none"> ■ ≥ 35 	<ul style="list-style-type: none"> ■ REGARDLESS/(Ribbed)
OKDOT	<ul style="list-style-type: none"> ■ ≥ 35 	<ul style="list-style-type: none"> ■ REGARDLESS/(Ribbed)
NYDOT	<ul style="list-style-type: none"> ■ ≥ 32 	<ul style="list-style-type: none"> ■ 40/(Ribbed)
INDOT	<ul style="list-style-type: none"> ■ ≥ 20 	<ul style="list-style-type: none"> ■ 40/(Smooth)
NCHRP-37	<ul style="list-style-type: none"> ■ ≥ 37 	<ul style="list-style-type: none"> ■ REGARDLESS/(Ribbed)

ODOT Commissioned Research

Author	Concerns
Liang and Chyi (2000)	<ul style="list-style-type: none">• Polishing and friction characteristics of aggregates produced in Ohio
Liang (2003)	<ul style="list-style-type: none">• Blending proportions of high skid and low skid aggregate
Liang (2005)	<ul style="list-style-type: none">• Current research

Polishing and friction characteristics of aggregates produced in Ohio (2000)

20 Aggregate Sources in Ohio

- Accelerated Polishing
- Friction Measurement
- Petrographic Analysis
- Acid Insoluble Residue (AIR) Test
- Chemical Analysis (ODOT)
- Soundness (ODOT)













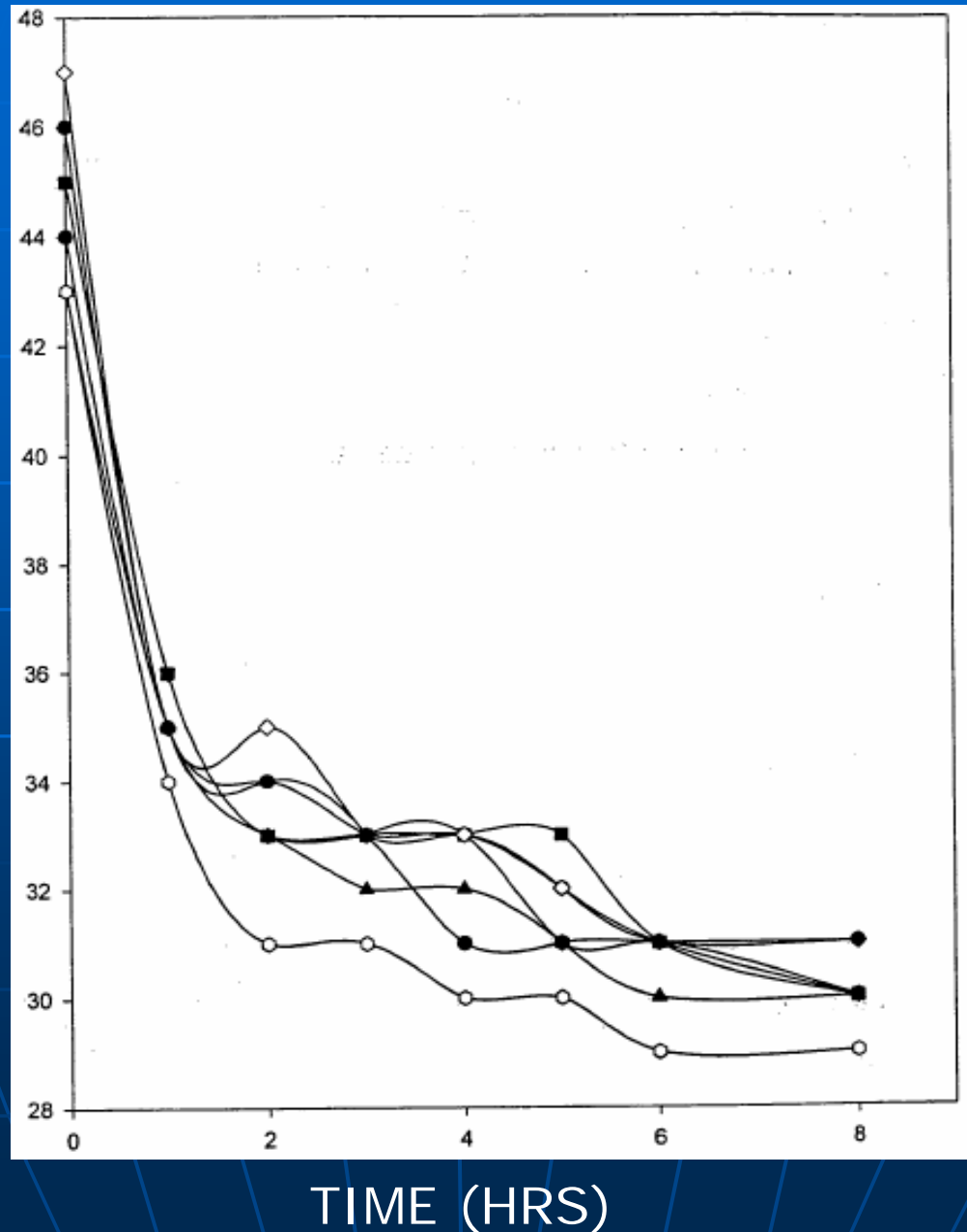






Typical Test Results

POLISH NUMBER (BPN)



Acid Insoluble Residue (AIR) (ASTM D 3042)

Non-carbonate (Insoluble Residue) in Aggregates

The Higher the Amount of Acid Insoluble
Residue



The Higher is the Skid Resistance

Soundness (ASTM C 88-90)

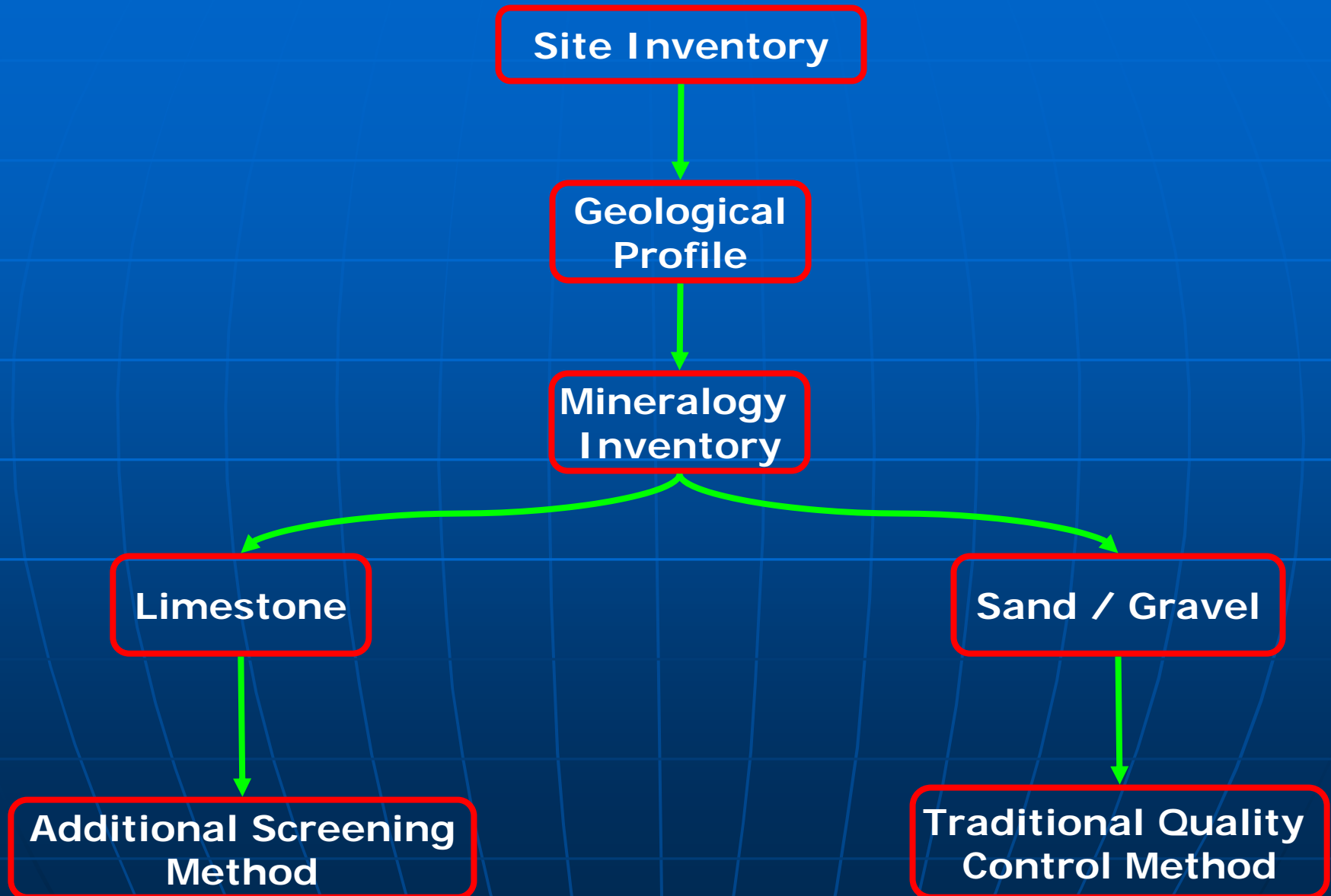
**Tests the Pavement Aggregate
Subjected to Weathering Changes**

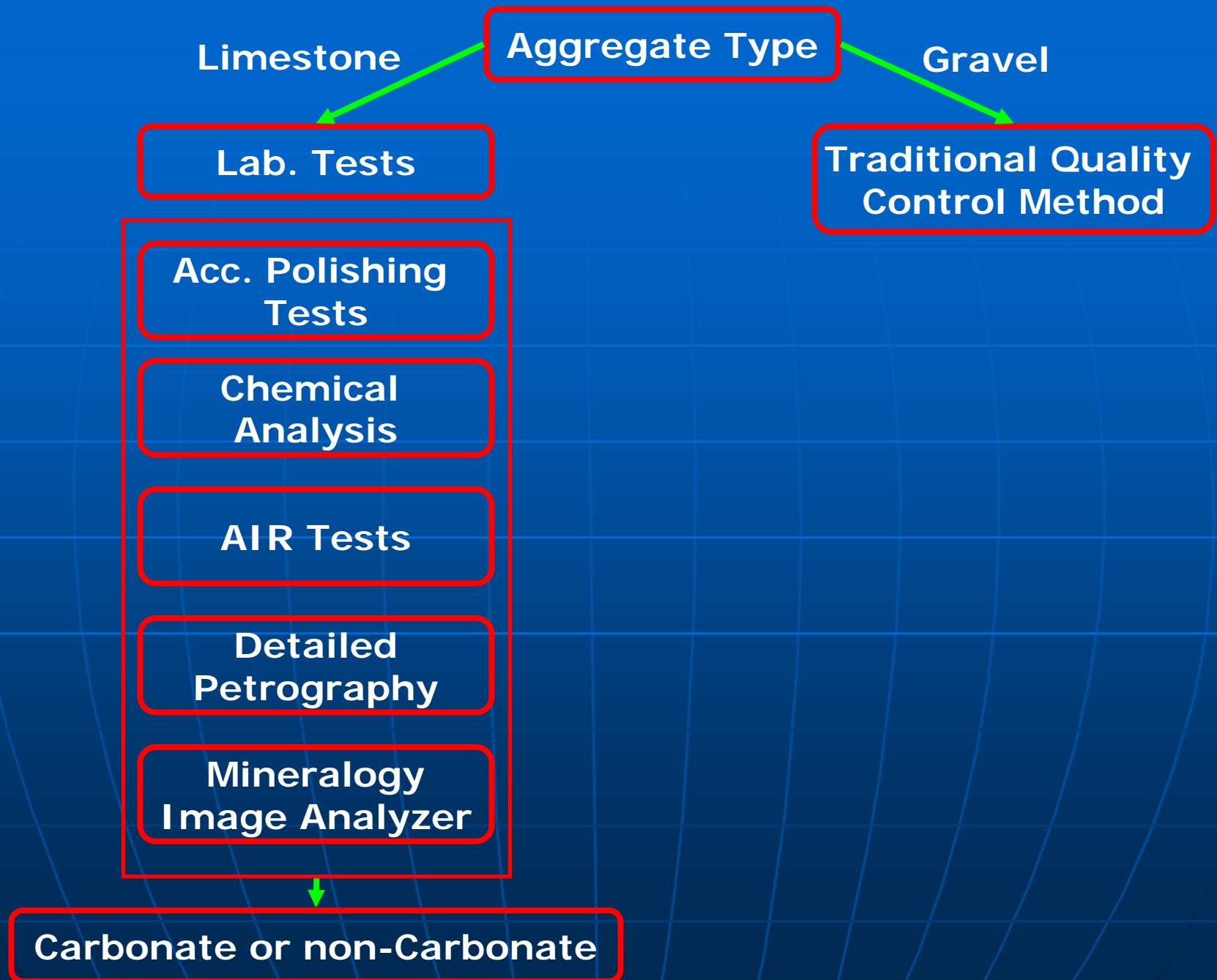
Good Polish Number Aggregate



Lower Soundness Loss Value

Aggregate Screening Method





1. Carbonate Aggregate

Selection of Aggregate
Could Involve One or more
Selection Criteria

Criteria II
Calcite content 60-70%
Dolomite content 20-30%

Criteria I
TxDOT Recommendations

ADT	PN
750-2000	28
2000-5000	30
5000-Above	32

Criteria III
ALDOT Recommendations

BPN	Max. % of Carbonate Stone
≤ 25	30
26-28	35
29-31	40
32-34	45
≥ 35	50

2. Non-Carbonate Aggregate

Selection of Aggregate
Could Involve One or more
Selection Criteria

Criteria I TxDOT Recommendations

ADT	PN
750-2000	28
2000-5000	30
5000-Above	32

Criteria II

NYDOT Recommendations

If ADT < 3000, THEN AIR% ≤ 15

If ADT > 3000, THEN AIR% ≥ 15

Blending proportions of high skid and low skid aggregate (2003)

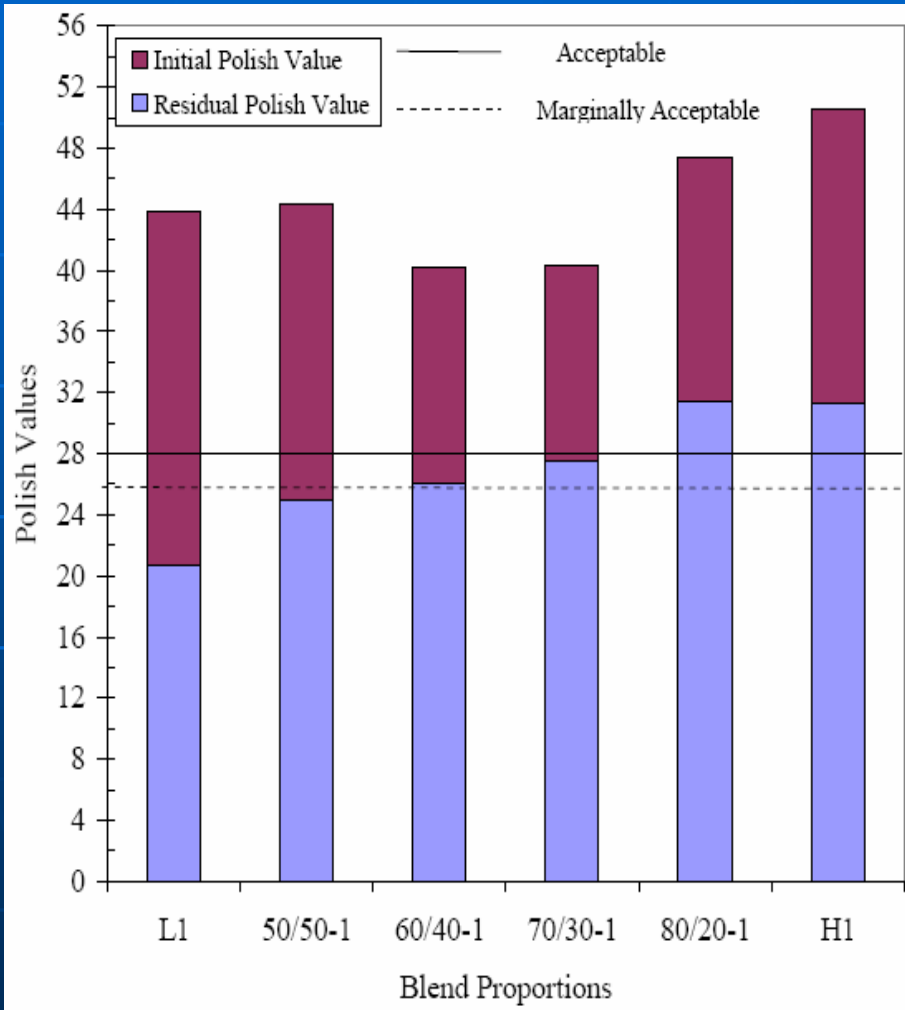
H = High Residual Friction

L = Low Residual Friction

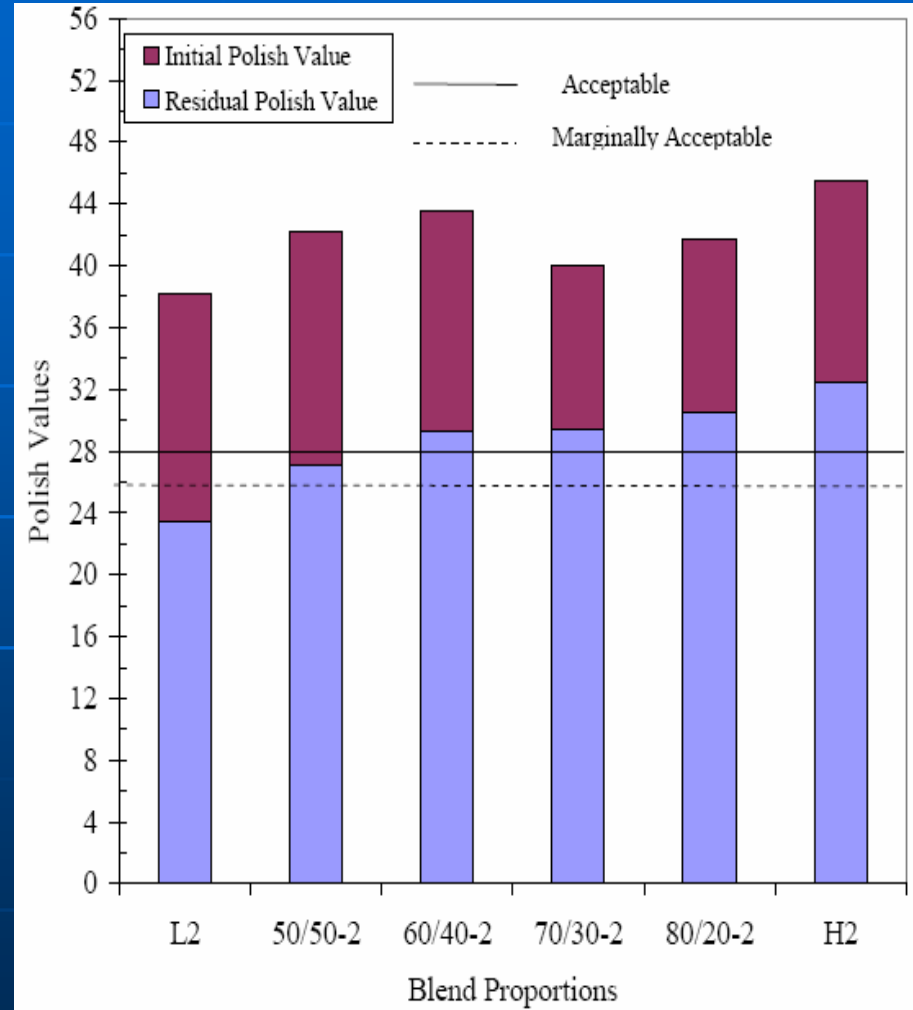
Lab study to find optimum
proportion

Lab Test Results

Initial & Residual PV for Blends 1 & 2



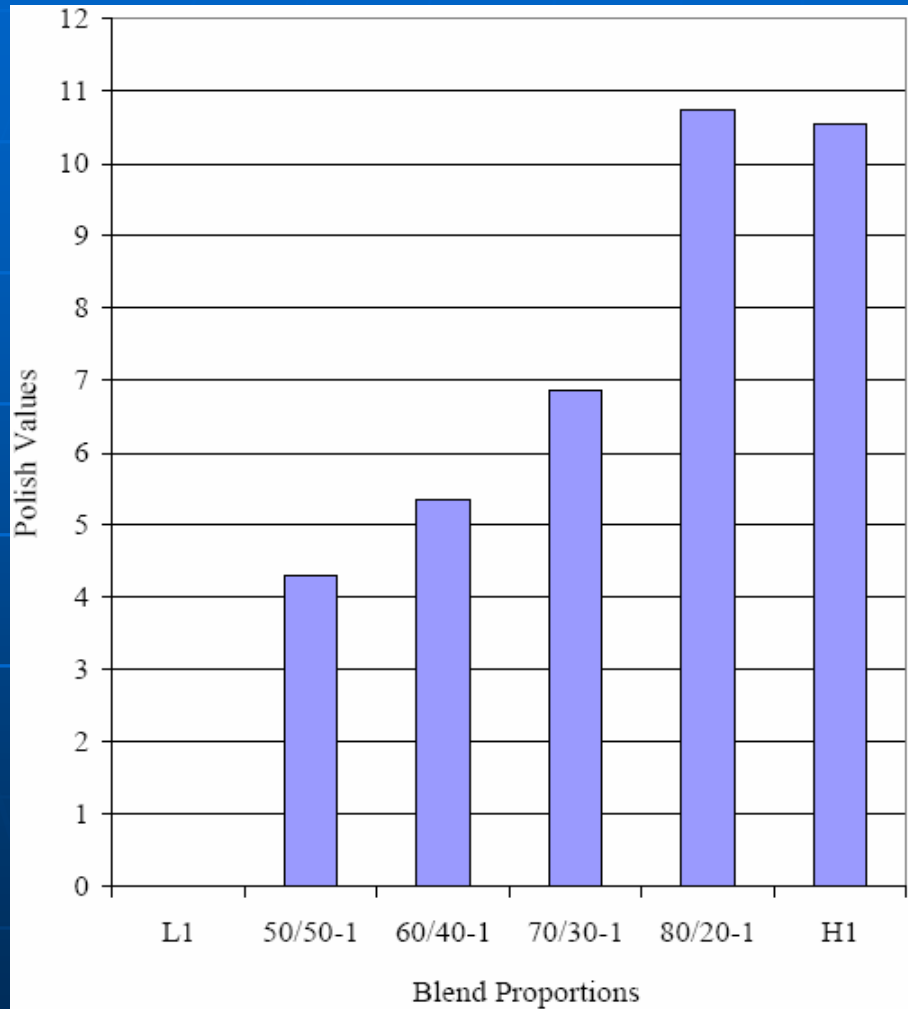
Blend 1



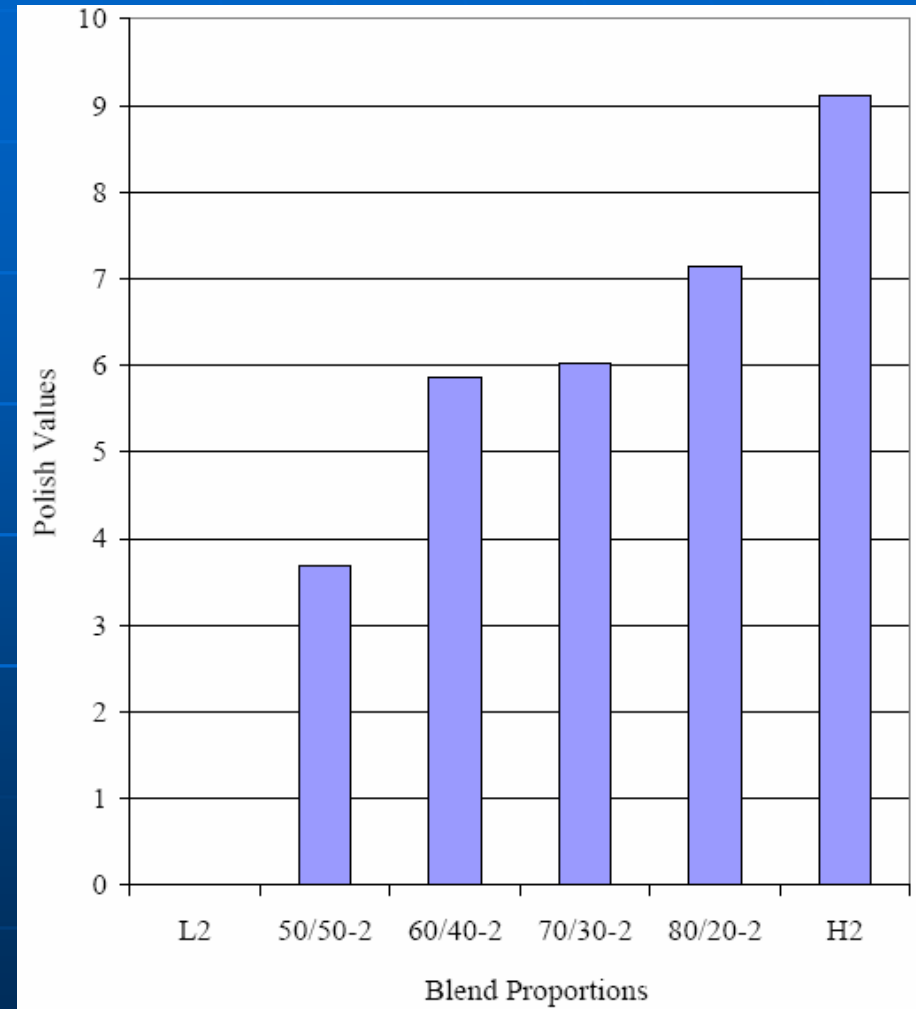
Blend 2

Lab Test Results

Improvement in PV of Low Skid Resistant



Blend 1

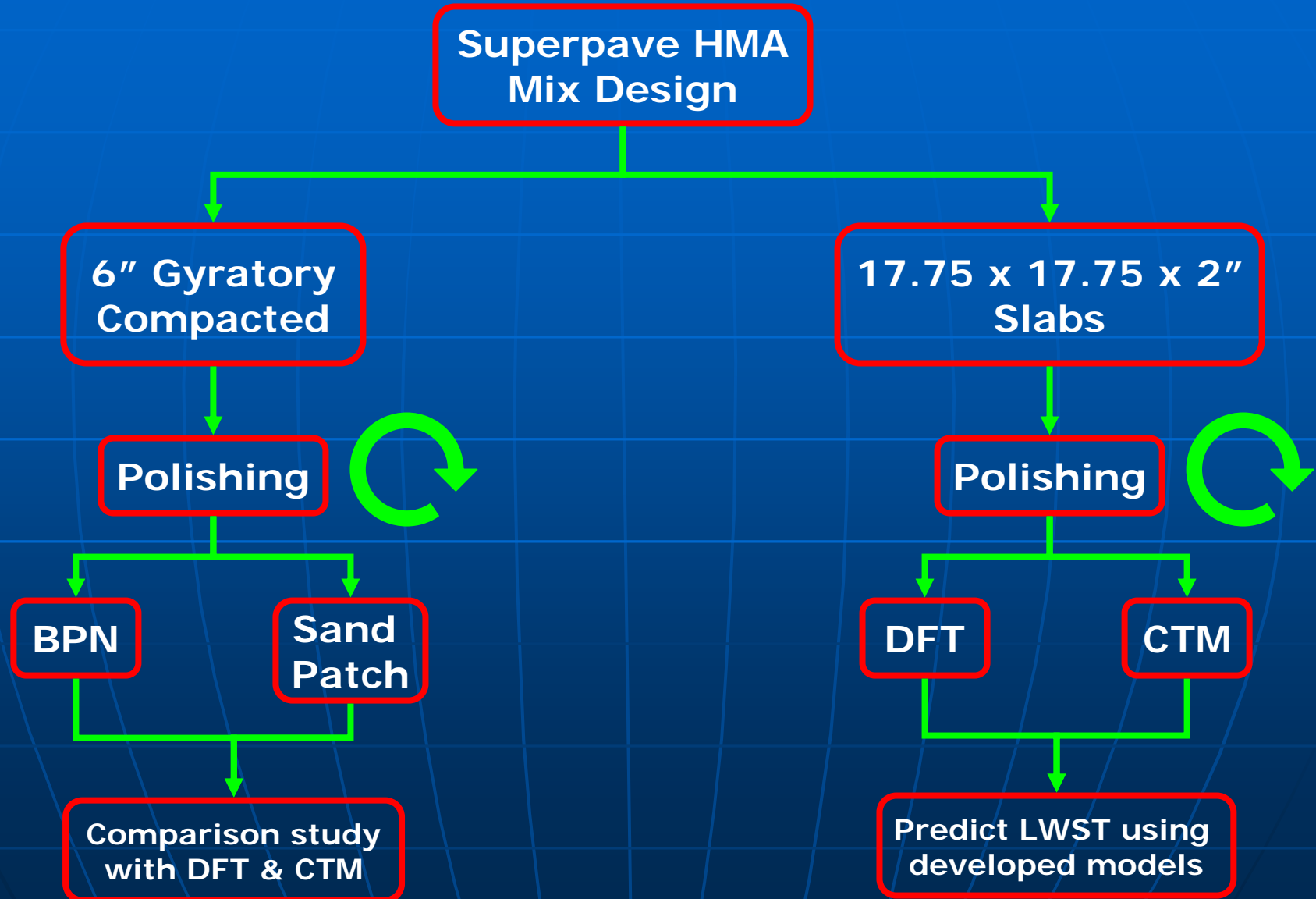


Blend 2

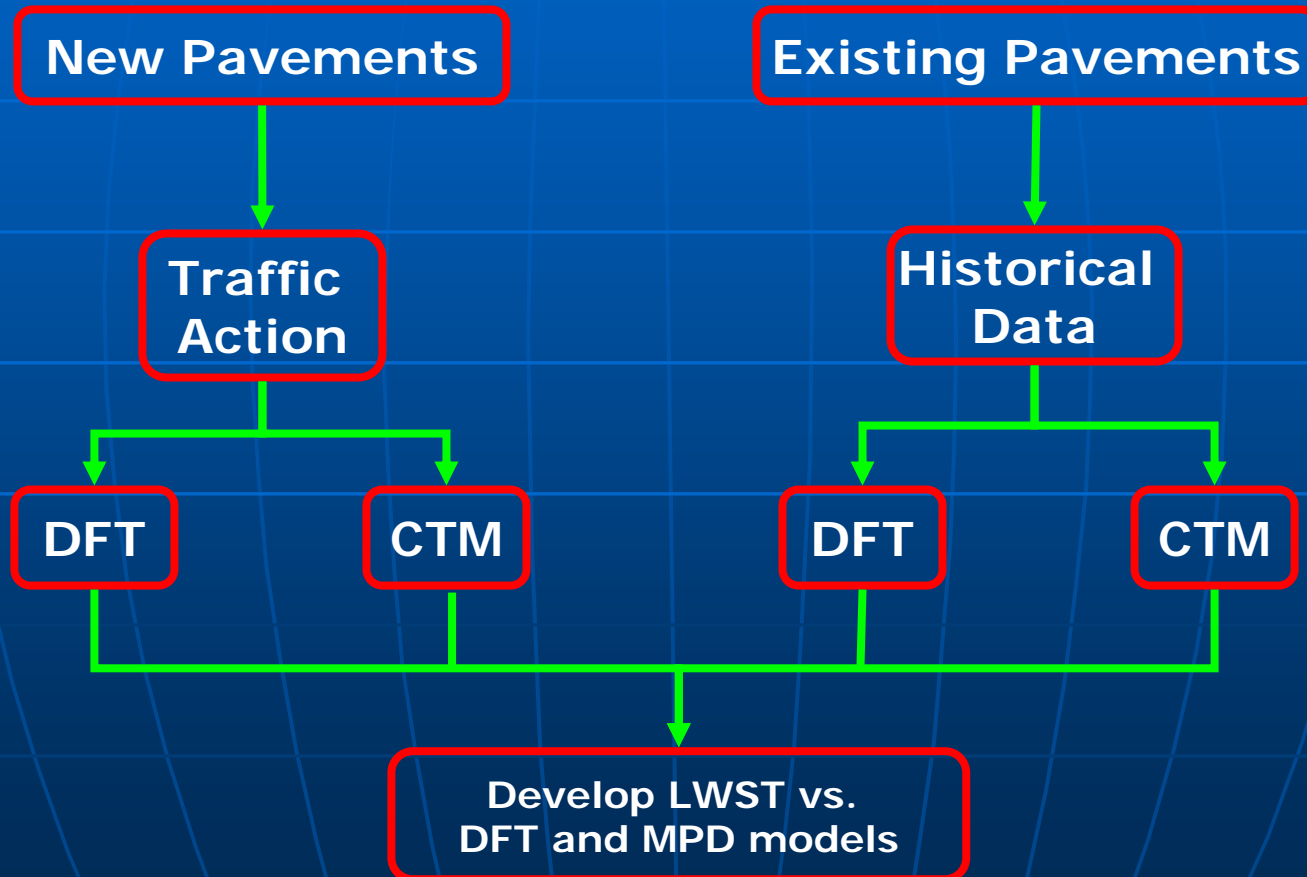
Objectives of Current Research

- Develop new accelerated polishing equipment for compacted HMA specimens.
- Develop a complete test protocol and Recommend specifications for the new test methods.

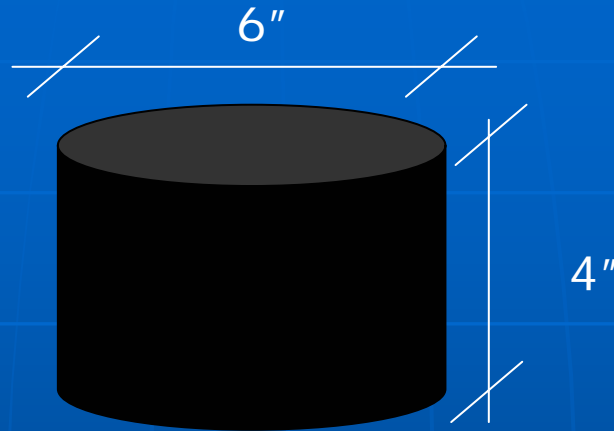
Test Sequence for Laboratory Prepared HMA Specimens



Test Sequence for Field HMA Pavements



Research Equipment

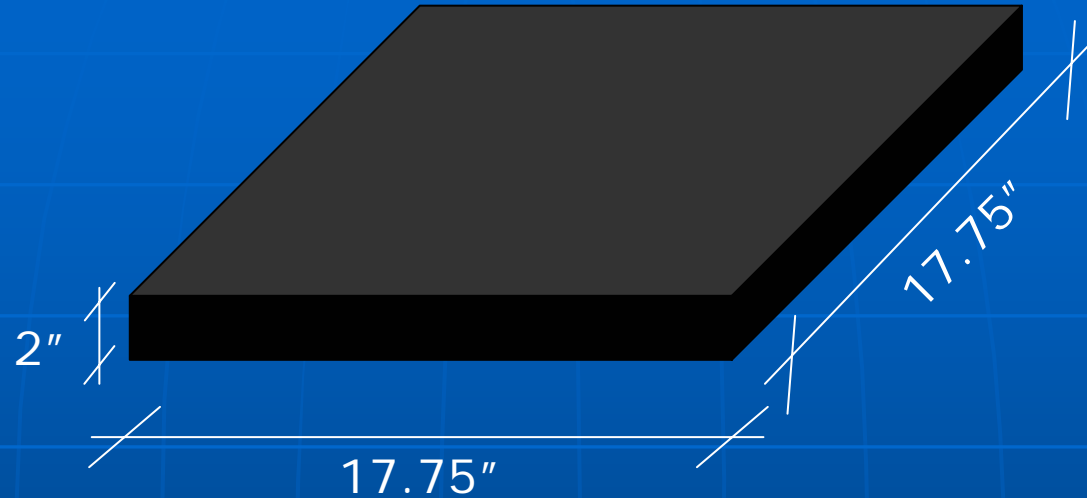


British Pendulum Tester



Sand Patch Method

Research Equipment

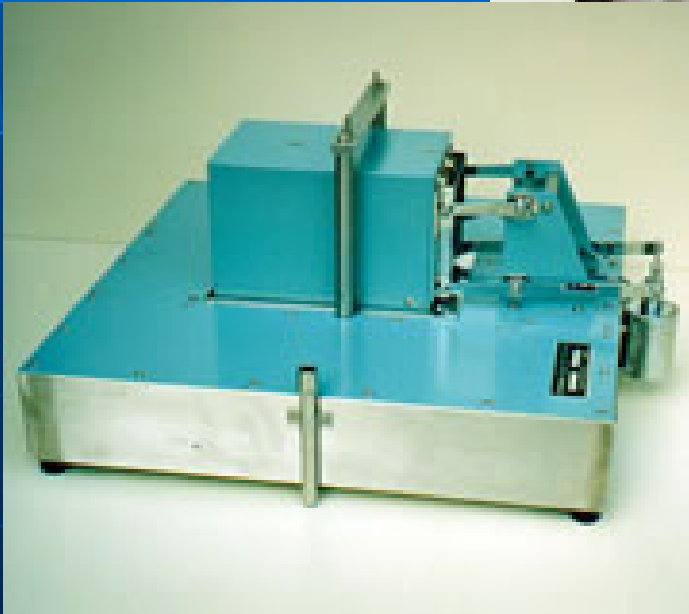


Dynamic Friction Tester



Circular Texture Meter

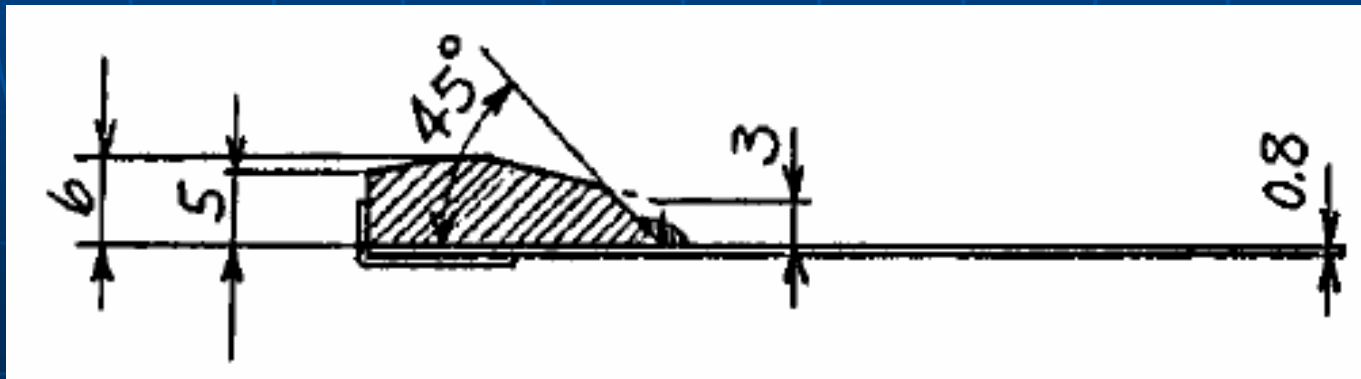
D.F. Tester



D.F. Tester

Sliders:

1. 0.25" x 0.63" x 0.79"
2. Synthetic rubber specified in ASTM E 501
3. Contact pressure = 21.5 psi
4. Hardness = 58



Circular Texture Meter (C.T.Meter)

Laser displacement sensor:

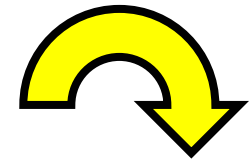
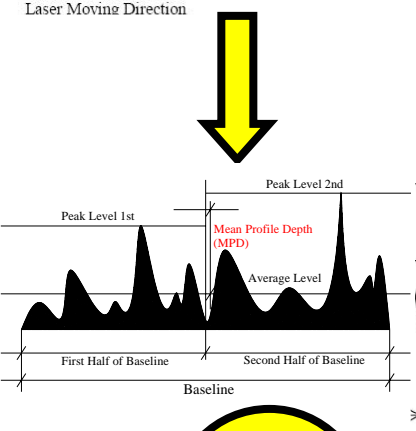
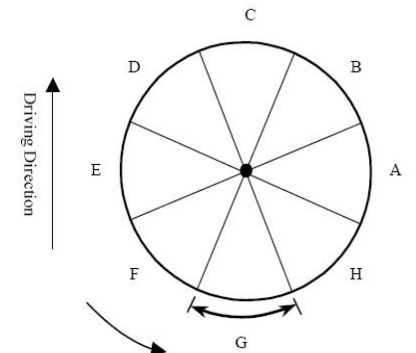
1. Spot size = $70\text{ }\mu\text{m}$ over a range of 65 to 90 mm



Picture-1 General View of Circular Texture Meter (CTM)

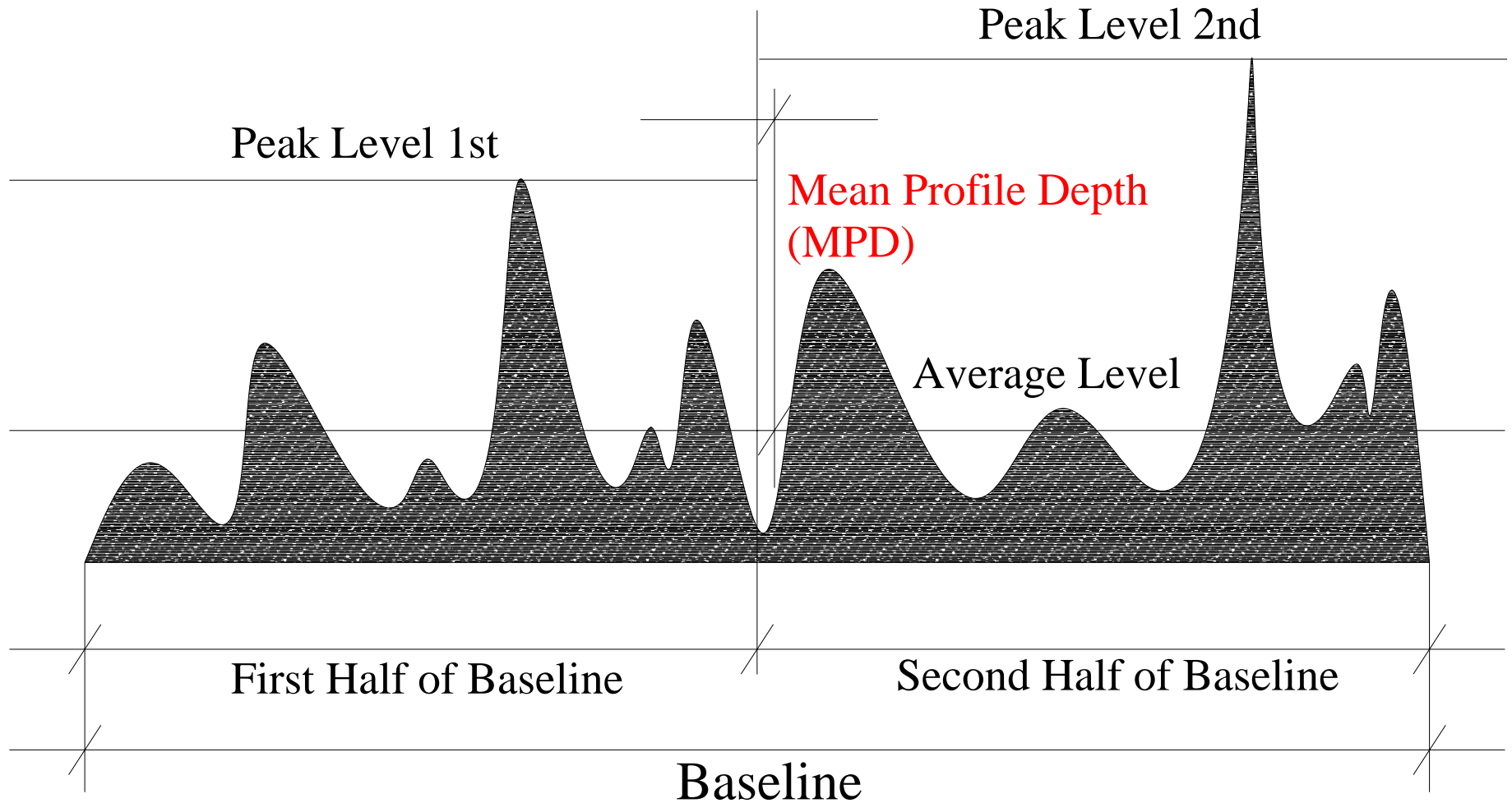


Picture-2 Laser Displacement Sensor of CTM

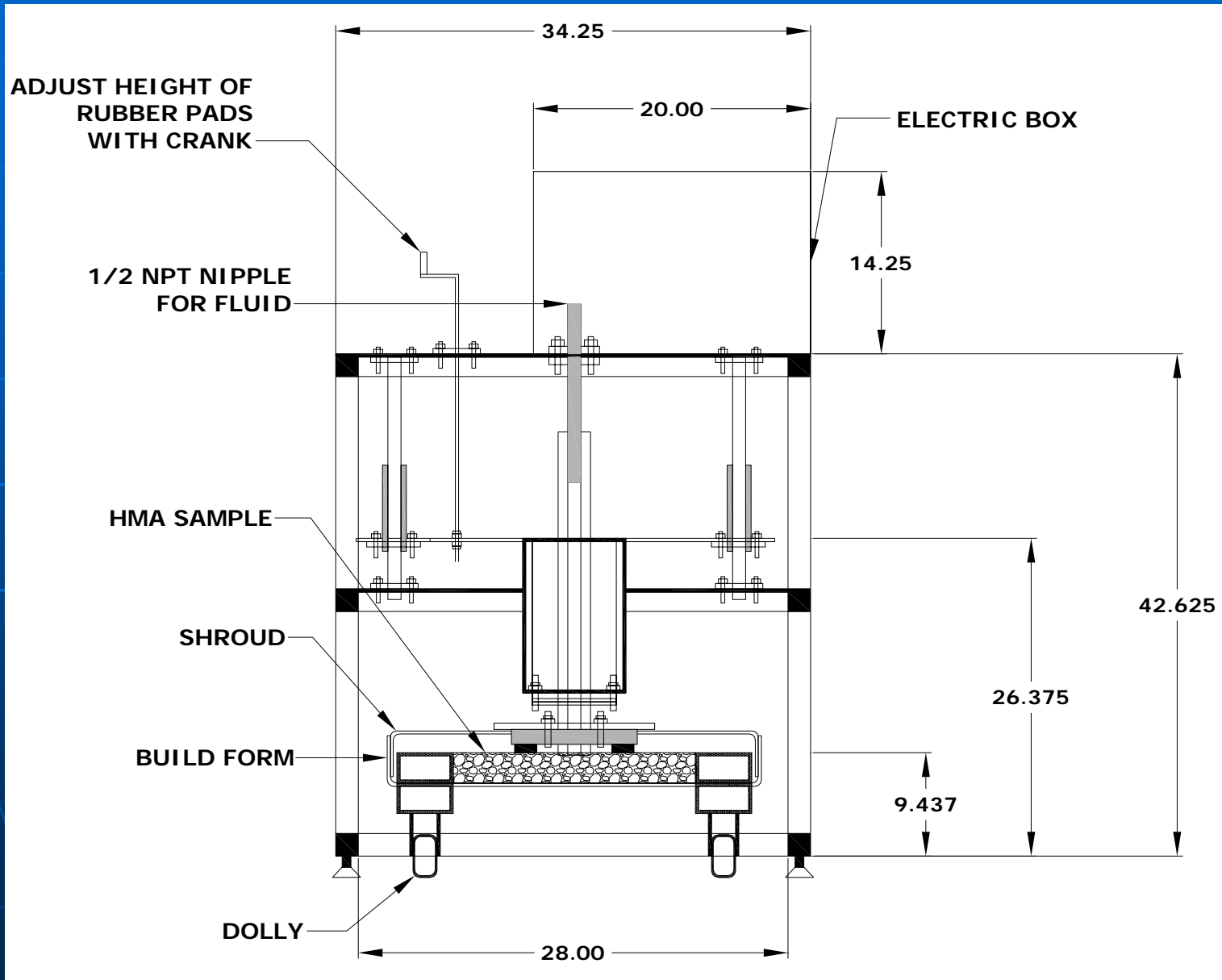


NEXT SLIDE

MPD Determination



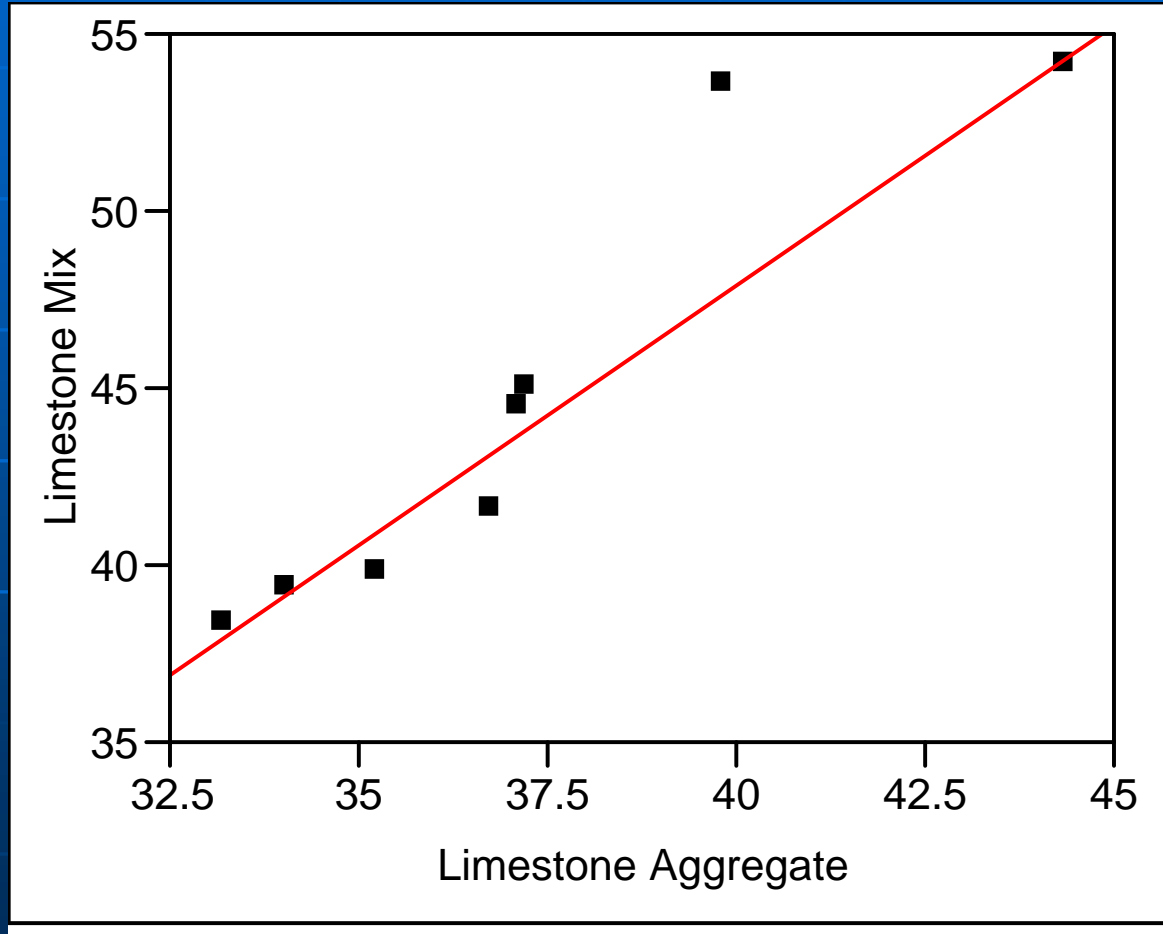
Rubber-Shoe Asphalt Polisher



Rubber-Shoe Asphalt Polisher

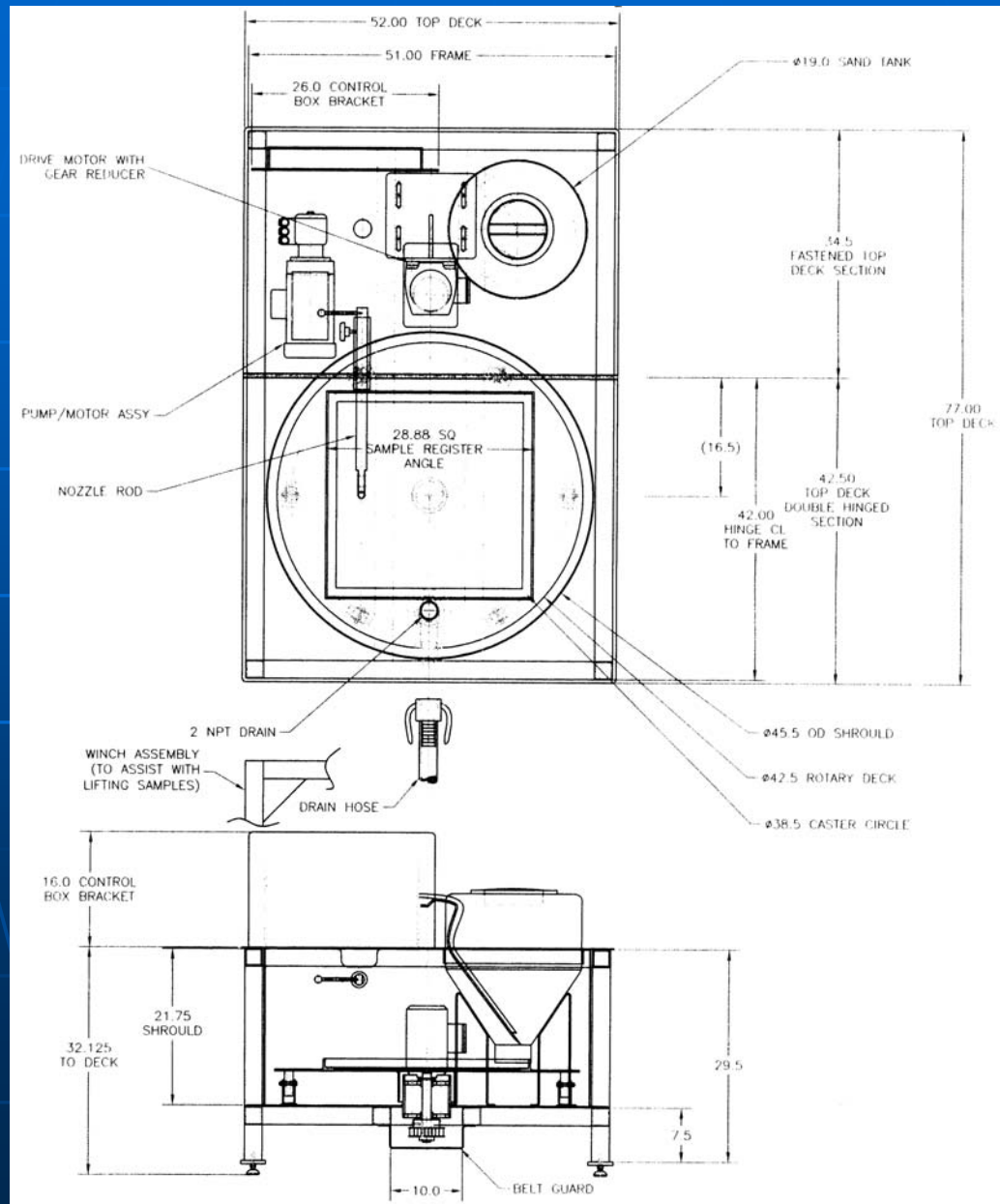


Correlation between HMA and Aggregate Friction



$$\text{Limestone Mix} = -10.70994 + 1.4647635 \text{ Limestone Aggregate}$$
$$R^2 = 97\%$$

Water-Pressure Asphalt Polisher



Water-Pressure Asphalt Polisher



Field Correlation Study

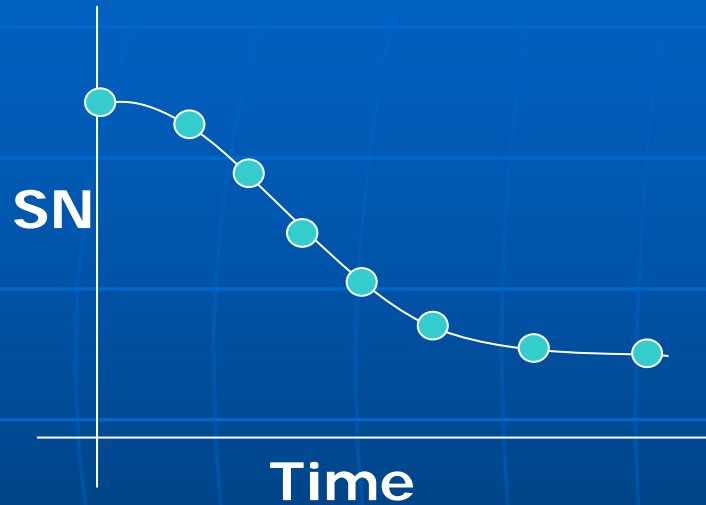


ODOT LWST

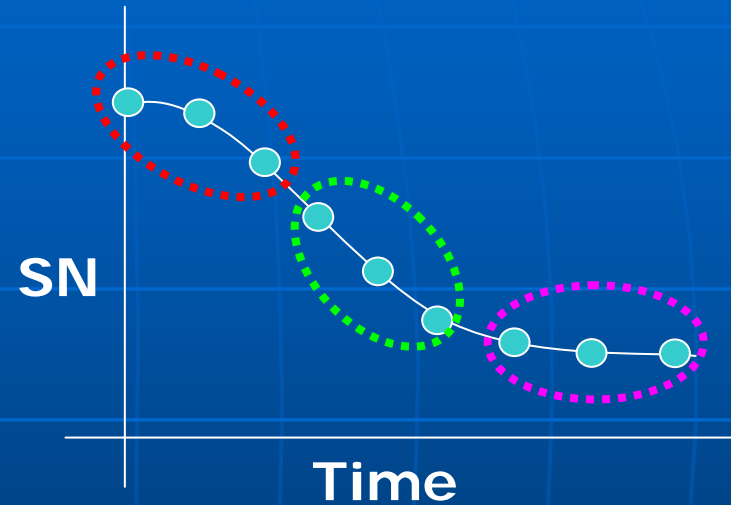


UA DFT

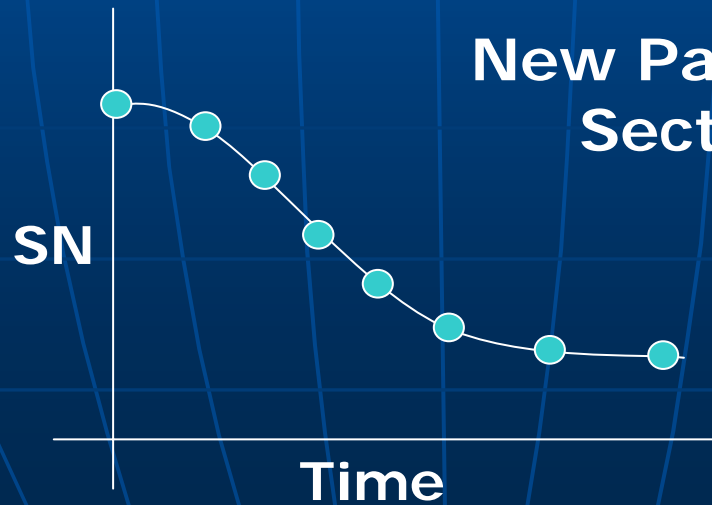
Polishing Equipment (Lab)



Existing Pavement Sections



New Pavement Sections



Existing Pavement Sections



- 64 Friction data points.
- 64 Texture data points.

Existing Pavement Sections

Polish Level	Stockpile	District (County)	Roadway	Route (Section)	Project	# of Data Points
Possible high Polish (Gravel)	Chesterhill @ Stockport (Shelly)	10 (Washington)	2-Lane	7(37.3- 39.0)	99-98	8
Possible medium Polish (Limestone)	Hanson (Sandusky Crushed) @ Parkertown	3 (Huron)	2-Lane	250(3.55 -5.11)	401-00	6
Possible medium Polish (Dolomite)	Stoneco @ Maumee	2 (Wood)	4-Lane	25(15.68 -22)	22-03	40
Possible low Polish (Gravel)	Martin Marietta @ Apple Grove	11 (Harrison)	2-Lane	250(22.5 -25.5)	460-04	10

Existing Pavement Sections

District (County)	Date LWST DFT	Temp. (°F) LWST DFT
10 (Washington)	09/20/60	60
	10/25/06	51
3 (Huron)	08/15/06	75
	10/30/06	63
2 (Wood)	10/08/06	70
	10/18/06	64
11 (Harrison)	5/24/06	55
	11/01/06	50

Field Measurements



Field Measurements



Field Measurements



Field Measurements



Field Measurements



Field Measurements



Field Measurements



Sample Field Results (DFT)

Project Name

Measurement Site

Weather

Date

Memo

2006 / 10 / 25

Time 12 : 47

Measurement Location

Pavement Surface Type

Moving Average

Operator

10

Frequency

1

File Name

3890

Control Number

1

out of

1

Runs

2

Coefficient of Friction at

15 km/h

30 km/h

45 km/h

60 km/h

0

0.625

0.619

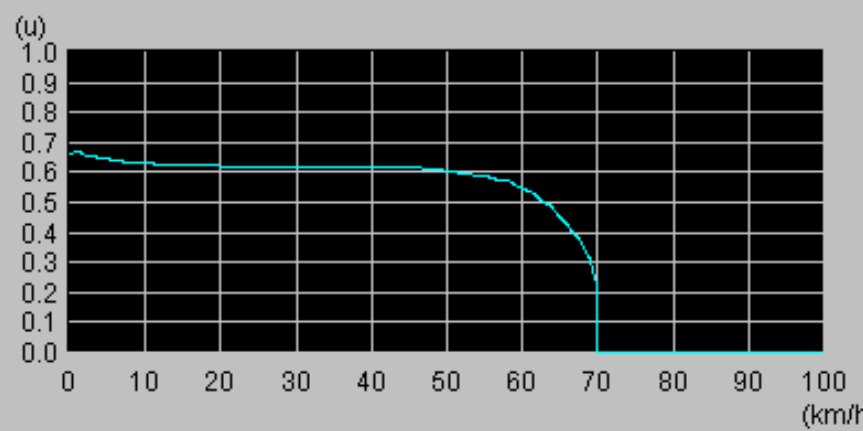
0.617

0.545

0.662

Measurement Result

Smoothed Data



Speed (km/h)	Coefficient of Friction (u)
0	0.65
10	0.64
20	0.63
30	0.62
40	0.61
50	0.60
60	0.55
70	0.00

Scale: S1 S2 S3

Graph Setup

<

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Smoothing

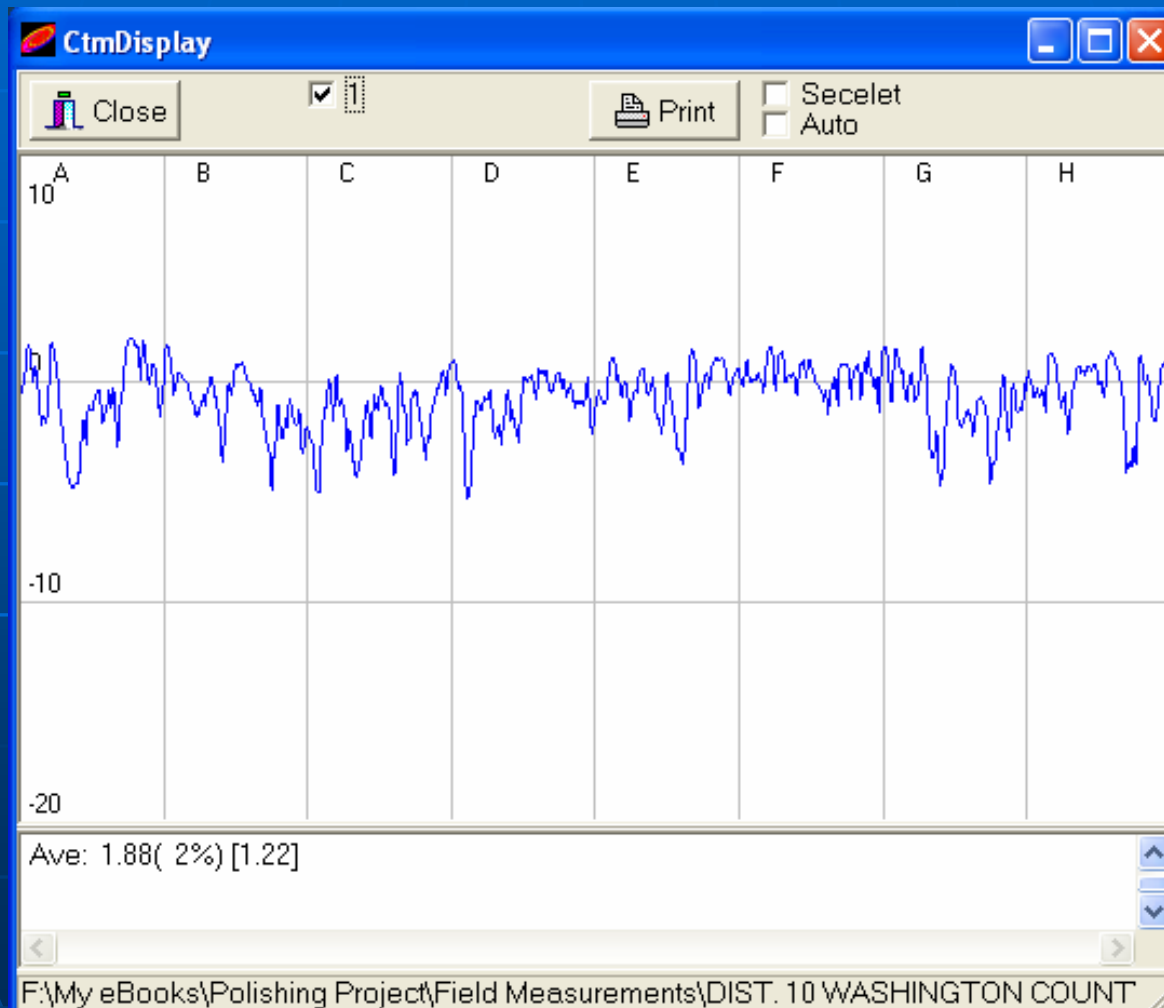
Load

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Sample Field Results (CTM)



Simple Linear Regression Models

Correlation Between	Model	R ² (%)
LWST vs. DFT Lime. + Gravel	$\text{LWST} = -14.49194 + 1.3941664 \text{ DFT}$	70.1
LWST vs. DFT Lime.	$\text{LWST} = -24.98032 + 1.6529471 \text{ DFT}$	64
LWST vs. DFT Gravel	$\text{LWST} = -19.40053 + 1.4582797 \text{ DFT}$	76.1
LWST vs. MPD	$\text{LWST} = 43.033601 + 8.7581079 \text{ MPD}$	22.7

Transformed Models

Correlation Between	Model	R ² (%)
LWST vs. DFT Lime. + Gravel	$\text{Sqrt}(\text{LWST}) = 2.2667266 + 0.1034807 \text{ DFT}$	70.5
LWST vs. DFT Lime.	$\text{Recip}(\text{LWST}) = 0.0576172 - 0.0008248 \text{ DFT}$	69.3
LWST vs. DFT Gravel	$\text{Square}(\text{LWST}) = -4813.828 + 154.20911 \text{ DFT}$	78.7
LWST vs. MPD	$\text{Square}(\text{LWST}) = 967.37705 + 1827.2516 \text{ Sqrt}(\text{MPD})$	25

Multiple Linear Regression Models using DFT & CTM

Model	R^2 (%)	$(R^2)_a$ (%)
LWST = -17.214+1.4943 DFT-2.438 MPD	71.1	70.2

IFI Determination

- Permanent International Association of road Conference (PIARC) Outcome
- Friction Measurement & Macrotexture Measurement

$$S_p = a + b \times T_x^{(mm)}$$

Measured using
CTM

Measured using
DFT

$$F60 = A + B \times FRS \times e^{\frac{S-60}{S_p}} + C \times T_x^{(mm)}$$

- IFI is then reported as (F60, S_p)

ASTM E 1960

$$S_p = a + b \times T_x^{(mm)}$$

Tx Estimate	a	b
MPD (CTM)	14.2	89.7
MTD (Sand Patch)	-11.6	113.6

$$F60 = A + B \times FRS \times e^{\frac{S-60}{S_p}} + C \times T_x^{(mm)}$$

FRS Estimate	A	B	C
FN40R	-0.023	0.607	0.098
FN40S	0.045	0.925	0
DFT @ 40 mph	-0.034	0.771	0
DFT @ 12.5 mph	0.081	0.732	0

Multiple Linear Regression Models using IFI Parameters

Model	R^2 (%)	$(R^2)_a$ (%)
LWST = -18.542+1.8193 F60- .0022 SC	71.2	70.2

Conclusions

- Aggregate screening methods for identifying high polishing/low skid resistance aggregates with acceptance criteria have been developed.
- Blending has proven effective to increase residual friction values.

Conclusions

- Two prototype accelerated HMA polishing equipment have been developed.
- Aggregate is key controlling factor to HMA friction.
- SN by LWST is significantly correlated with SN by DFT.

Conclusions

- Predictive equation for LWST measured SN is developed based on IFI parameters (F60, SC).
- Predictive equation for LWST measured SN is developed based on DFT & CTM measured values.
- The last two findings enable us to link lab results with field data, thus allowing the establishment of acceptance criteria based on lab tests.



Thank You