Pavement Design Workshop Jan. 10, 2011

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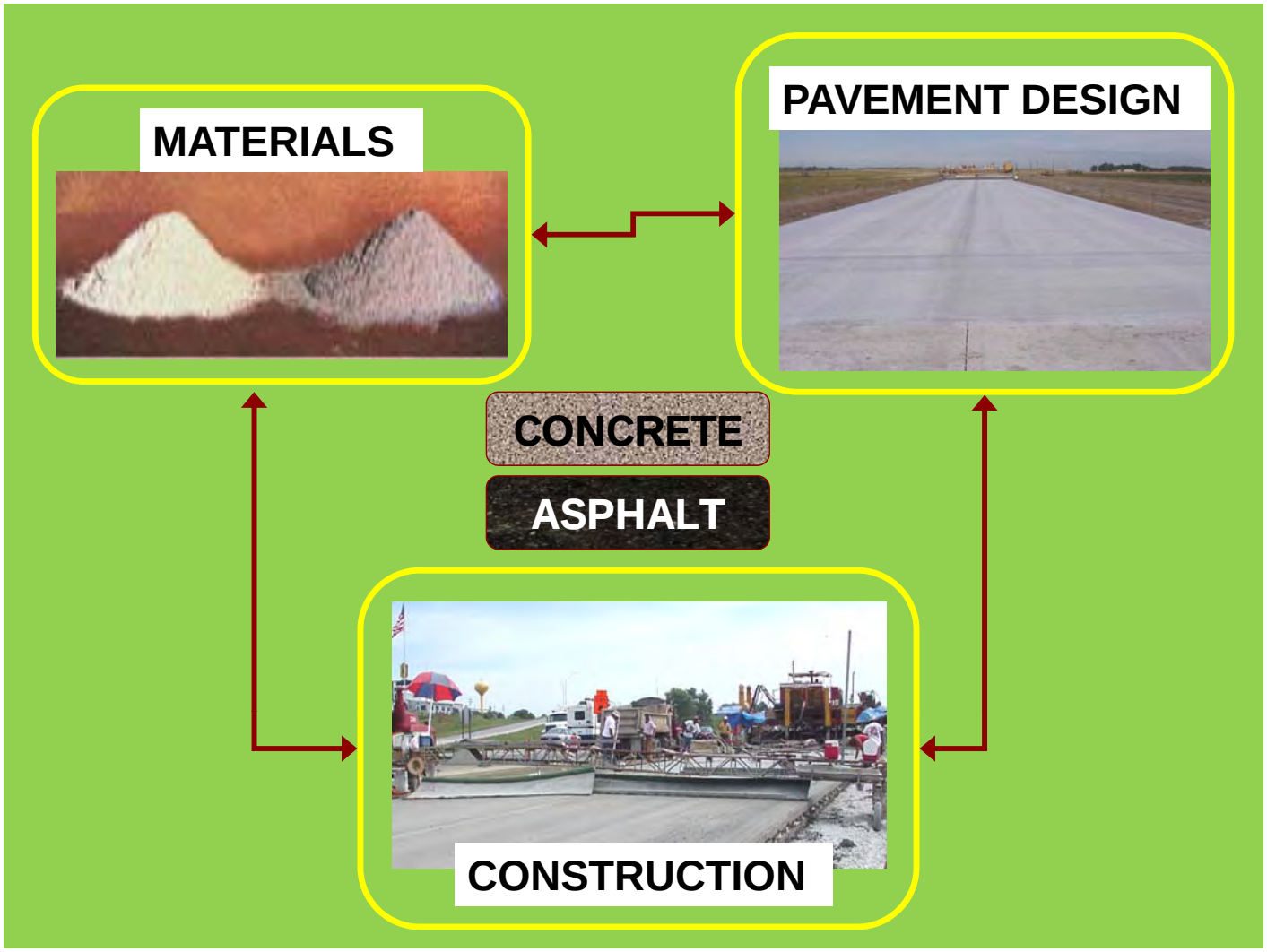
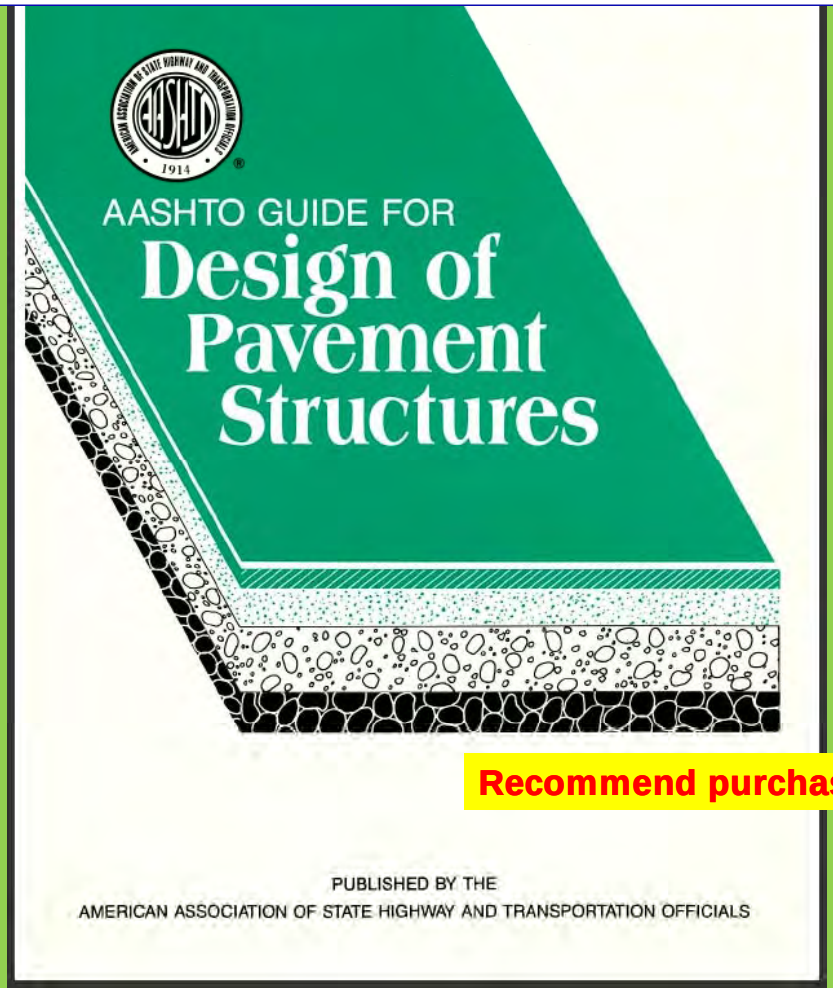

MATERIALS
PAVEMENT DESIGN
CONCRETE
ASPHALT
CONSTRUCTION

OUTLINE

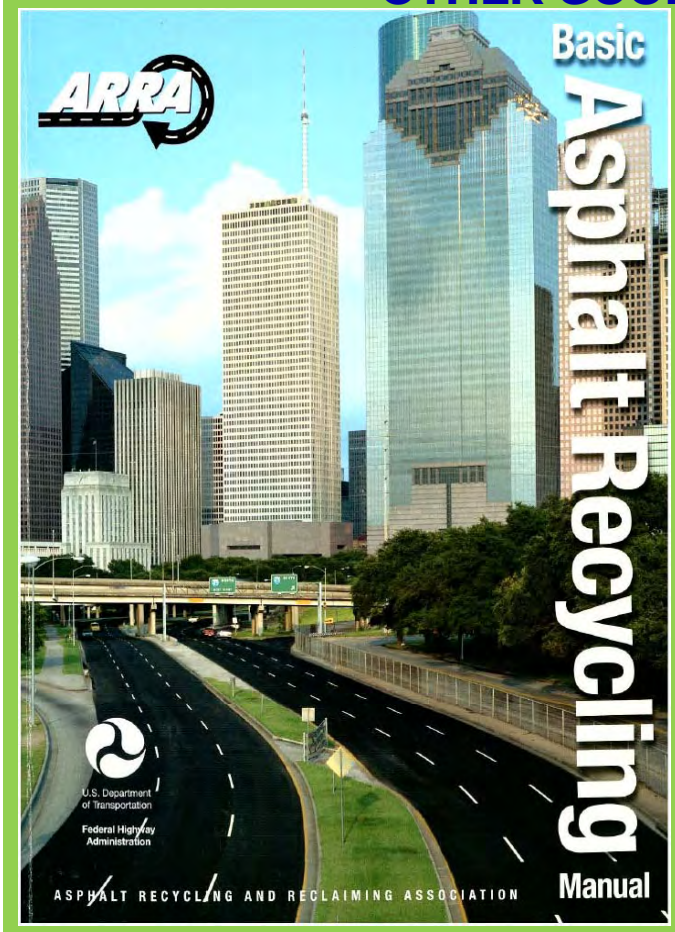
- Deliverables
- Subgrade
- Foundation Courses
- Pavement
  - Concrete (Rigid)
  - White Topping
  - Asphalt (Flexible)
  - Recycling
- Pavement Design
- Review Deliverables
- NDOR Pavement Design Manual
- Quick References
- Maintenance

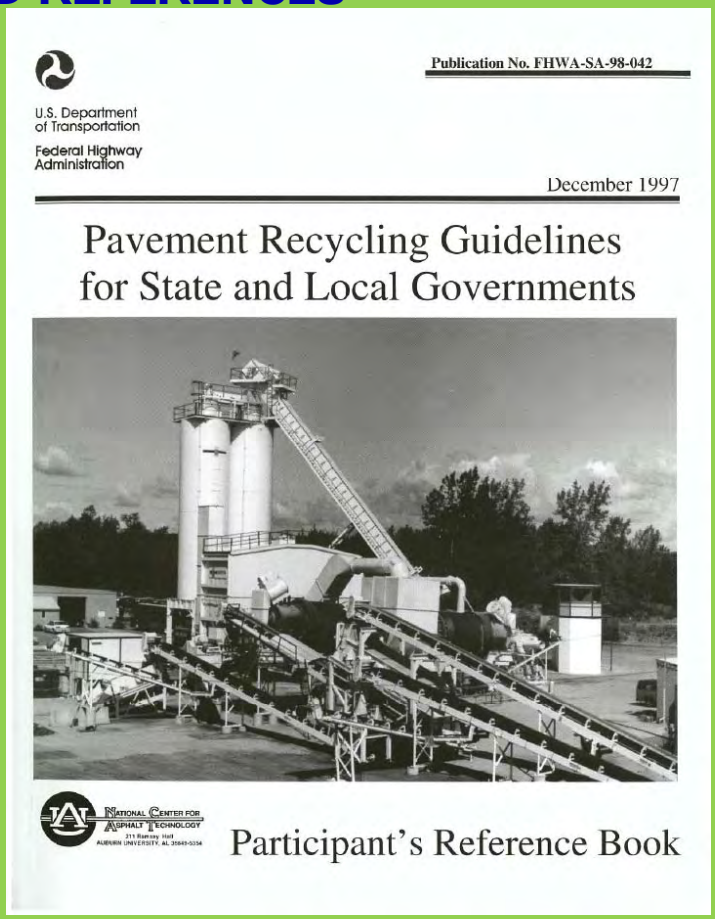
Class is based on the 1993 AASHTO procedure.



Recommend purchasing this book

OTHER GOOD REFERENCES





Deliverables

Pavement Determination Data Sheet

Project Name
Project No.
Control No.
Letting Date
Prepared by:

Scoping Information

Pavement Determination

Mainline-

Shoulder-

Patching-

Pavement History

Top Layer	
Intermediate	
Intermediate	
Base layer	
Subgrade	

Pavement Management System or Field visit Information

HMA	
Rutting (mm)	
Cracking (%)	
Rating	

PCC	
Cracking(%)	
Faulting	
Rating	

Cores

Location	Depth	Comments
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Soils	
Classification	
Optimum Modulus	
Wet Modulus	
Dry Modulus	
Frozen Modulus	

Traffic	
Current ADT	
20 yr Forecast ADT	
% Heavy trucks	
Predicted ESAL's	

Structure Number(HMA) or Thickness(PCC) Required for ESAL's	
Structure Number or Thickness Designed *(must ≥ required)*	

Pavement Determination Data Sheet

Project Name
Project No.
Control No.
Letting Date
Prepared by:

Scoping Information

Pavement Determination

Mainline-

Shoulder-

Patching-

Pavement History

Top Layer	
Intermediate	
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Base layer	
Subgrade	

Pavement Management System or Field visit Information

HMA	
Rutting (mm)	
Cracking (%)	
Rating	

PCC	
Cracking(%)	
Faulting	
Rating	

Cores

Location	Depth	Comments
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Soils	
Classification	
Optimum Modulus	
Wet Modulus	
Dry Modulus	
Frozen Modulus	

Traffic	
Current ADT	
20 yr Forecast ADT	
% Heavy trucks	
Predicted ESAL's	

Structure Number(HMA) or Thickness(PCC) Required for ESAL's	
Structure Number or Thickness Designed *(must ≥ required)*	

Flexible Design Inputs

Structural Number based off ESAL's

Use this method for New Build design or for establishing Required structure number for comparison to rehabilitation design.

Expected Performance Years	
No. Lanes	
% Trucks in Design Lane	
% Trucks in Design Direction	
Ave. Initial Truck Factor	
Annual Truck Factor Growth Rate	
Annual Truck Volume Growth Rate	
Growth Rate Method	
Intial Serviceability	
Terminal Serviceability	
Reliability Level	
Overall Standard Deviation	
Structure Number Required	

Use these inputs & the Flexible Pavement Nomograph (Figure 5.1, pg.II-12).

HMA Condition Survey Method (Rehabilitation)

Use this method for Rehabilitation of existing asphalt roadways or for alternative recycling strategies

Surface Course

Type		
Depth (D_1,inches)		
Layer Coefficient (a_1)		
Structure No. for Layer(SN_1)		$SN_1=D_1 \times a_1$

Base Layer

Type		
Depth (D_2,inches)		
Layer Coefficient(a_2)		
Drainage Coefficient(m_2)		
Structure No. for Layer(SN_2)		$SN_2=D_2 \times a_2 \times m_2$

Sub-Base Layer

Type		
Depth (D_3,inches)		
Layer Coefficient(a_3)		
Drainage Coefficient(m_3)		
Structure No. for Layer(SN_3)		$SN_3=D_3 \times a_3 \times m_3$

Total Structure Provided ($SN_1 + SN_2 + SN_3 + ..$)

Add or subtract layers as needed

Comments:

Flexible Design Inputs

Structural Number based off ESAL's	
Expected Performance Years	
No. Lanes	
% Trucks in Design Lane	
% Trucks in Design Direction	
Ave. Initial Truck Factor	
Annual Truck Factor Growth Rate	
Annual Truck Volume Growth Rate	
Growth Rate Method	
Intial Serviceability	
Terminal Serviceability	
Reliability Level	
Overall Standard Deviation	
Structure Number Required	

Use this method for New Build design or for establishing Required structure number for comparison to Rehabilitation design.

Use these inputs & the Flexible Pavement Nomograph (Figure 3.1, pg.II-32)

HMA Condition Survey Method (Rehabilitation)

Use this method for Rehabilitation of existing asphalt roadways or for Bituminous Recycling Strategies

Surface Course		
Type		
Depth (D_1,inches)		
Layer Coefficient (a_1)		
Structure No. for Layer(SN_1)		$SN_1=D_1 \times a_1$
Base Layer		
Type		
Depth (D_2,inches)		
Layer Coefficient(a_2)		
Drainage Coefficient(m_2)		
Structure No. for Layer(SN_2)		$SN_2=D_2 \times a_2 \times m_2$
Sub-Base Layer		
Type		
Depth (D_3,inches)		
Layer Coefficient(a_3)		
Drainage Coefficient(m_3)		
Structure No. for Layer(SN_3)		$SN_3=D_3 \times a_3 \times m_3$
Total Structure Provided ($SN_1 + SN_2 + SN_3$+...)		

Add or Subtract Layers as needed

Comments:

Rigid Design Inputs

Thickness based off ESAL's

Use this method for New Build design or for establishing Residual thickness for conversion to Rehabilitation design.

Expected Performance Years _____
No. lanes _____
% Trucks in Design Lane _____
% Trucks in Design Direction _____
Ave. Initial Truck Factor _____
Annual Truck Factor Growth Rate _____
Annual Truck Volume Growth Rate _____
Growth Rate Method _____
Intial Serviceability _____
Terminal Serviceability _____
28-Day Mean PCC Modulus Rupture _____
28-day Mean PCC Elastic Modulus of Slab _____

Base Type _____
Base Thickness _____
Depth to Bedrock _____
Project Slab Thickness _____
Loss of Support _____
Reliability Level _____
Overall Standard Deviation _____
Load Transfer Coefficient _____
Drainage Coefficient _____

Thickness Required (D_r) [ ]

Use these inputs & the Rigid Pavement Nomograph (Figure 3-7, pg. 45)

PCC Condition Survey Method (Rehabilitation)

Use for Rehabilitation of HMA overlay for existing concrete roadways

$$D_{ovl} = A\left(D - D_{eff}\right)$$

$$A = 2.2231 - 0.0099\left(D - D_{eff}\right)^2 + 0.1537\left(D - D_{eff}\right)$$

$$D_{eff} = F_{jc} \times F_{fat} \times F_{dur}$$

Definitions:
D_{ovl} = HMA overlay thickness (inches)
D = PCC required thickness (inches) based on ESAL's
D_{eff} = Condition Survey or Factor of existing PCC as thickness (inches)
A = Conversion number for PCC to HMA
F_{jc} = Joint & Crack adjustment factor (1.0 - 0.5)
F_{fat} = Fatigue Damage adjustment factor (1.0 - 0.8)
F_{dur} = Durability Factor (1.0 - 0.8)

F_{jc} = _____
F_{fat} = _____
F_{dur} =
D_{eff} =

A= [ ]

D_{ovl} = [ ]

Comments:

Rigid Design Inputs

Thickness based off ESAL's

Use this method for New Build design or for establishing Required thickness for comparison to Rehabilitation design.

Expected Performance Years		Base Type	
No. lanes		Base Thickness	
% Trucks in Design Lane		Depth to Bedrock	
% Trucks in Design Direction		Project Slab Thickness	
Ave. Initial Truck Factor		Loss of Support	
Annual Truck Factor Growth Rate		Reliability Level	
Annual Truck Volume Growth Rate		Overall Standard Deviation	
Growth Rate Method		Load Transfer Coefficient	
Intial Serviceability		Drainage Coefficient	
Terminal Serviceability			
28-Day Mean PCC Modulus Rupture		Thickness Required (D_r)	
28-day Mean PCC Elastic Modulus of Slab			

Use these inputs & the Rigid Pavement Nomograph (Figure 3.7, pg.II-45)

PCC Condition Survey Method (Rehabilitation)

Use for Rehabilitation(HMA overlay) for existing concrete roadways

$$D_{ovl} = A\left(D_r - D_{eff}\right)$$

$$A = 2.2233 + 0.0099\left(D_r - D_{eff}\right)^2 - 0.1534\left(D_r - D_{eff}\right)$$

$$D_{eff} = F_{jc} \times F_{fat} \times F_{dur}$$

Definitions:

D_{ovl} = HMA overlay thickness (inches)
D_r = PCC required thickness (inches) based on ESAL's
D_{eff} = Condition Survey or Factor of exsting PCC as thickness (inches)
A= Conversion number for PCC to HMA
F_{jc} = Joint & Crack adjustment factor (1.0 - 0.5)
F_{fat} = Fatigue Damage adjustment factor(1.0 - 0.9)
F_{dur} =Durability Factor (1.0 - 0.8)

F_{jc}=	
F_{fat}=	
F_{dur}=	
D_{eff} =	

A=	

D_{ovl}=	

Comments:

OUTLINE

- Deliverables
- **Subgrade**
  - **Subgrade Preparation**
  - **Subgrade Stabilization**
  - **Classification & Modulus**
- Foundation Courses
  - Stability
  - Types
  - Drainage
- Pavement
  - Concrete (Rigid)
    - Cement
    - ASR
    - Joints
    - PCC Construction
  - White Topping & PCC Overlays
    - UltraThin
    - Conventional

Let’s Begin

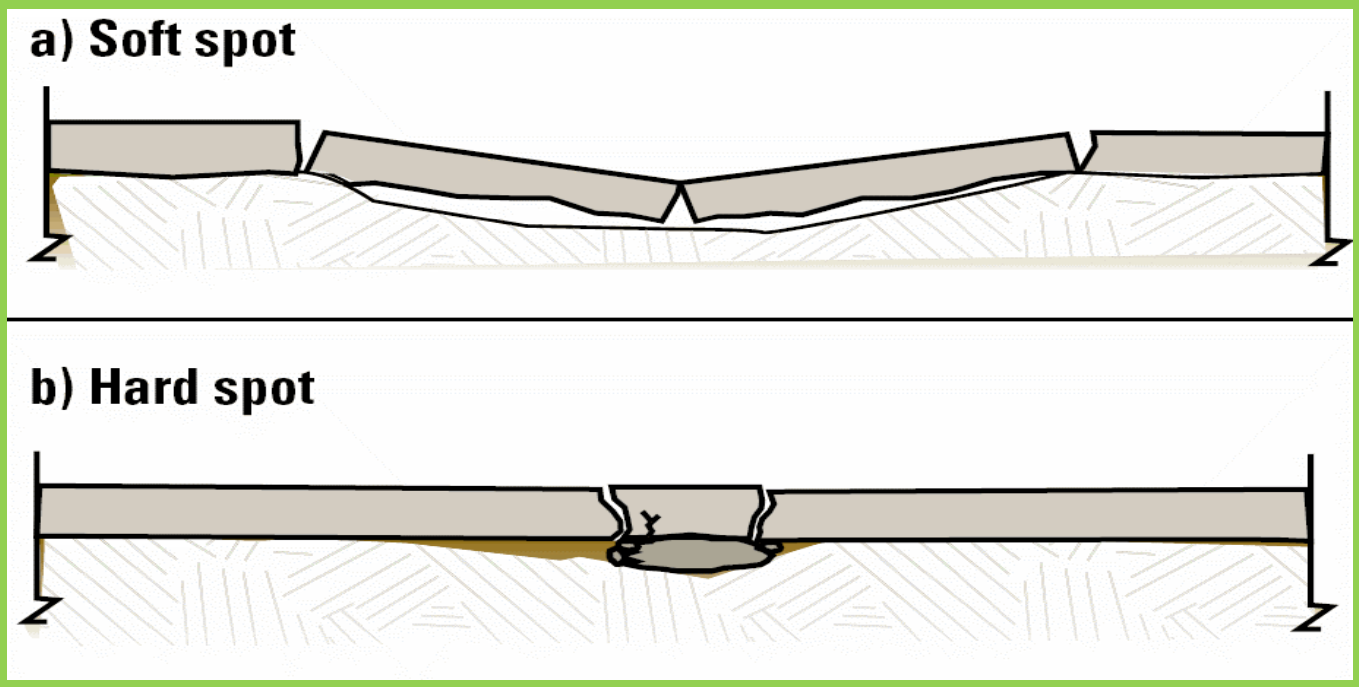
Subgrade Preparation

Standard processing depth is 6”

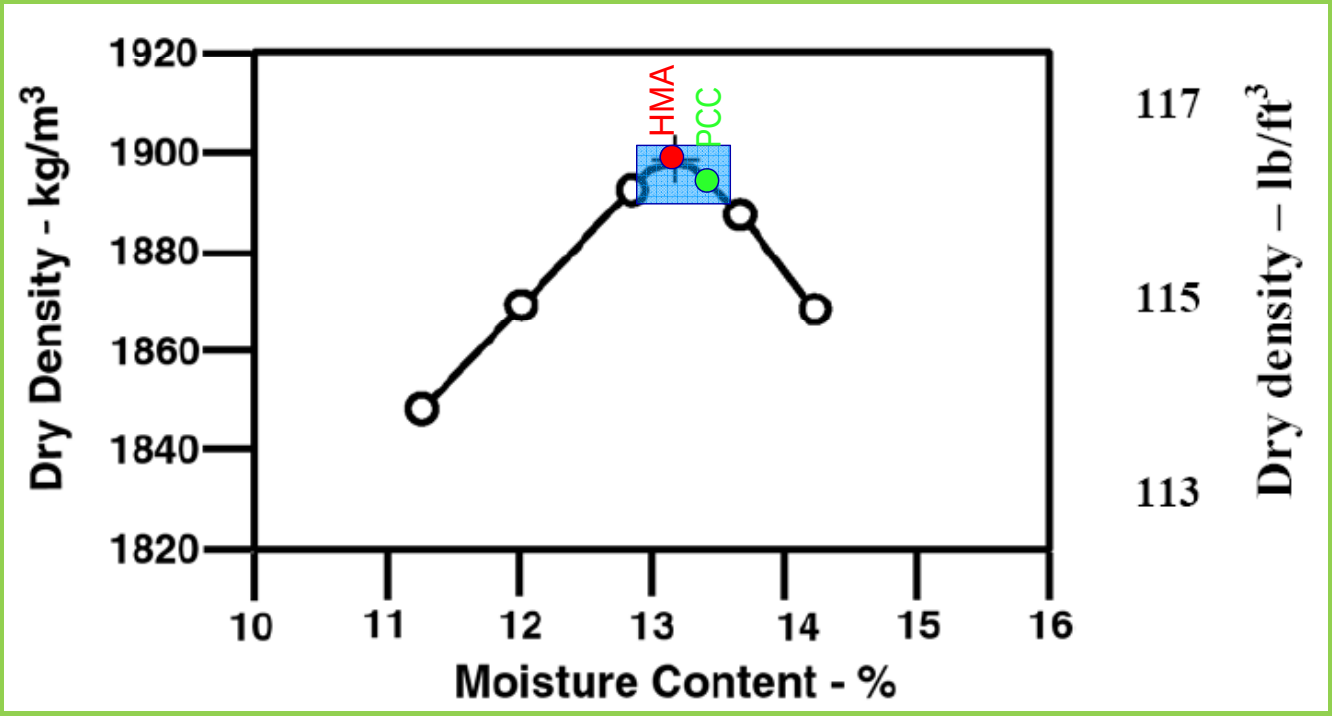
Water is incorporated to obtain the proper density

COHESIVE SUBGRADE

Subgrade Preparation



Subgrade Preparation



Compaction Table

Class III (See Specifications)

	SOIL TYPE	DEPTH BELOW FINISH SUBGRADE	PERCENT DENSITY	MOISTURE REQUIREMENTS MINIMUM	MOISTURE REQUIREMENTS MAXIMUM
Embankment / Roadway Grading, including driveways, to receive concrete pavement	Silt-Clay	Upper 3 feet	98 Min.	Opt. -3%	Opt. +2%
	Silt-Clay	At depths greater than 3 feet	95 Min.	Opt. -3%	Opt. +2%
	Granular	All depths	100 Min.	**	**
Embankment / Roadway Grading, including detours, temporary roads, and driveways, to receive flexible pavement	Silt-Clay	Upper 3 feet	100 Min.	Opt. -2%	Opt. +1%
	Silt-Clay	At depths greater than 3 feet	95 Min.	Opt. -3%	Opt. +2%
	Granular	All depths	100 Min.	**	**
Embankment / Roadway Grading to receive gravel surfacing	All	All depths	95 Min.	**	**
Embankment / Roadway Grading not to be surfaced, and Noise Wall Berm	All	All depths	95 Min.	Opt. -3%	Opt. +2%

Surcharge Height =	5'					
Upper	4'	All	- -	Class II	(See Specifications)	
Lower	1'	Silt-Clay	- -	100 Min.	Opt. -2%	Opt. +1%
		Granular	- -	100 Min.	**	**

Subgrade Preparation

Pay Items

- **Subgrade Preparation**
  - **Typically paid by the STATION**
  - **For small or unusual areas paid by SQUARE YARD**
- **Water**
  - **Paid by the MGALLON (1000 gallons)**

COHESIVE SUBGRADE

8430

11 1:44PM

Rubber Balloon Method ASTM D-2167

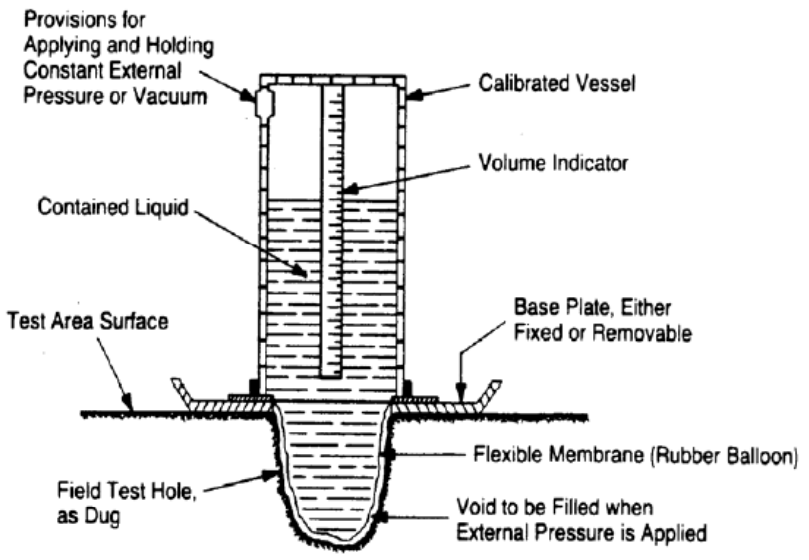
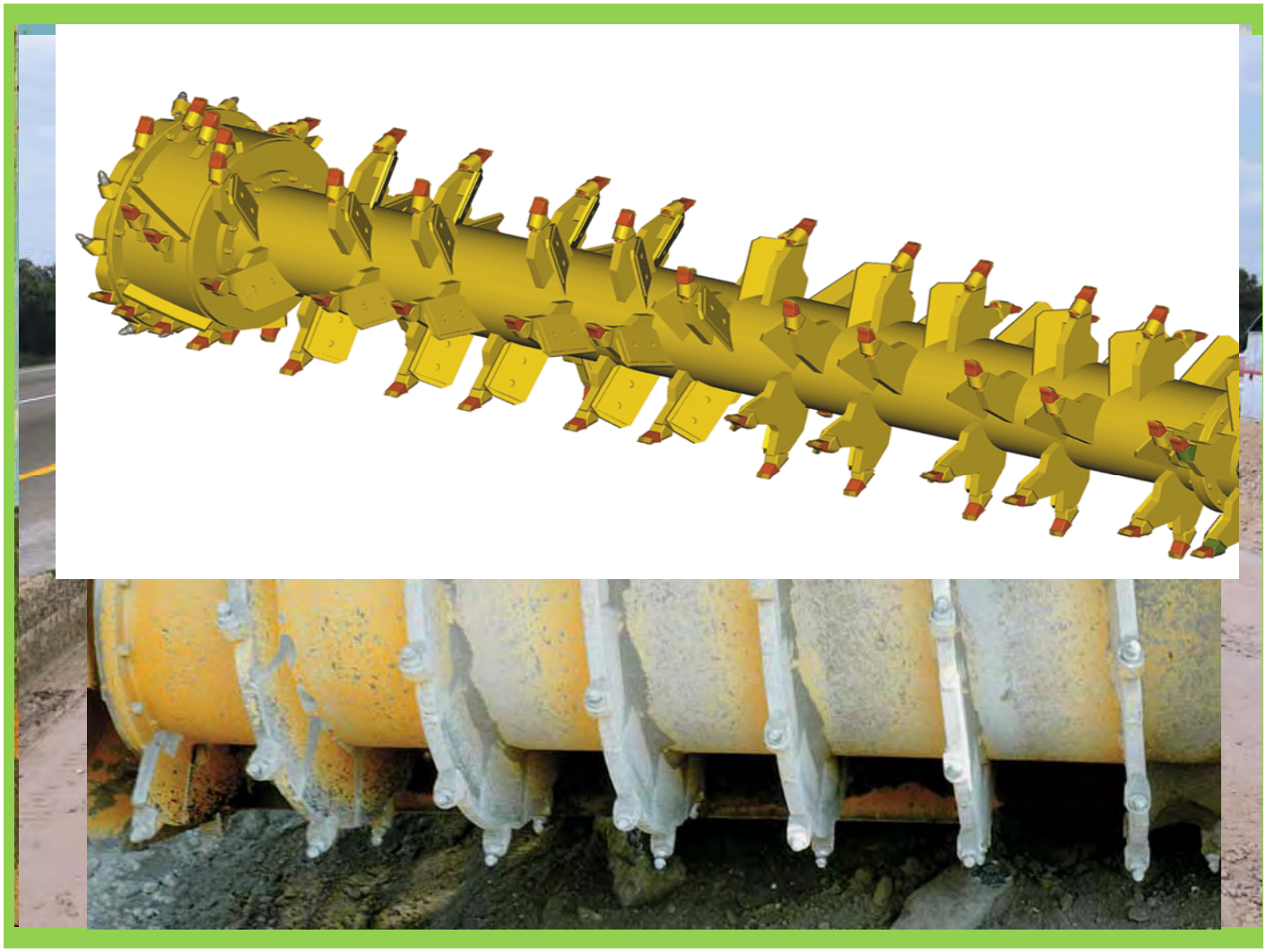
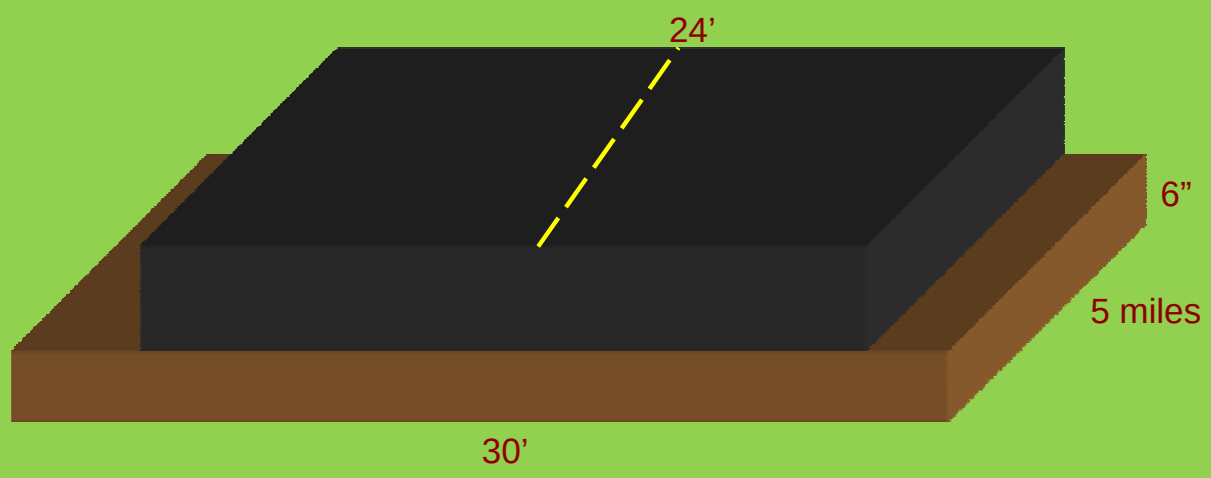


Figure 1 – Schematic Drawing of Calibrated Vessel Indicating Principle

200



Subgrade Preparation



Uniform pavement width 24’

5 miles x 5280’ = 26,400’ / 100’ = 264 Stations Subgrade Prep

264 Sta x 1.0 MGal/Sta = 264 MGal of water

3-foot extra width

Sandy Soils

Subgrade Stabilization

Standard processing depth is 6”

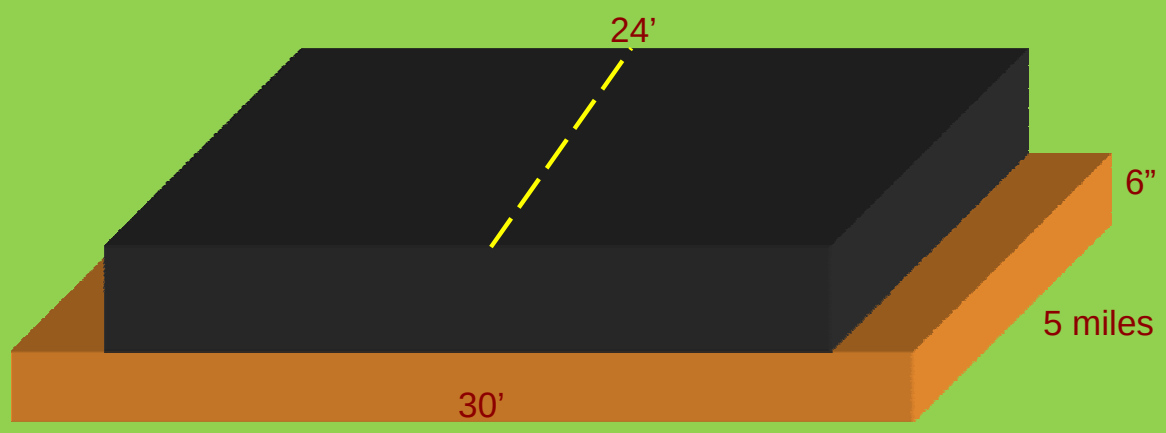
Water & Cohesive soil are incorporated into the sand.

Subgrade Stabilization

Non-Cohesive (sand)

Cohesive (clay)

Subgrade Stabilization



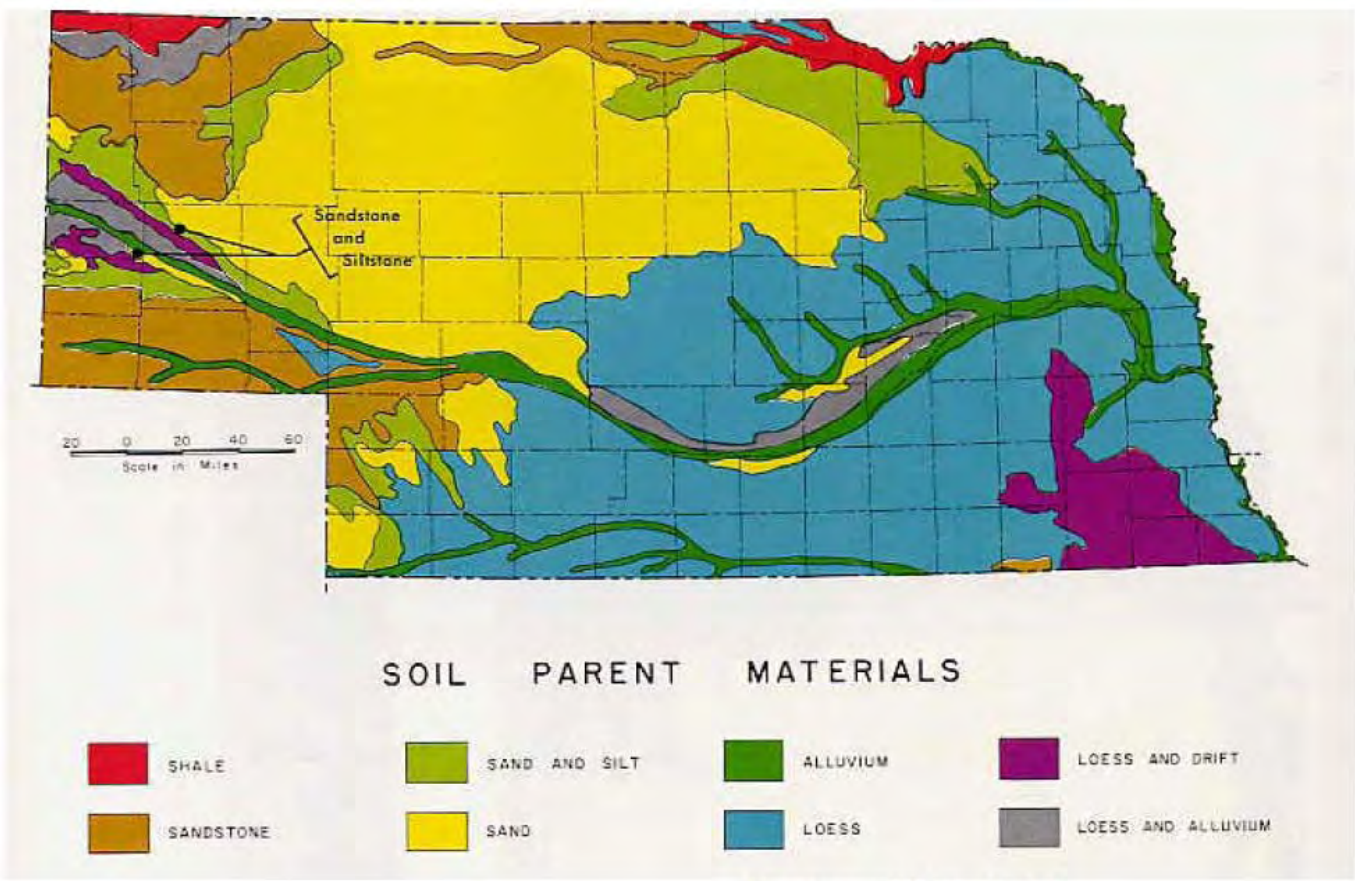
Uniform pavement width 24’

5 miles x 5280’ = 26,400’ / 100’ = 264 Stations Subgrade Stabilization

264 Sta x 1.0 MGal/Sta = 264 MGal of water

264 Sta x 12.5yd^3/Sta = 3300 yd^3 of Soil Binder (30’ wide)

Classification & Modulus



(Source: Elder, 1969)

SITE INVESTIGATION

Classification & Modulus

Inputs for NGI **(Nebraska Group Index)**:

Liquid Limit (LL) – Moisture content where soil goes from Plastic to Liquid.

Plastic Limit (PL) – Moisture content where soil goes from Semi-Solid to Plastic.

Plastic Index (PI) – Range in moisture content between Liquid and Plastic limits.

Percent (%) Retained on
#10 Sieve
#40 Sieve
#200 Sieve

Classification & Modulus

Example Soil:
LL=50
PI=26
#200=50%

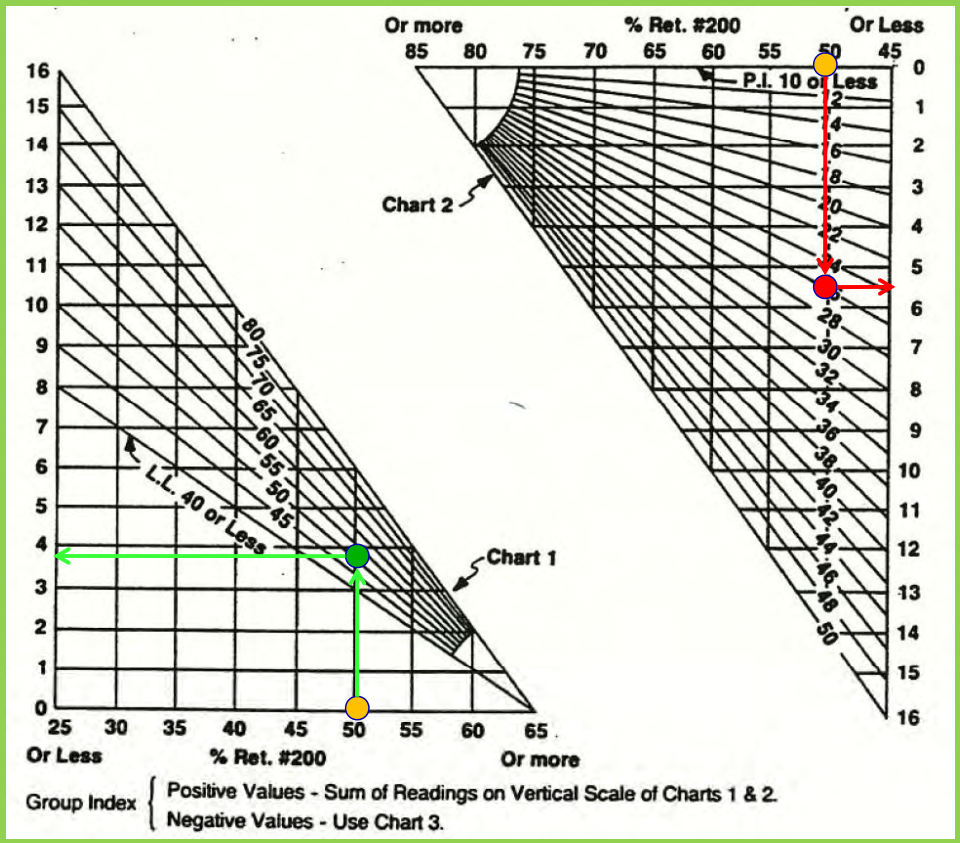
Chart $_1$ 3.8

+

Chart $_2$ 5.5

Sum= 9.3

NGI=9



Classification & Modulus

Nebraska Group Index (NGI)

Seven classifications

Soil Type	NGI
Gravel	-2
Fine Sand	-1 to 1
Sandy Silt	2 to 7
Loess	8 to 12
Loess/Till	13 to 14
Till	15 to 21
Shale/alluvium	22 to 24

NGI = 9

Classification & Modulus

	Well Graded Gravel Base	Clean Coarse Sand	Clean Fine Sand	Loamy Coarse Sand	Loamy Fine Sand	Loamy Very Fine Sand
Group Index	- 4	- 3	- 2		- 1	0
% Ret. #10	40 Min.					
% Ret. #40	60 Min.	35 Min.	34 Max.	35 Min.	34 Max. 10 Min.	9 Max.
% Ret. #200	85 Min.	85 Min.	85 Min.	84 Max. 65 Min.	84 Max. 65 Min.	84 Max. 65 Min.
P.I.	4 Max.	4 Max.	4 Max.	10 Max.	10 Max.	10 Max.

The first group from the left into which the test data will fit is the correct classification.

If sum of charts 1 & 2 is $\leq$ 0,

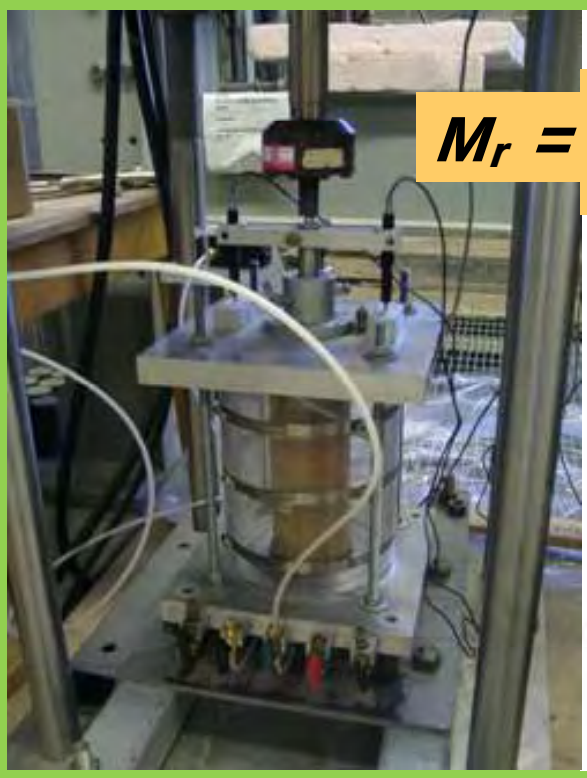
then use this chart for NGI.

We then use the NGI to figure the Resilient Modulus, M_r (Psi) for design

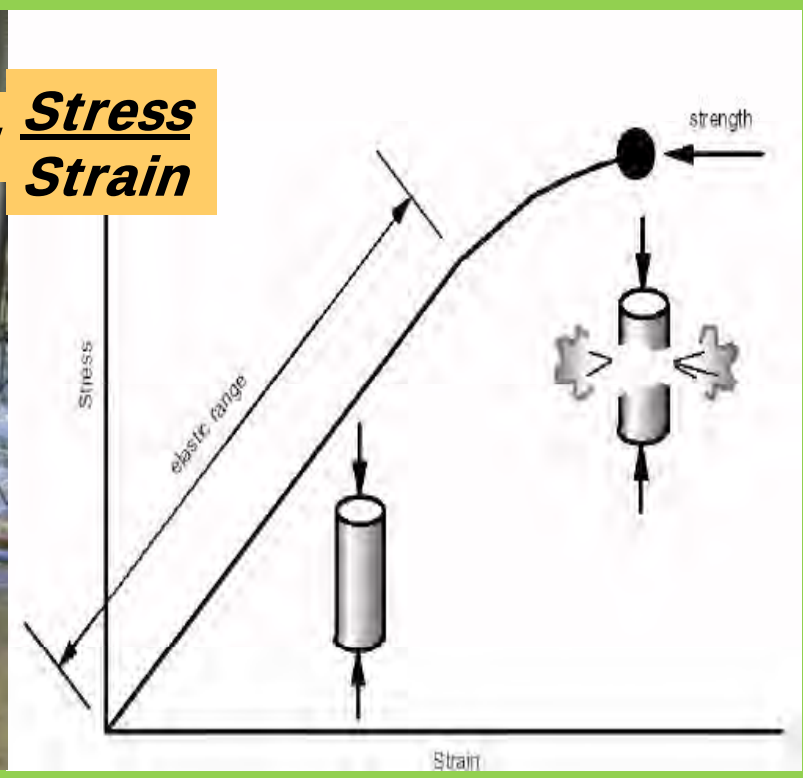
Resilient Modulus, M_r (Psi)

M_r is a measure of stress vs. strain which is typically used for materials that can be permanently deformed from loading, such as soils or flexible pavement.

Resilient Modulus, M_r (Psi)



$$M_r = \frac{Stress}{Strain}$$



Classification & Modulus

NGI = 9

group index	optimum	wet	dry
-2	20500	20000	21000
-1	16400	12500	13600
0	14100	10300	12600
1	11200	7400	10300
2	6400	4000	5000
3	7200	4100	7300
4	5700	5000	6300
5	5300	2500	6100
6	5000	2300	5900
7	4600	2500	6100
8	6200	2100	8300
9	6500	3900	8700
10	7500	5000	6100
11	8700	6100	11400
12	9800	7100	12700
13	10900	8300	13000
14	11800	9500	14500
15	12500	10400	15000
16	13200	11200	15400
17	13600	12000	15500
18	13900	12300	15200
19	13900	12800	14800
20	13600	12900	13900
21	13400	12900	13500
22	12400	11400	12800
23	11800	9800	12100
24	10300	8300	11400

Resilient Modulus, M_r (Psi)

group index	optimum	wet	dry
-2	20500	20000	21000
-1	16400	12600	13600
0	14100	10300	12500
1	11200	7400	10300
2	6400	4000	5000
3	7200	4100	7300
4	5700	5000	6300
5	5300	2500	8100
9	6500	3900	8700
10	7800	5000	8100
11	8700	6100	11400
12	9800	7100	12700
13	10900	8300	13000
14	11800	9500	14500
15	12500	10400	15000
16	13200	11200	15400
17	13500	12000	15600
18	13900	12300	15200
19	13900	12800	14800
20	13600	12900	13900
21	13400	12900	13600
22	12400	11400	12800
23	11800	9800	12100
24	10300	8300	11400

Pavement Management System or Field visit Information

HMA	
Rutting (mm)	
Cracking (%)	
Rating	

PCC	
Cracking(%)	
Faulting	
Rating	

Cores

Location	Depth	Comments
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Soils	
Classification	Loess, NGI 9
Optimum Modulus	6500
Wet Modulus	3900
Dry Modulus	8700
Frozen Modulus	20000

Traffic	
Current ADT	
20 yr Forecast ADT	
% Heavy trucks	
Predicted ESAL's	

Structure Number(HMA) or Thickness(PCC) Required for ESAL's	
Structure Number or Thickness Designed *(must ≥ required)*	

CHEMICAL STABILIZATION

Stabilized Subgrade

Standard processing depth is 8”

Water & Stabilizing Agent are incorporated to obtain the proper density

Fly Ash, Hydrated Lime and CKD

Stabilized Subgrade

Pay items:

Stabilized Subgrade paid by SQUARE YARD

Water is paid by MGALLONS

AGENT paid by the TON

COHESIVE SUBGRADE

Stabilized Subgrade

FLY ASH Sources & Chemical Composition

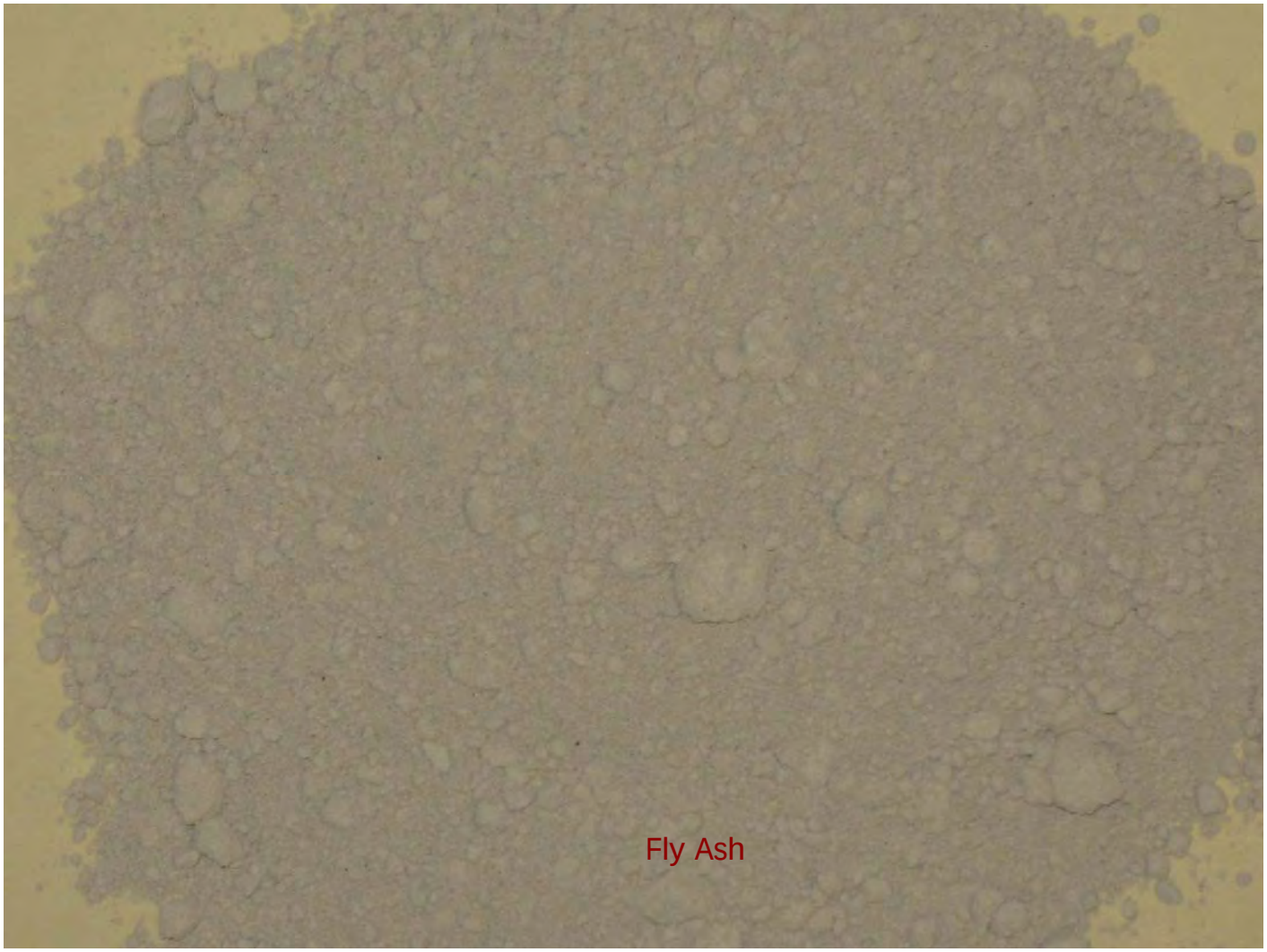
Plastic Index < 19 (silt-loess-lean clay)

Use 12% for estimate (range from 10-15%)

Incorporate with water and compact, no curing.

Good strength, minimal soil modification.

COHESIVE SUBGRADE


Fly Ash

Stabilized Subgrade

HYDRATED LIME

Plastic Index > 19 (lean clay – heavy clays)

Use 5% for estimate (range from 3-7%)

Incorporate with water, light compaction, cure for 48 hrs, re-mix then full compaction.

Medium Strength, Great soil modification

COHESIVE SUBGRADE

Stabilized Subgrade

Stabilized Subgrade

CEMENT KILN DUST (CKD)

All Plastic Soils

Use 7% (ranges from 5-9%)

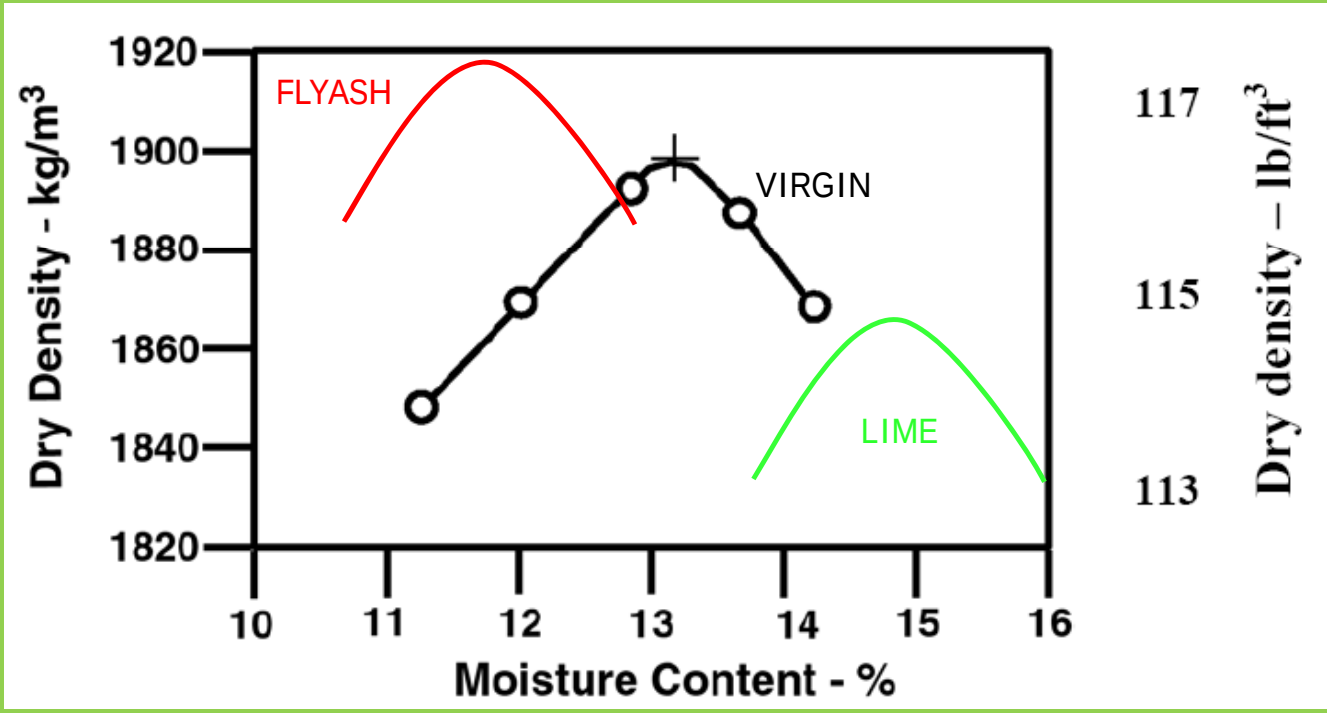
Incorporate with water and compact, no cure.

Great Strength and Good Soil Modification

COHESIVE SUBGRADE

Cement Kiln Dust

Stabilized Subgrade



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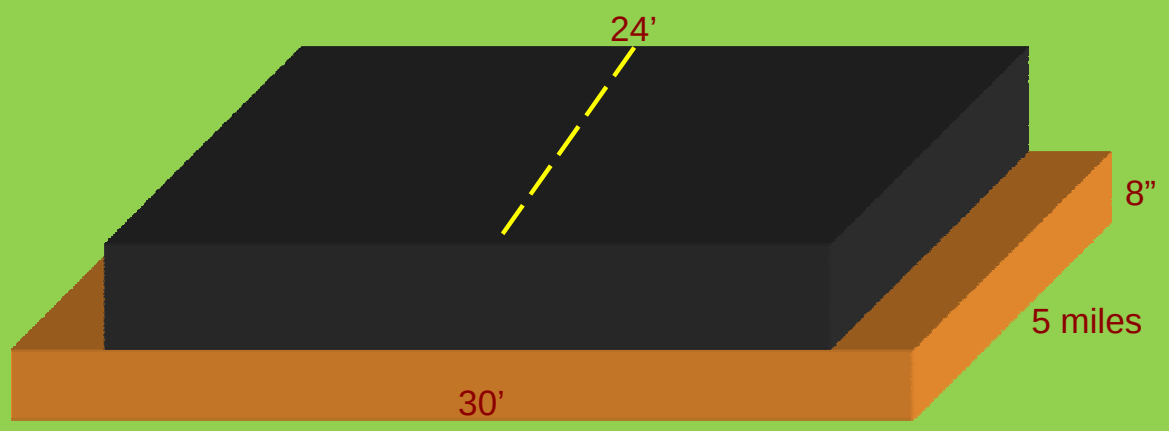
TIMPTE
TIMPTE

Stabilized Subgrade



Uniform pavement width 24' and (5 miles x 5280') 26,400' long

633,600 ft^2 = 70,400 yd^2 Stabilized Subgrade Type Lime

8" depth with 5% Lime= 33 lbs/yd^2 (*soil weighs 110 lbs/ft^3*)

30' x 26,400' = 792,000 ft^2 = 88,000 yd^2

33 lbs/yd^2 x 88,000 yd^2 = 2,904,000 lbs = 1,452 tons of Hydrated Lime

88,000 yd^2 x 0.003MGal/yd^2 = 264 MGal of Water

Classification & Modulus

group index	optimum	wet	dry
-2	20500	20000	21000
-1	16400	12500	13600
0	14100	10300	12600
1	11200	7400	10300
2	6400	4000	5000
3	7200	4100	7300
4	5700	5000	6300
5	5300	2500	6100
6	5000	2300	5900
7	4600	2500	6100
8	6200	2100	8300
9	6500	3900	8700
10	7500	5000	6100
11	8700	6100	11400
14	11600	9500	14300
15	12500	10400	15000
16	13200	11200	15400
17	13600	12000	15500
18	13900	12300	15200
19	13900	12800	14800
20	13600	12900	13900
21	13400	12900	13500
22	12400	11400	12800
23	11800	9800	12100
24	10300	8300	11400

NGI = 9

Remember this slide from Subgrade Discussion

Pozzolan Stabilized Subgrades

Nebraska Department of Roads Research Project SPR-1 (06) 578

By

Timothy T. Hensley, P.E.

Graduate Committee
Wayne Jensen, Ph.D., P.E.

Table 4: Atterberg Limits Results

Soil	Gravel		Fine Sand		Sandy Silt		Loess		Loess/Till		Till		Shale	
NGI	2		0		5		8		13		8		13	
Atterburg Limits	LL	PI	LL	PI	LL	PI	LL	PI	LL	PI	LL	PI	LL	PI
Native	NP	NP	NP	NP	25	5	31	9	42	21	44	28	65	43
Lime														
2%	NP	NP	NP	NP	-	-	-	-	-	-	-	-	-	-
4%	-	-	-	-	NP	NP	-	-	-	-	-	-	-	-
5%	-	-	-	-	-	-	NP	NP	NP	NP	NP	NP	-	-
6%	-	-	-	-	-	-	-	-	-	-	-	-	NP	NP
Fly Ash														
10%	NP	NP	NP	NP	NP	NP	30	6	39	9	47	17	62	32
13%	NP	NP	NP	NP	NP	NP	27	4	38	5	44	15	59	28
15%	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	59	29
CKD														
5%	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	49	13	64	20
7%	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP

Resilient Modulus Testing - AASHTO T 307-99 English Units

Report Date: 18-Apr-07
Lab No.: Till Fly Ash
Project No.: 03071078

Soil Map Unit:	Till 12% Fly Ash
Soil Symbol:	0
Depth (in.)	0
Compaction Method	Static
Max. Dry Density (pcf)	107.5
Opt. Moisture Content (%)	17.0
Inside Mold Diameter (in)	3.94

Weight of Wet Soil (lb)	6.5
Initial Sample Diameter (in)	3.9
Initial Sample Height (in)	7.9
Initial Sample Area (in^2)	12.
Sample Volume (in^3)	96.
Compacted Moisture Content(%)	16
Wet Density (pcf)	118
Dry Density (pcf)	100

Chamber Confining Pressure (S_3) psi	Nominal Maximum Axial Stress (S_{cyclic}) psi	Actual Applied Max. Axial Load (P_{max}) lb	Actual Applied Cyclic Load (P_{cyclic}) lb	Actual Applied Contact Load ($P_{contact}$) lb	Actual Applied Max. Axial Stress (S_{max}) psi	Actual Applied Cyclic Stress (S_{cyclic}) psi	Actual Applied Contact Stress ($S_{contact}$) psi	Recov LVD Rea (H in					Resilient Modulus (M_r) psi
5.99	1.80	16.4	20.8	-4.5	1.34	1.71	-0.3671	0.00					
5.95	3.60	40.3	42.4	-2.1	3.31	3.48	-0.1752	0.00					
5.93	5.41	64.3	63.8	0.5	5.28	5.24	0.0414	0.00					
6.07	7.21	88.8	85.8	3.0	7.29	7.04	0.2493	0.00					
6.00	8.99	112.8	107.5	5.4	9.27	8.83	0.4417	0.00					
4.00	1.80	17.3	21.2	-3.9	1.42	1.74	-0.3206	0.00					
4.01	3.60	41.4	42.9	-1.5	3.40	3.53	-0.1240	0.00					
4.00	5.41	65.5	64.0	1.5	5.38	5.26	0.1200	0.00					
4.01	7.21	89.7	86.1	3.6	7.36	7.07	0.2927	0.00					
4.03	8.99	113.8	107.5	6.3	9.35	8.83	0.5206	0.0030	0.0025	0.0027	0.0003448	25602.4	30413.4
1.98	1.80	18.3	21.1	-2.8	1.50	1.73	-0.2296	0.0007	0.0006	0.0007	0.0000843	20545.6	
1.97	4.00	42.6	42.9	-0.4	3.50	3.53	-0.0301	0.0015	0.0012	0.0013	0.0001691	20853.1	
1.97	6.00	66.6	64.4	2.1	5.47	5.29	0.1764	0.0022	0.0018	0.0020	0.0002526	20949.3	

Resilient Modulus Testing - AASHTO T 307-99 English Units

Report Date: 18-Apr-07
Lab No.: Till Lime
Project No.: 03071078

Soil Map Unit:	Till 5% Lime
Soil Symbol:	0
Depth (in.)	0
Compaction Method	Static
Max. Dry Density (pcf)	92.5
Opt. Moisture Content (%)	18.0
Inside Mold Diameter (in)	3.94

Weight of Wet Soil (lb)	5.75
Initial Sample Diameter (in)	3.94
Initial Sample Height (in)	7.87
Initial Sample Area (in^2)	12.17
Sample Volume (in^3)	95.86
Compacted Moisture Content(%)	20.0
Wet Density (pcf)	103.7
Dry Density (pcf)	86.4

Chamber Confining Pressure (S_3) psi	Nominal Maximum Axial Stress (S_{cyclic}) psi	Actual Applied Max. Axial Load (P_{max}) lb	Actual Applied Cyclic Load (P_{cyclic}) lb	Actual Applied Contact Load ($P_{contact}$) lb	Actual Applied Max. Axial Stress (S_{max}) psi	Actual Applied Cyclic Stress (S_{cyclic}) psi	Actual Applied Contact Stress ($S_{contact}$) psi	Recov. Def. LVDT #1 Reading (H_1) in	Recov. Def. LVDT #2 Reading (H_2) in	Resilient Modulus (M_r) psi
6.02	1.80	16.7	21.1	-4.3	1.38	1.73	-0.3569	0.0005	0.0004	
6.04	3.60	41.3	43.3	-2.1	3.39	3.56	-0.1713	0.0010	0.0007	
5.99	5.41	65.7	65.0	0.7	5.40	5.34	0.0580	0.0016	0.0012	
6.00	7.21	90.3	87.2	3.1	7.42	7.16	0.2564	0.0022	0.0016	31740.0
5.99	8.99	114.8	109.3	5.5	9.43	8.98	0.4519	0.0027	0.0021	
4.01	1.80	17.5	21.1	-3.6	1.44	1.73	-0.2972	0.0005	0.0004	
4.02	3.60	42.0	43.5	-1.4	3.45	3.57	-0.1172	0.0011	0.0009	
4.02	5.41	66.6	65.4	1.2	5.47	5.37	0.0983	0.0018	0.0013	0.0015	0.0001954	27501.3
3.96	7.21	91.1	87.3	3.8	7.48	7.17	0.3104	0.0024	0.0018	0.0021	0.0002642	27140.3
4.03	8.99	115.4	108.8	6.6	9.48	8.93	0.5454	0.0029	0.0022	0.0026	0.0003243	27542.1
1.94	1.80	18.2	21.3	-3.1	1.50	1.75	-0.2516	0.0007	0.0005	0.0006	0.0000762	22945.0
2.04	4.00	42.7	43.2	-0.5	3.50	3.55	-0.0448	0.0013	0.0010	0.0012	0.0001479	23995.7
1.97	6.00	67.3	65.4	1.9	5.53	5.37	0.1586	0.0019	0.0015	0.0017	0.0002154	24933.0
2.01	8.00	91.8	86.9	4.9	7.54	7.13	0.4040	0.0025	0.0019			

Stabilized Subgrades

Pavement Management System or Field visit Information

HMA	
Rutting (mm)	
Cracking (%)	
Rating	

PCC	
Cracking(%)	
Faulting	
Rating	

Cores

Location	Depth	Comments
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Soils	
Classification	Till, NGI 8
Optimum Modulus	30000
Wet Modulus	30000
Dry Modulus	30000
Frozen Modulus	30000

Traffic	
Current ADT	
20 yr Forecast ADT	
% Heavy trucks	
Predicted ESAL's	

Structure Number(HMA) or Thickness(PCC) Required for ESAL's	
Structure Number or Thickness Designed *(must ≥ required)*	

CAT

CAT
CAT
HAWKINS
06/10/2009 14:25

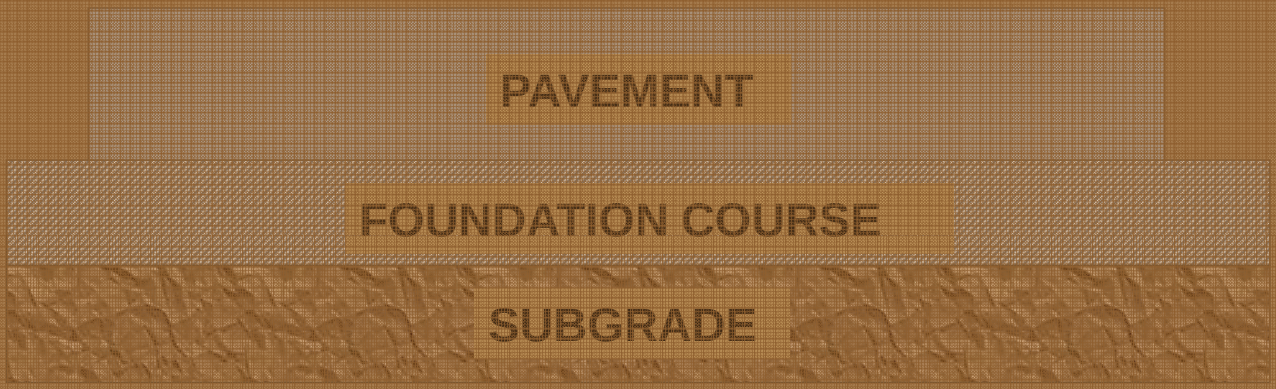
TX160
Tensar
BX1200
Tensar
MIRAFI
BASXGRID 11
Geogrids for Base Course Reinforcement

OUTLINE

- Deliverables
- Subgrade
  - Subgrade Preparation
  - Subgrade Stabilization
  - Classification & Modulus
- **Foundation Courses**
  - **Stability**
  - **Types**
  - **Drainage**
- Pavement
  - Concrete (Rigid)
    - Cement
    - ASR
    - Joints
    - PCC Construction
  - White Topping & PCC Overlays
    - UltraThin
    - Conventional

Foundation Courses

The purpose of a foundation course is to provide a stable, uniform and drainable base for our pavements.



STABILITY

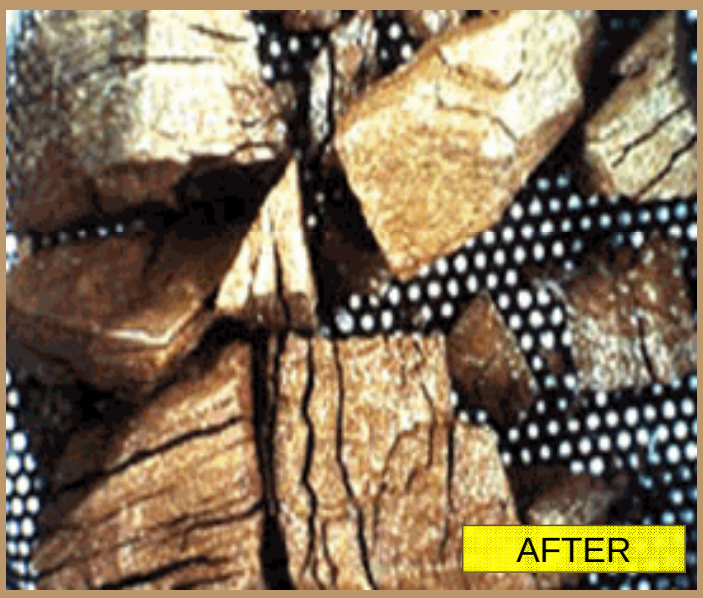
- **Surface Characteristics – Angularity**
- **Soundness / Durability**
- **Gradation**

STABILITY

Surface Characteristics – Angularity

STABILITY

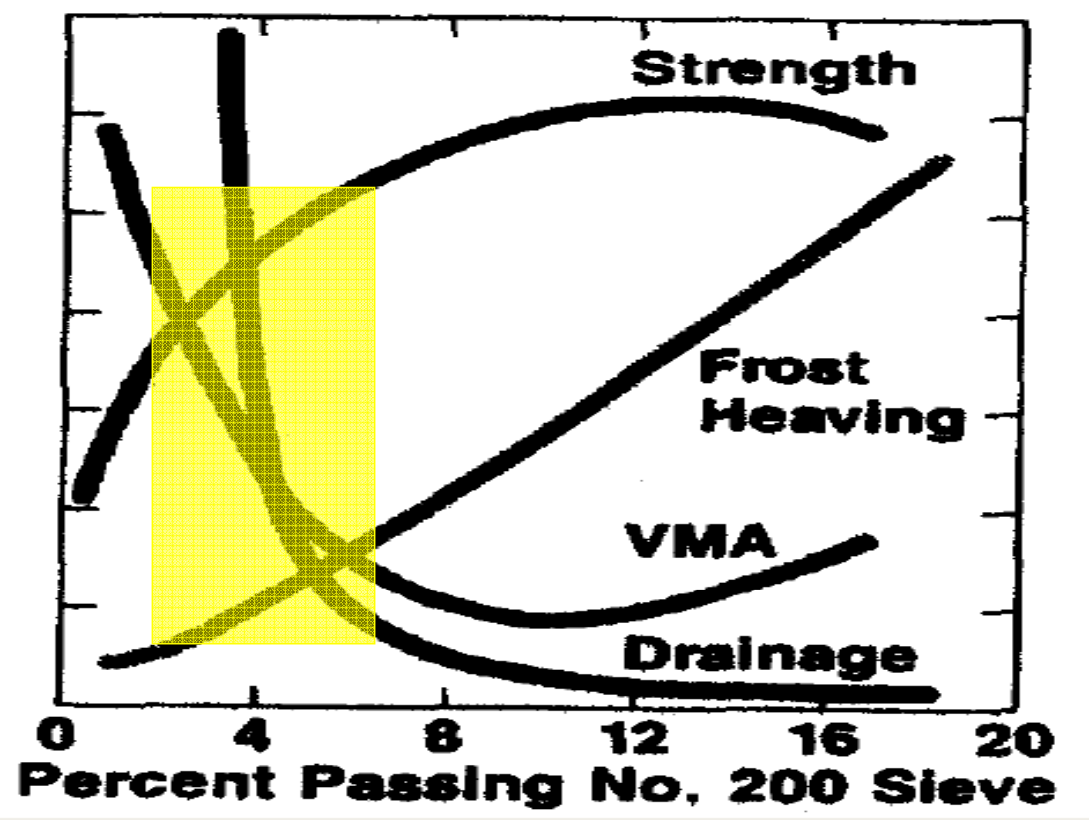
Soundness / Durability



STABILITY

GRADATION – Max Density

FOUNDATION COURSE



STABILITY WITH GRADATIONS

Types of Aggregate Gradation

No. 100 No. 30
No. 200 No. 50 No. 16 No. 8 No. 4 3/8-inch 1/2-inch 3/4-inch

$$P = \left(\frac{d}{D}\right)^n (100)$$

Percent Passing

P = percent finer than an aggregate size

d = aggregate size being considered

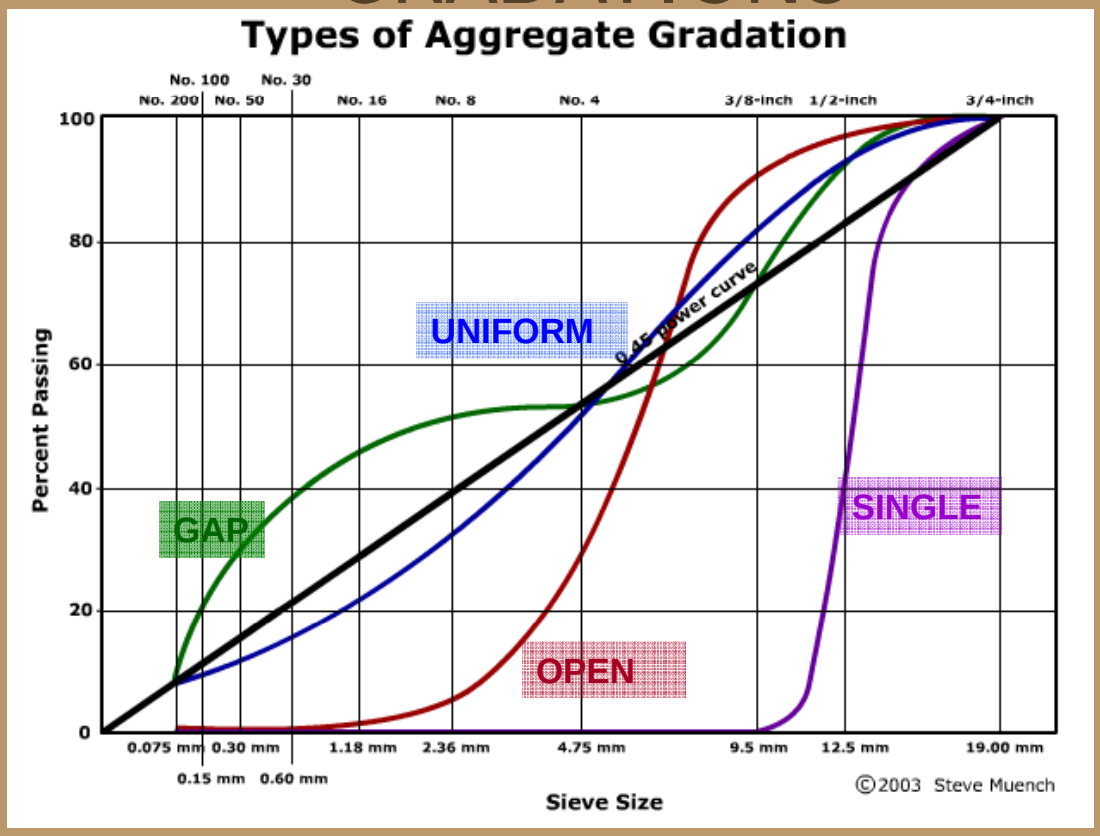
D = maximum aggregate size

n = parameter which adjusts curve for fineness or coarseness (for maximum particle density n ≈ 0.5 according to Fuller and Thompson)

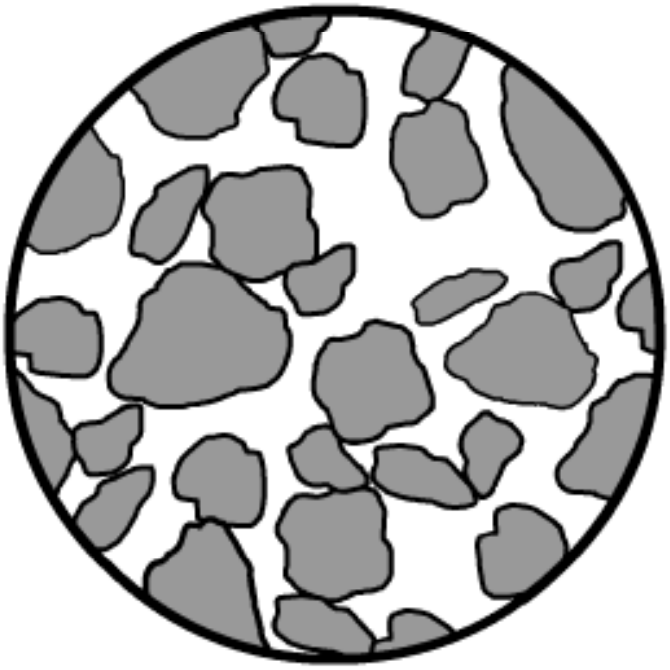
Sieve Size

©2003 Steve Muench

GRADATIONS

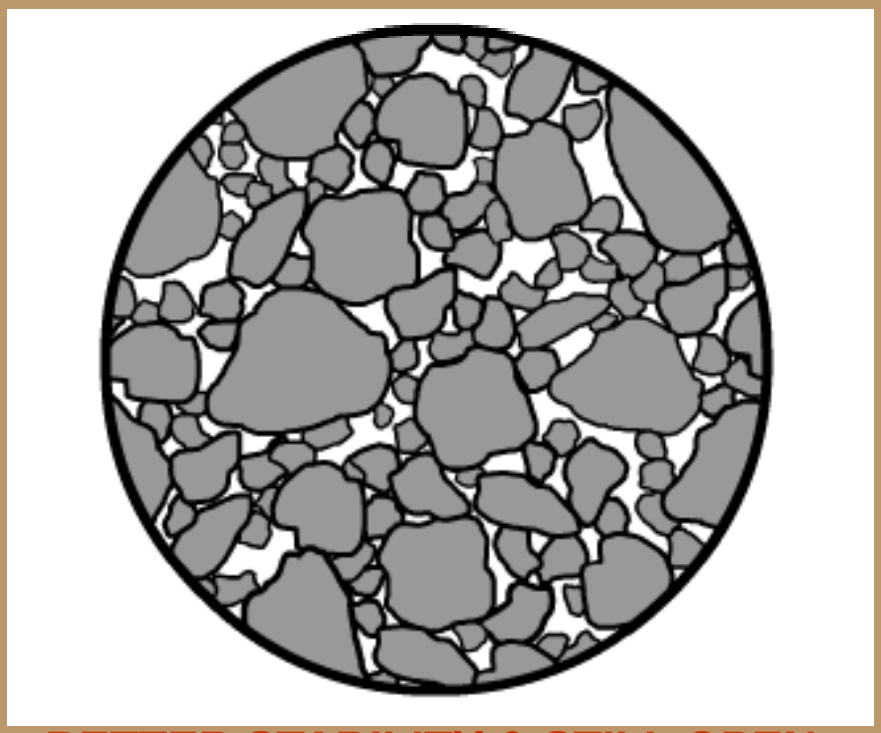

Types of Aggregate Gradation
No. 100
No. 30
No. 200
No. 50
No. 16
No. 8
No. 4
3/8-inch
1/2-inch
3/4-inch
100
80
60
40
20
0
Percent Passing
UNIFORM
0.45 power curve
GAP
SINGLE
OPEN
0.075 mm
0.30 mm
1.18 mm
2.36 mm
4.75 mm
9.5 mm
12.5 mm
19.00 mm
0.15 mm
0.60 mm
Sieve Size
©2003 Steve Muench

GRADATIONS



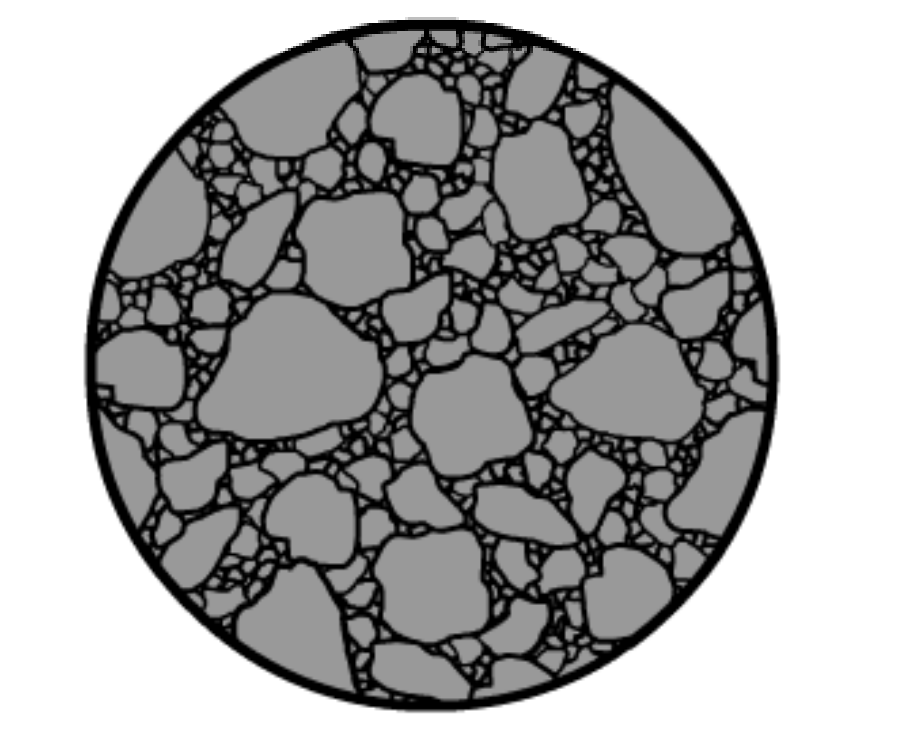
POOR STABILITY & TOO OPEN

GRADATIONS



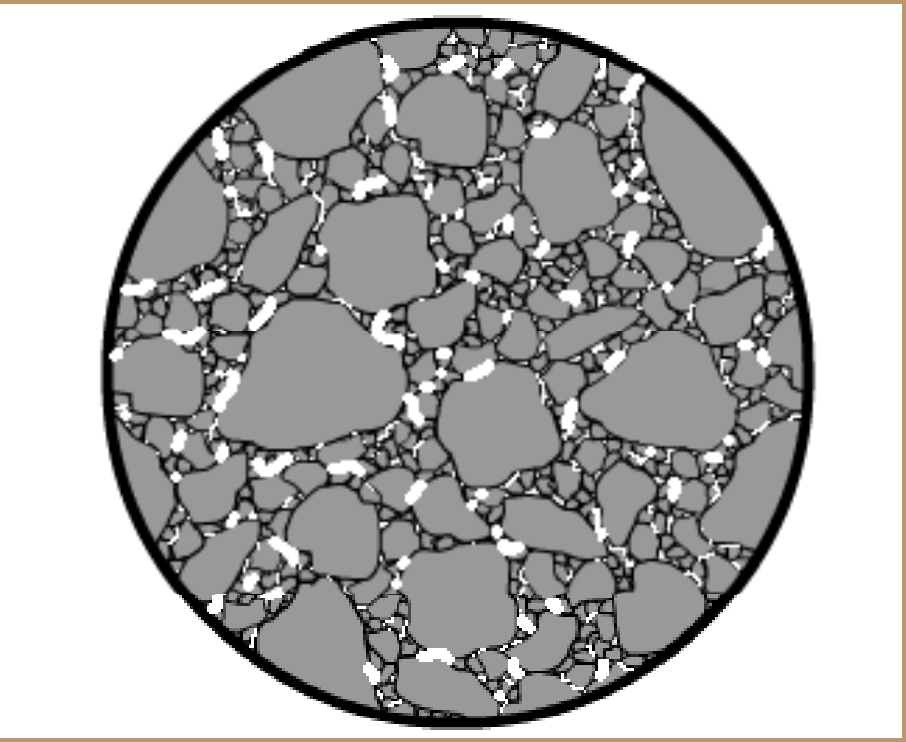
BETTER STABILITY & STILL OPEN

GRADATIONS



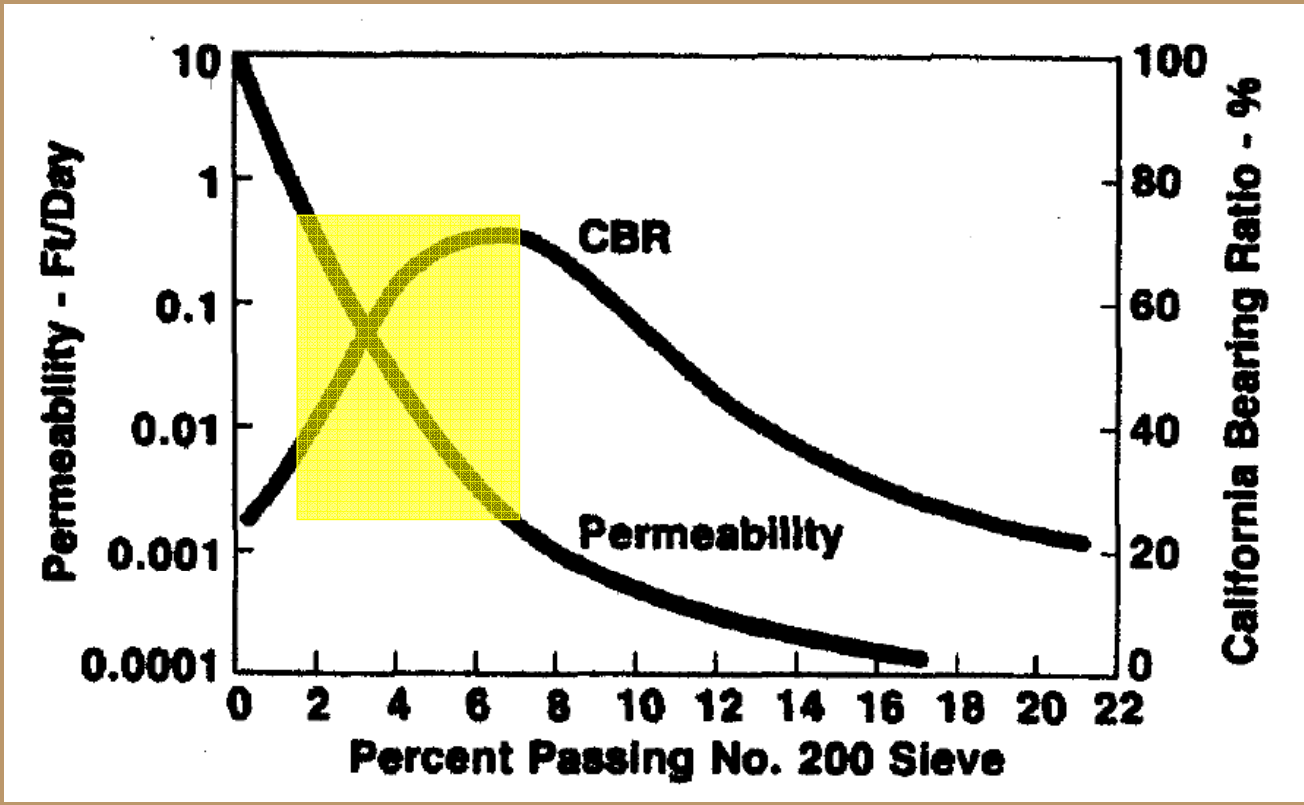
GREAT STABILITY & NO DRAINAGE

GRADATIONS



GOOD STABILITY & GOOD DRAINAGE

FOUNDATION COURSE



FILTER CRITERIA

Must protect the base, prevent base from plugging filter and provide adequate drainage.

$$\frac{D_{15(filt)}}{D_{15(base)}} < 20 \qquad \frac{D_{15(filt)}}{D_{15(base)}} > 4$$

$$\frac{D_{15(filt)}}{D_{85(base)}} < 5 \qquad \frac{D_{50(filt)}}{D_{50(base)}} < 25$$

FOUNDATION COURSE

Filter Analysis for Foundation Coarse

To Avoid head loss in filter, Check $D_{15F}/D_{15B} > 4$

Subbase		Project Data		
Type	D_{15B}	D_{15F}	D_{15F}/D_{15B}	Good Filter
SM	0.007	0.0096	1.37	no
CH	0.0018	0.0096	5.33	yes
CL	0.0021	0.0096	4.57	yes
CL/ML	0.0022	0.0096	4.36	yes

Type	D_{50B}	D_{50F}	D_{50F}/D_{50B}	Good Filter	D_{50F}	D_{50F}/D_{50B}										
SM	0.03	0.23	7.67	yes	0.5	16.67										
CH	0.00225	0.23	102.22	no	0.5	222.22										
CL	0.0029	0.23	79.31	no	0.5	172.41	no	0.044	15.17	yes	0.088	30.34	no	0.088	30.34	no
CL/ML	0.0039	0.23	58.97	no	0.5	128.21	no	0.044	11.28	yes	0.088	22.56	yes	0.088	22.56	yes

To avoid the movement of partials from base into filter, Check $D_{15F}/D_{15B} < 20$

Subbase		Upper Limit			Lower Limit			Type D Aggregate: Upper Limit			Type D Aggregate: Lower Limit			Project Data		
Type	D_{15B}	D_{15F}	D_{15F}/D_{15B}	Good Filter	D_{15F}	D_{15F}/D_{15B}	Good Filter	D_{15F}	D_{15F}/D_{15B}	Good Filter	D_{15F}	D_{15F}/D_{15B}	Good Filter	D_{15F}	D_{15F}/D_{15B}	Good Filter
SM	0.007	0.028	4.00	yes	0.16	22.86	no	0.0096	1.37	yes	0.016	2.29	yes	0.0096	1.37	yes
CH	0.0018	0.017	9.44	yes	0.16	88.89	no	0.0096	5.33	yes	0.016	8.89	yes	0.0096	5.33	yes
CL	0.0021	0.017	8.10	yes	0.16	76.19	no	0.0096	4.57	yes	0.016	7.62	yes	0.0096	4.57	yes
CL/ML	0.0022	0.017	7.73	yes	0.16	72.73	no	0.0096	4.36	yes	0.016	7.27	yes	0.0096	4.36	yes

FOUNDATION COURSE

THREE TYPES

- AGGREGATE - D
- BITUMINOUS MILLINGS
- CRUSHED CONCRETE

FOUNDATION COURSE

AGGREGATE - D

FOUNDATION COURSE

BITUMINOUS MILLINGS

FOUNDATION COURSE

CRUSHED CONCRETE

FOUNDATION COURSE

ISSUES

- GRADATIONS & STOCK PILE MANAGEMENT
- WHERE TO PULL SAMPLES
- DENSITY

FOUNDATION COURSE

GRADATIONS & STOCK

FOUNDATION COURSE

GRADATIONS & STOCK

FOUNDATION COURSE

GRADATIONS & STOCK

FOUNDATION COURSE

GRADATIONS & STOCK

FOUNDATION COURSE

GRADATIONS & STOCK

FOUNDATION COURSE

GRADATIONS & STOCK

FOUNDATION COURSE

WHERE TO PULL SAMPLES

- ON GRADE….NOT STOCK PILES

FOUNDATION COURSE

WHERE TO PULL SAMPLES

- ON GRADE....NOT STOCK PILES
- EVERY 500 TONS FIELD SAMPLES (must be a WASHED test)
- EVERY 2500 TONS CENTRAL LAB SAMPLES

FOUNDATION COURSE

DENSITY

- **AGGREGATE-D**
  LAB ESTABLISHES

- **CRUSHED CONCRETE & BITUMINOUS**
  ROLLING PATTERN

FOUNDATION COURSE

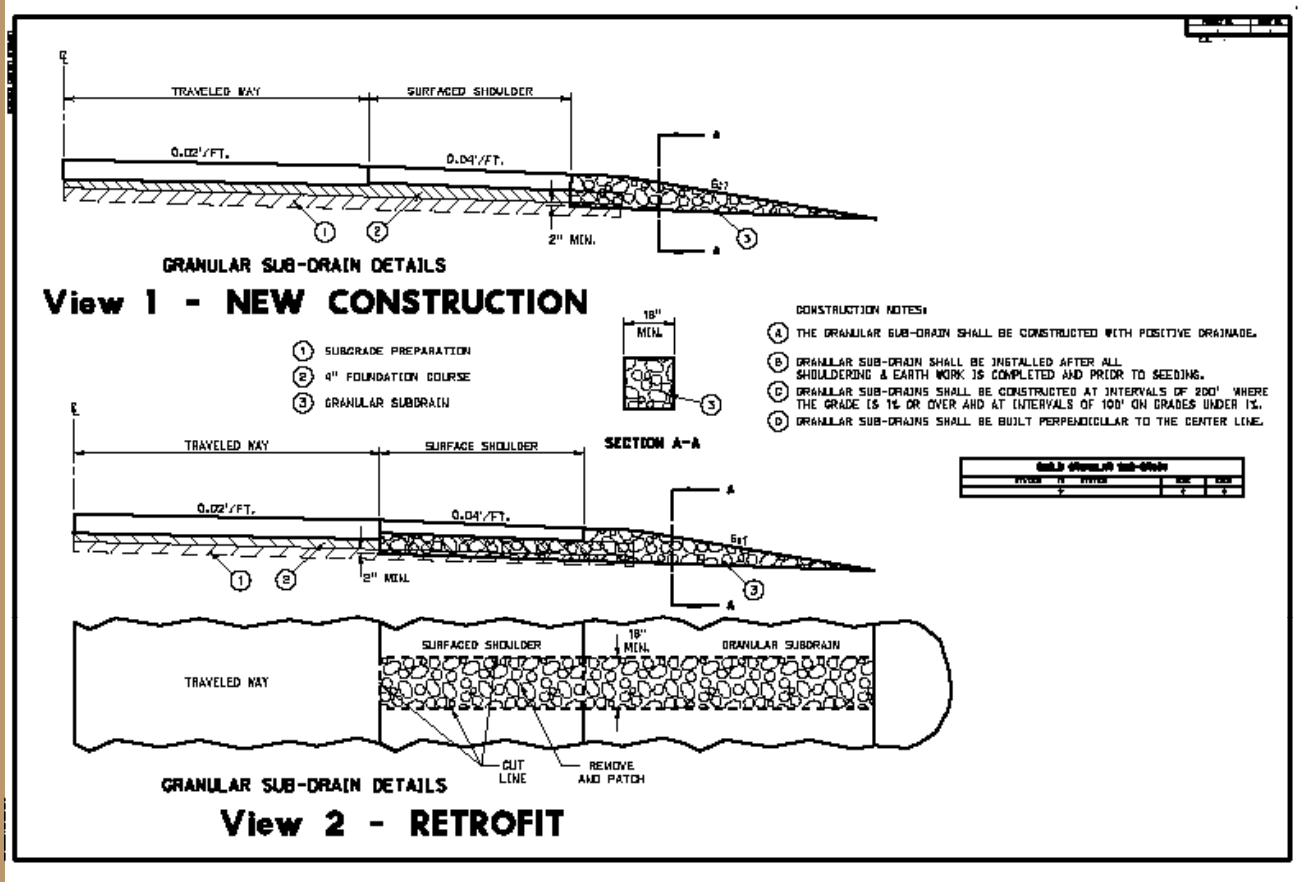
GOMACO
9500

3-Foot extra width

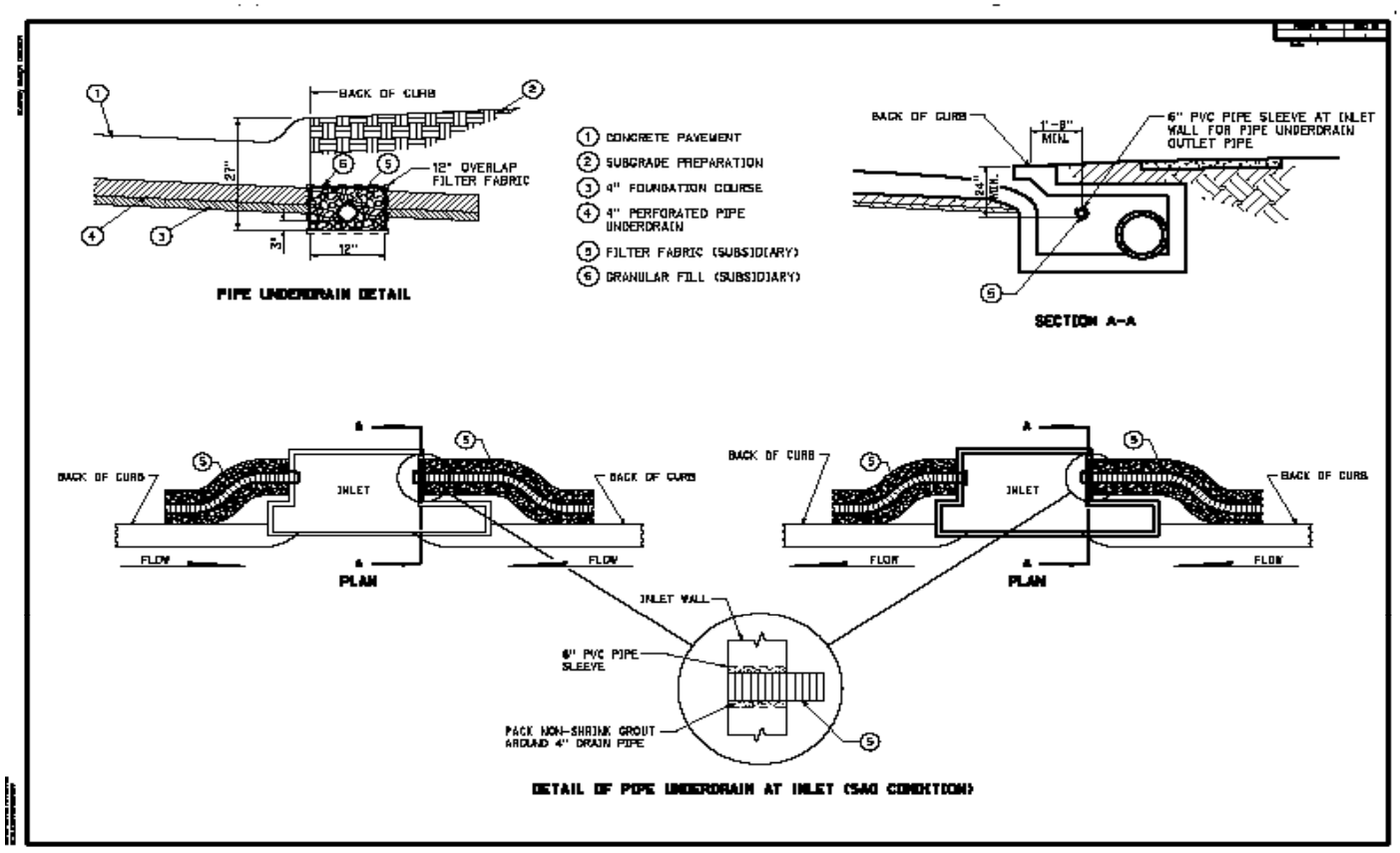
WHY ALL THIS WORK

WHY ALL THIS WORK

Granular drains



Urban Subdrains



SEP 20 2004

Resilient Modulus, M_r (Psi) For Foundation Course

M_r = 22,000 psi

Drainage Coefficient For Foundation Course

[Factor is compared to AASHTO road test section]

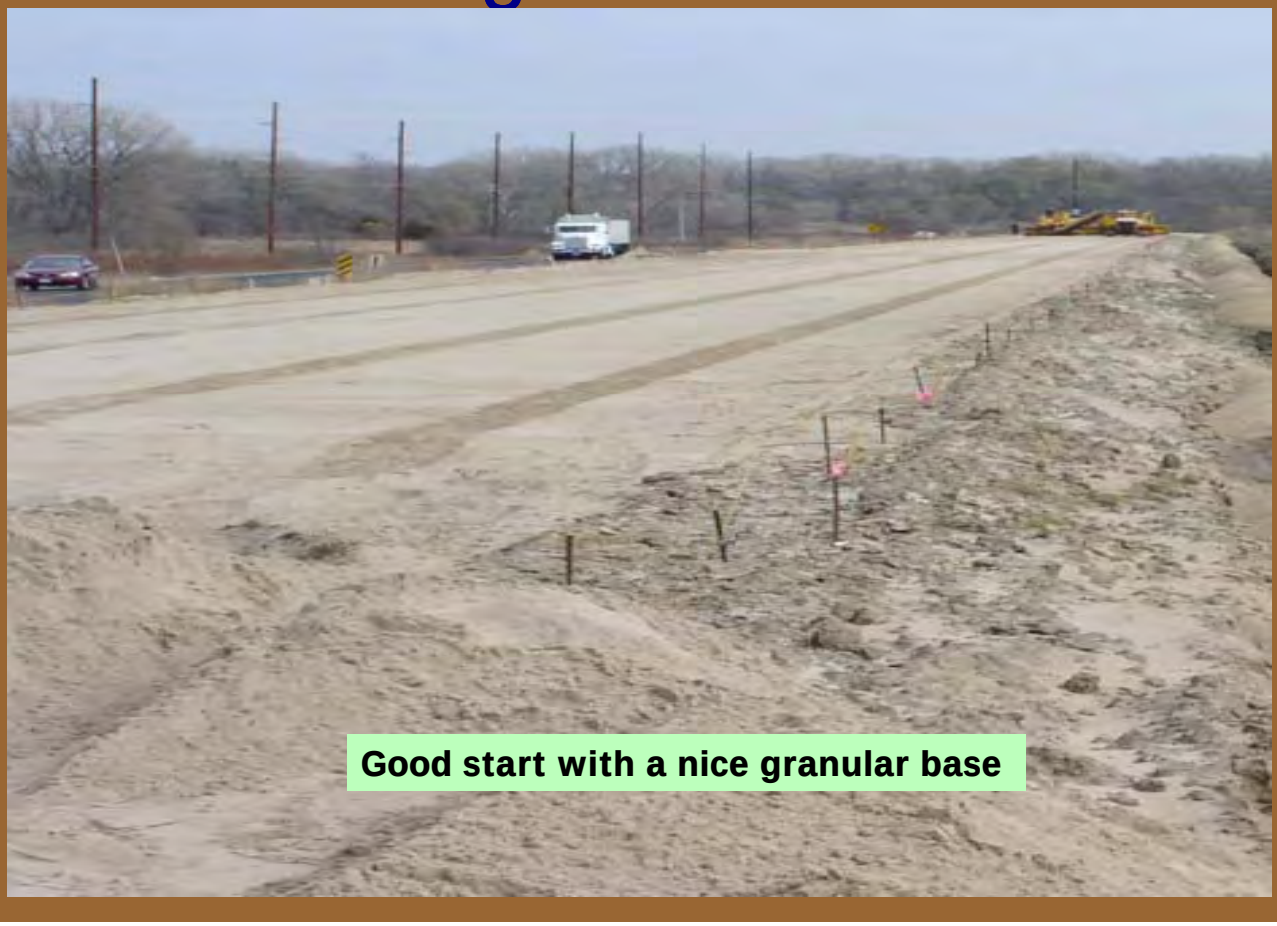
Range

0.4 (very poor) - 1.4 (Excellent)

Typical

1.0 (pore pressure relief)

During Construction



COMACO
Contractor built haul road on outside edge with full depth cohesive soils

Had a lot of rain and the water was trapped against the haul road.
No hauling + no paving = Major delays and costs.

Trenched out edges and you could see the water coming out. This eventually allowed water out and with some reworking the paving could begin.

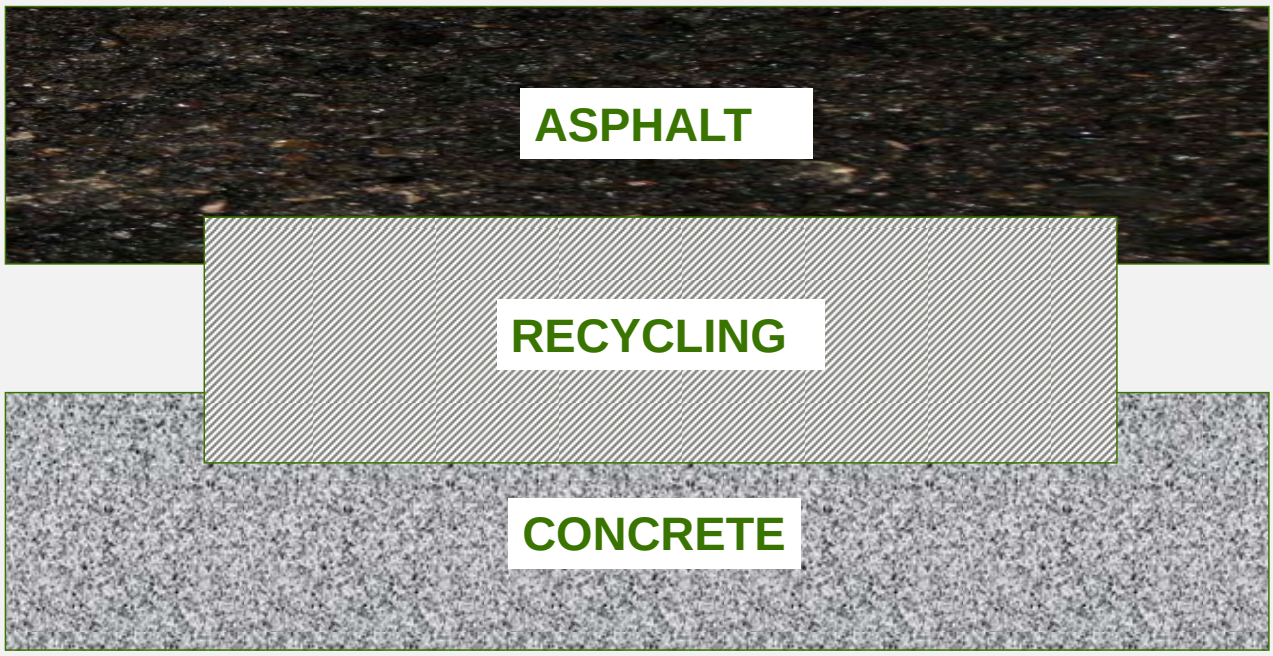
?

OUTLINE

- Deliverables
- Subgrade
  - Subgrade Preparation
  - Subgrade Stabilization
  - Classification & Modulus
- Foundation Courses
  - Stability
  - Types
  - Drainage
- **Pavement**
  - **Concrete (Rigid)**
    - **Cement**
    - **ASR**
    - **Joints**
    - **PCC Construction**
  - White Topping & PCC Overlays
    - UltraThin
    - Conventional

Pavement

Pavement



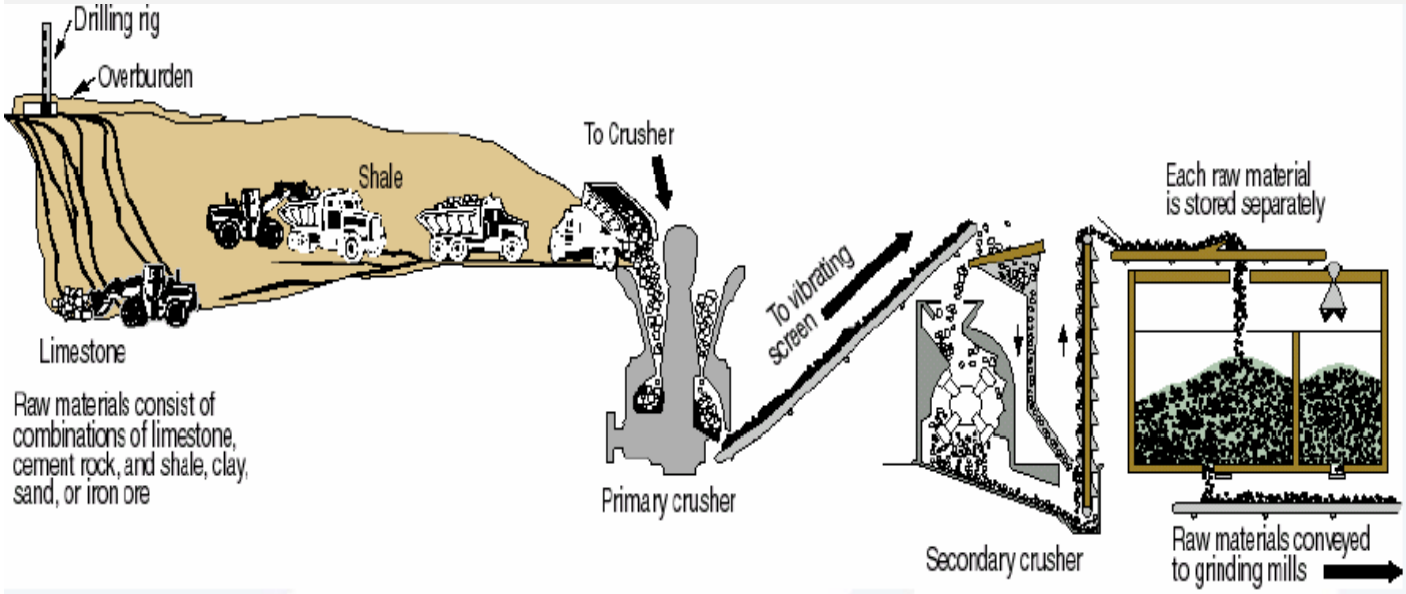
CONCRETE

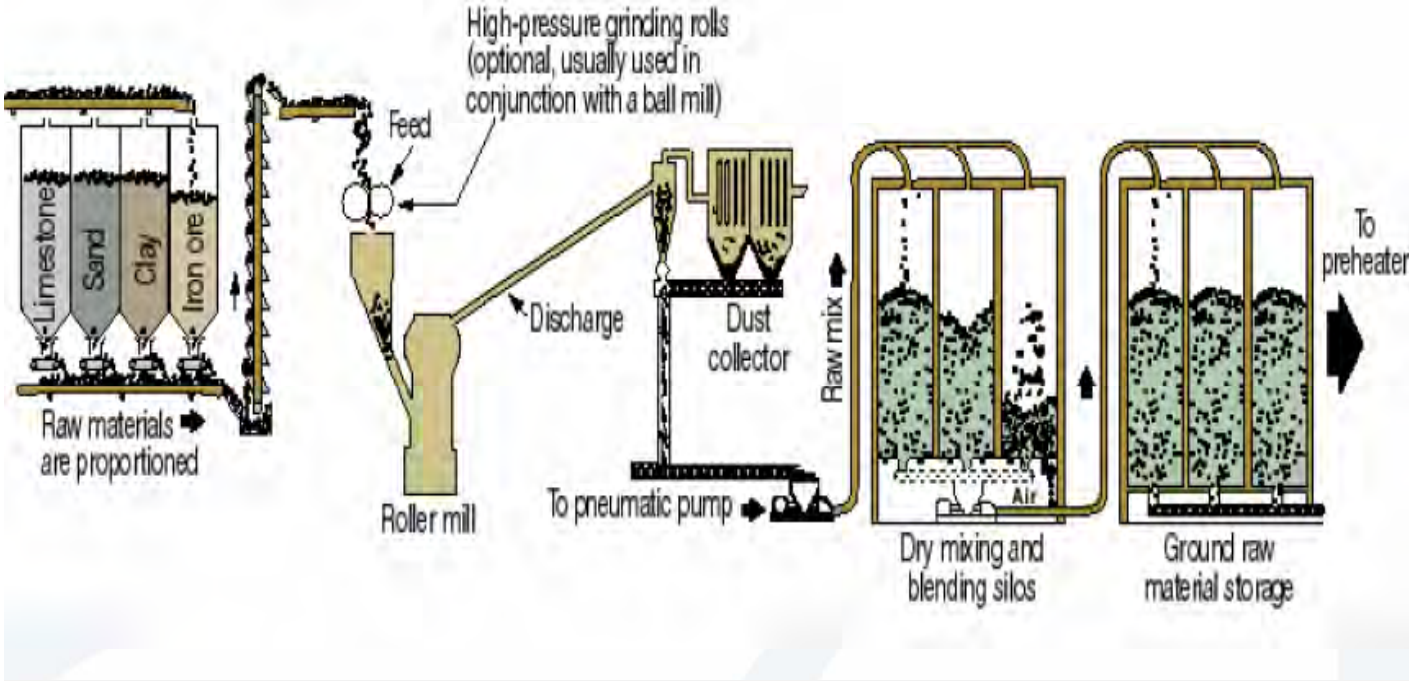
RIGID Pavement

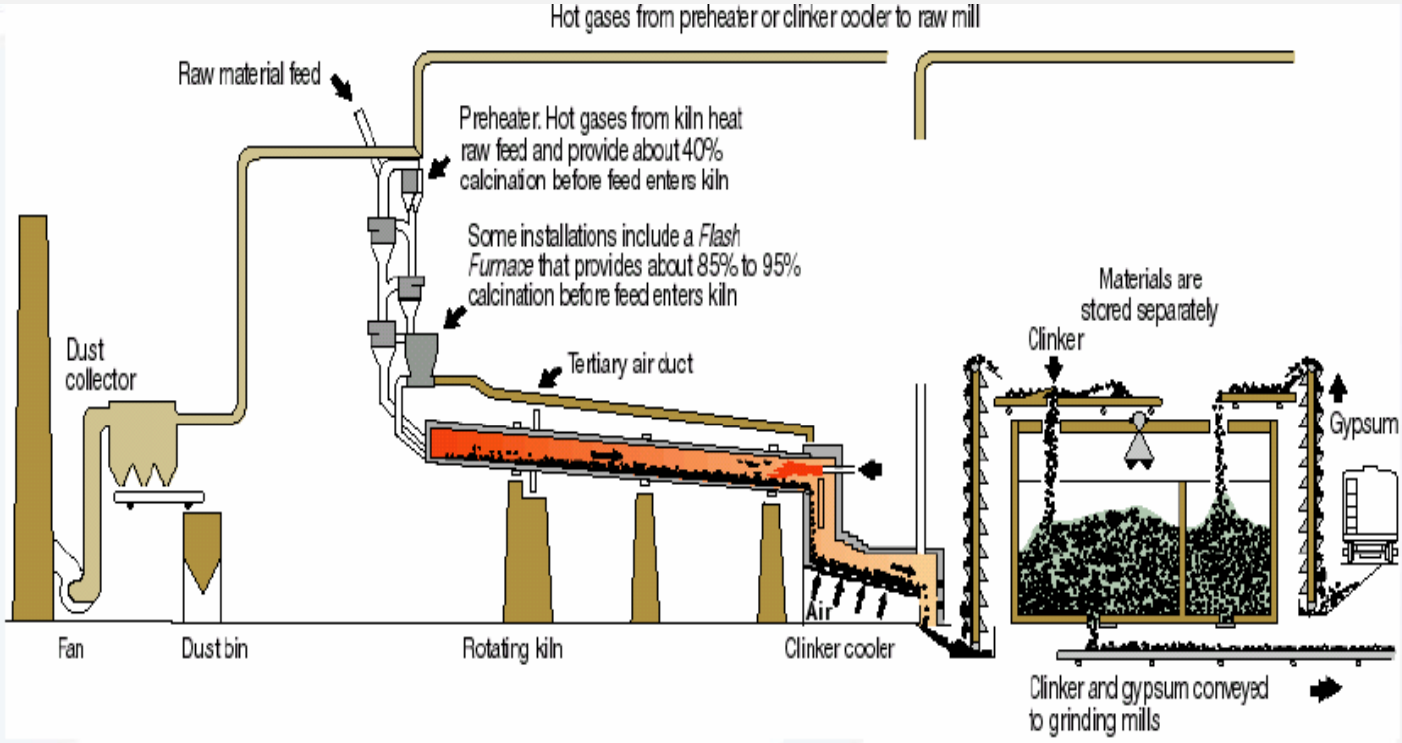
Portland Cement

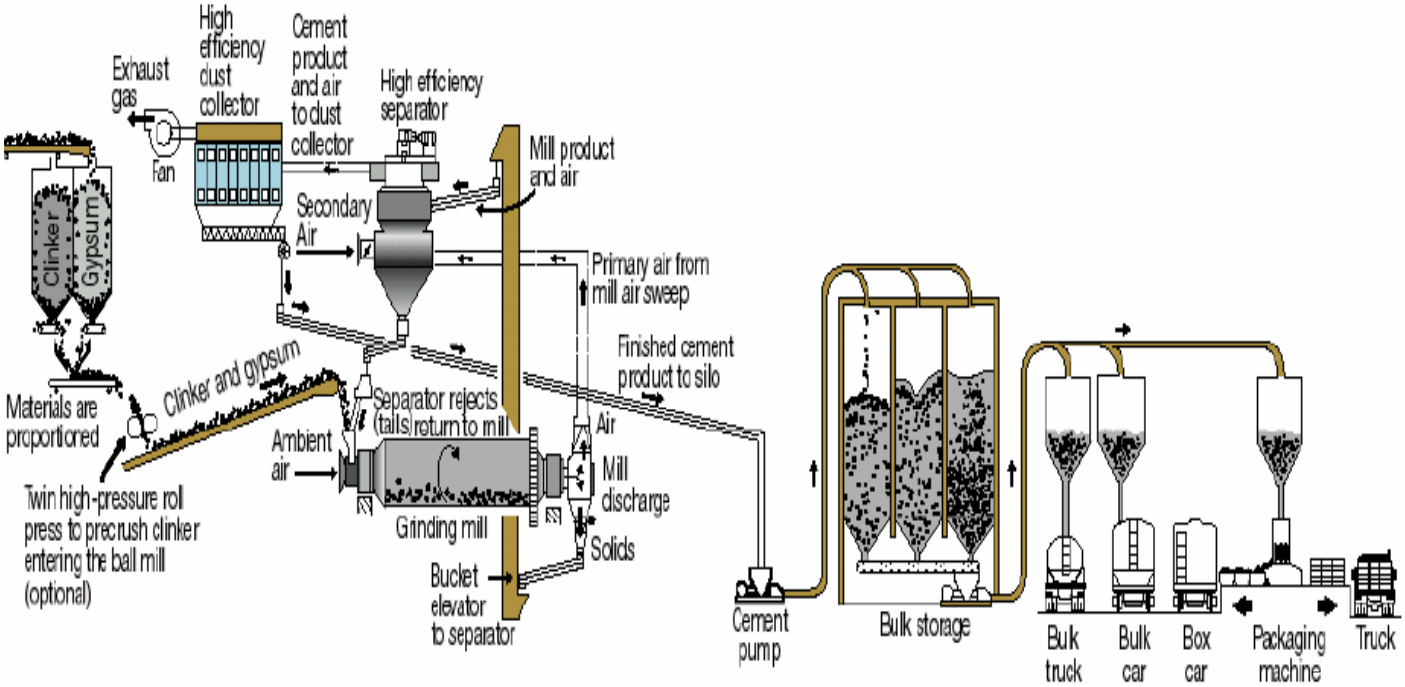
Aggregate (ledge rock, gravel, sand)

Water


Drilling rig
Overburden
Shale
Limestone
Raw materials consist of combinations of limestone, cement rock, and shale, clay, sand, or iron ore
To Crusher
Primary crusher
To vibrating screen
Secondary crusher
Each raw material is stored separately
Raw materials conveyed to grinding mills


High-pressure grinding rolls (optional, usually used in conjunction with a ball mill)
Feed
Limestone
Sand
Clay
Iron ore
Raw materials are proportioned
Roller mill
Discharge
Dust collector
To pneumatic pump
Raw mix
Air
Dry mixing and blending silos
Ground raw material storage
To preheater


Hot gases from preheater or clinker cooler to raw mill
Raw material feed
Preheater. Hot gases from kiln heat raw feed and provide about 40% calcination before feed enters kiln
Some installations include a *Flash Furnace* that provides about 85% to 95% calcination before feed enters kiln
Materials are stored separately
Clinker
Dust collector
Tertiary air duct
Gypsum
Air
Fan
Dust bin
Rotating kiln
Clinker cooler
Clinker and gypsum conveyed to grinding mills


High efficiency dust collector
Cement product and air to dust collector
Exhaust gas
Fan
High efficiency separator
Mill product and air
Clinker
Gypsum
Secondary Air
Primary air from mill air sweep
Finished cement product to silo
Clinker and gypsum
Materials are proportioned
Separator rejects (tails) return to mill
Air
Ambient air
Mill discharge
Twin high-pressure roll press to precrush clinker entering the ball mill (optional)
Grinding mill
Solids
Bucket elevator to separator
Cement pump
Bulk storage
Bulk truck
Bulk car
Box car
Packaging machine
Truck

PORTLAND CEMENT

Type I Cement – Slow Cure Type II Cement – Slow/Med Cure	These are used in “standard” concrete. More can be added to increase strength and set times.
Type III Cement – Rapid Cure	Used for rapid set applications (repairs). Finely ground.

WHAT HAS HAPPENED

PORTLAND CEMENT

Type I Cement – Slow Cure

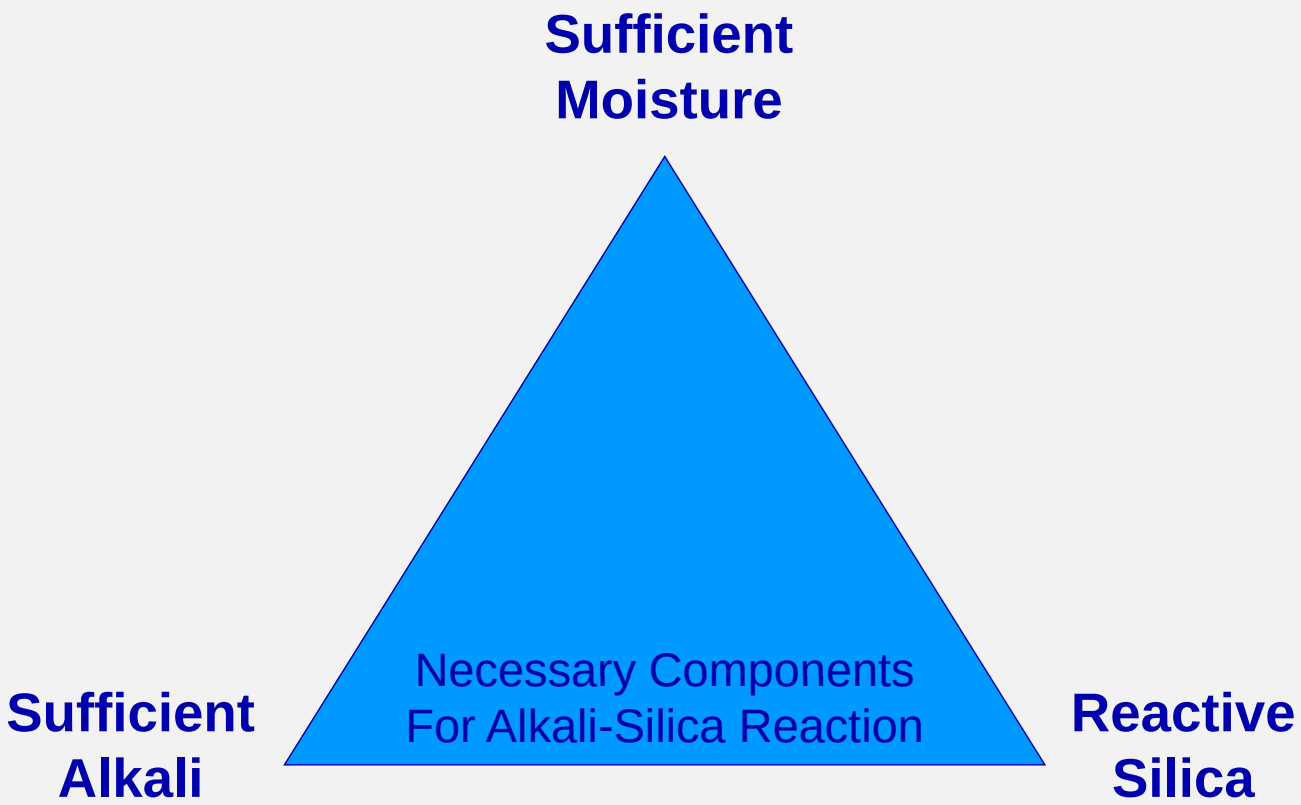
Type II Cement – Slow/Med Cure

Type III Cement – Rapid Cure

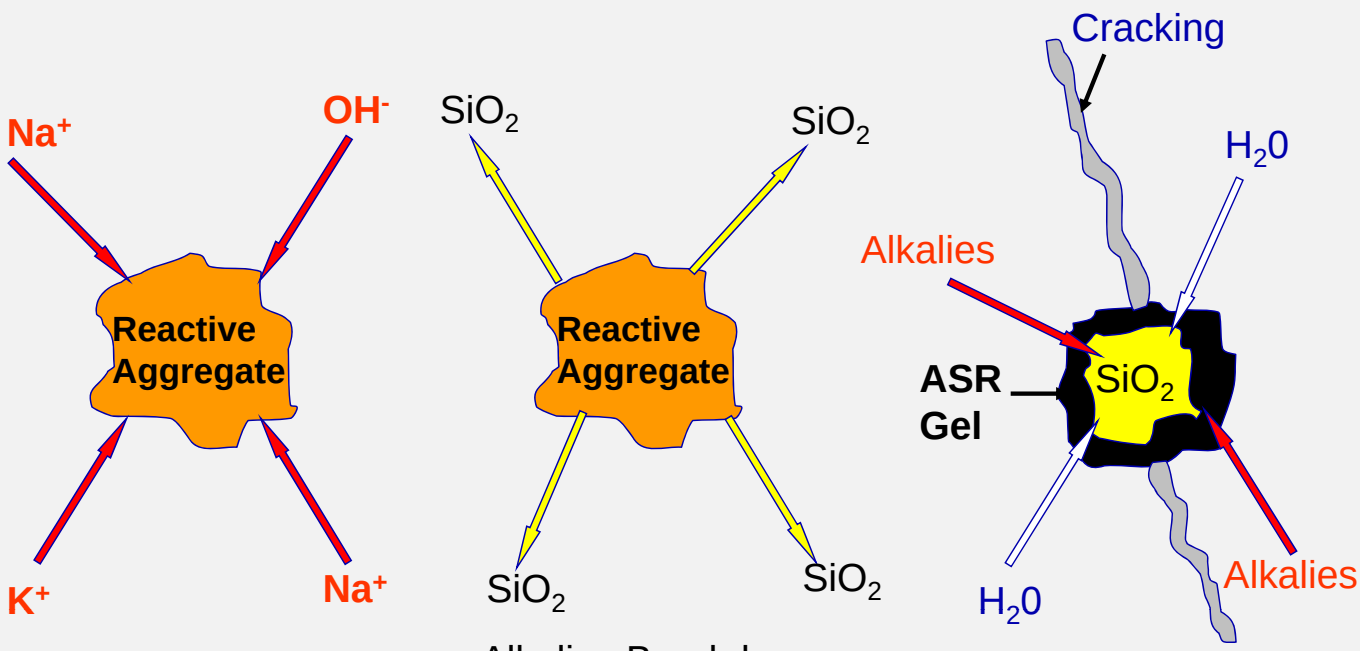
80's Environmental Constraints & Available materials

- Higher Alkali
- Natural Pozzolans no longer made, clay (IPN Cement)

ASR (Alkali Silica Reaction)


Sufficient
Moisture
Necessary Components
For Alkali-Silica Reaction
Sufficient
Alkali
Reactive
Silica

ASR Mechanism



Alkalies in Pore Solution

Alkalies Breakdown Aggregate and Release Reactive Silica

Silica Reacts with Alkalies and Absorbs Water to Produce Expansive ASR Gel

Mitigation Measures

Not Practical In Nebraska

- Eliminate one of necessary components
  - Use non-reactive aggregates
  - Limit the alkalies in cement and concrete
  - Limit the ingress of water
- Use of Supplementary Cementitious Materials
  - Fly Ash
  - Slag

PORTLAND CEMENT

Type IPF Cement

- **Type I/II Cement (Slow/Med Cure)**
- **“F” is Fly Ash Class F (25% replacement)**
- **Mitigates ASR at the Chemical Level**

CONCRETE

Classes of Concrete used today

CONCRETE

Class of Concrete

47B

47BD

PR1

PR3

SF

47BHE

BX

Concrete Mixes (Cubic Yard Batch)

Class of Concrete (1)	Base Cement Type*	Portland Cement (Min. lb/cy)	Pre-Blended Class Fly Ash (Min. lb/cy)	GGBFS Slag (Min. lb/cy)	Class C Fly Ash (Min. lb/cy)	Silica Fume (Min. lb/cy)	Total Cementitious Materials (Min. lb/cy)	Total Agg. (Min. lb/cy)	Total Agg. (Max. lb/cy)	Coarse Agg. (%) (3)	Type of Coarse Agg.	Air Content (% Min.-Max.) (2)	Water/Cement Ratio Max. (4)	28-Day Required Strength (Min. psi)
47B**	1PF	423	141*	0	0	0	564	2850	3150	30±3	Limestone	7.5-10.0	0.48	3500
47B***	1PF	423	141	0	0	0	564	2850	3150	30±3	Limestone	6.0 – 10.0	0.48	3500
47BD	1PF	494	164	0	0	0	658	2500	3000	30±3	Limestone	6.0 – 10.0	0.42	4000
PR1	I/II	752	0	0	0	0	752	2500	2950	30±3	Limestone	6.0 – 10.0	0.36	3500
PR3	III	799	0	0	0	0	799	2500	2950	30±3	Limestone	6.0 – 10.0	0.45	3500
SF	I/II	564	0	0	0	25	589	2850	3200	50±3	Limestone	6.0 – 10.0	0.36	3500
47BHE	1PF	564	188	0	0	0	752	2500	3000	30±3	Limestone	6.0 – 10.0	0.40	3500
BX	1PF	423	141	0	0	0	564	2850	3150	0	0 (5)	6.0 – 10.0	0.48	3500

(1) Each class shall identify the minimum strength requirement. (For example, 47B-3500, where the last four digits indicate the strength in pounds per square inch. In the chart, strength of 3500 psi is indicated fro 47B-3500; however, other strengths may be authorized elsewhere in the contract. The classes shown in the chart are typical examples.)
All classes of concrete shall be air-entrained.
A slump test shall be performed to check for consistency and/or workability. Any increase in slump must be pre-approved by the Engineer.
A water reducer admixture shall be used at the manufacturer's recommendations.

(2) As determined by ASTM C 138 or ASTM C 231.

(3) Coarse aggregate shall be limestone unless otherwise specified.

(4) The Contractor is responsible to adjust the water/cement ratio so that the concrete supplied achieves the required compressive strength without exceeding the maximum water/cement ratio. The minimum water/cement ratio for any slip form concrete pavement is 0.38.

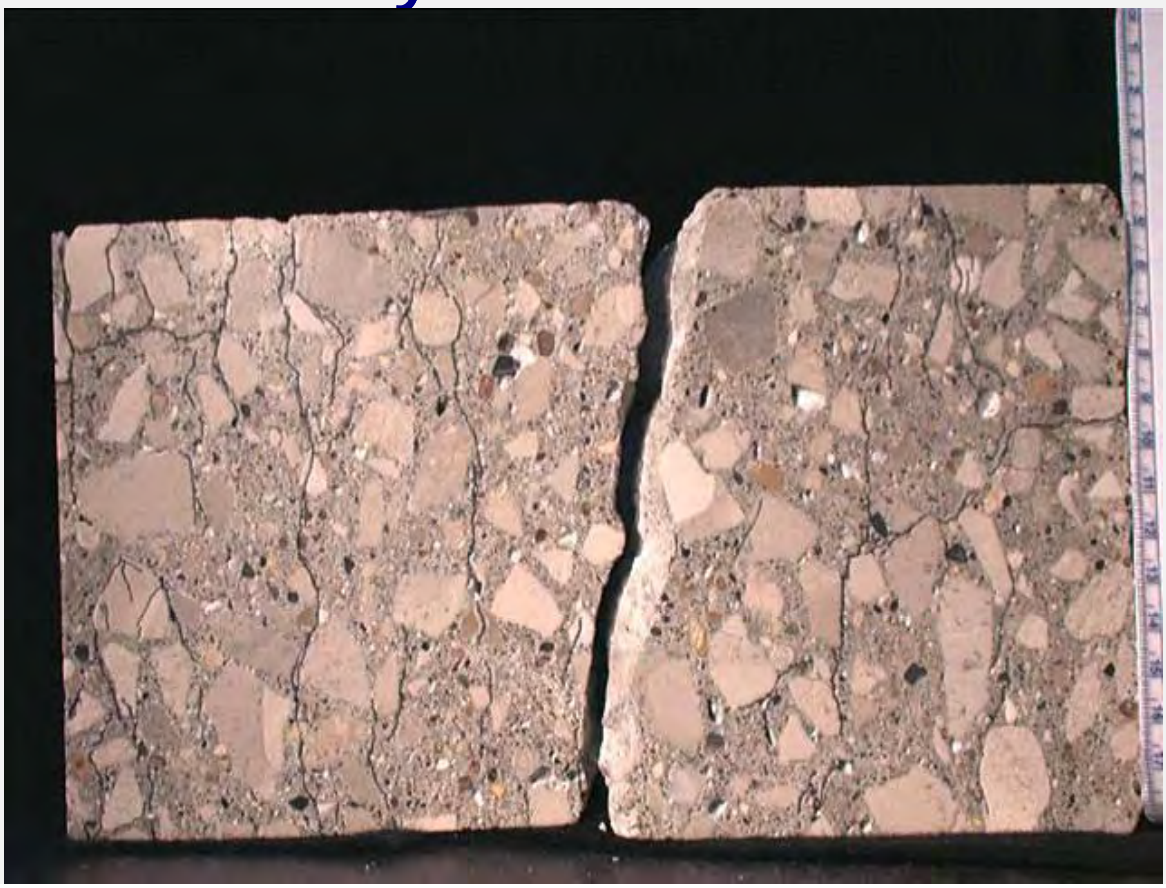
(5) Single aggregate (sand-gravel) used for these classes of concrete.

(*) Mixes with Type 1PF and Class F fly ash designation are pre-blended or interground with Class F fly ash by the cement mill producer at a rate of 25%±2%, no additional Class F fly ash is added at the batch plant.

(**) For slip form applications.

(***) For hand-pours and substructures applications.

Air System in PCC



PORTLAND CEMENT

Improve design for controlling moisture and load related issues

- Foundation Courses
- Granular Drains
- Dowel Bars
- 30’ Tops
- Joint Sealing

CONCRETE DESIGN PROPERTIES

Elastic Modulus (E_c) vs. Resilient Modulus (M_r)

M_r is a measure of stress vs. strain which is typically used for materials that can be permanently deformed from loading, such as soils or flexible pavement.

E_c is a fundamental engineering measurement of stiffness and is used for concrete design because loading of PCC does not cause permanent deformation (rigid).

E_c is based directly from compressive strength.

$$E_c = 57{,}000(f'_c)^{0.5}$$

f'_c is compressive strength (typically at 28-days)

CONCRETE DESIGN PROPERTIES

$$E_c = 57{,}000(f'_c)^{0.5}$$

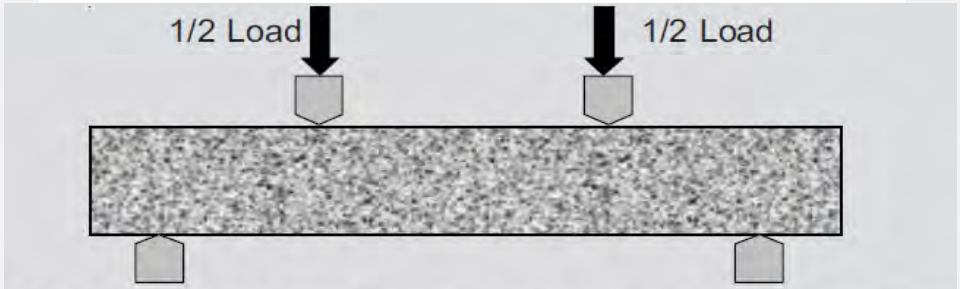
If f'_c =3500 psi, then E_c =3,372,165 psi

Traditionally we have achieved f'_c =5174 psi average 28-day strength on 47B-3500 mixes which results in

E_c =4,100,000 psi

CONCRETE DESIGN PROPERTIES

Modulus of Rupture *(Flexural Strength)*



ASTM C 78 - Third-Point Loading - half the load is applied at each third of the span length. MR is lower than center-point loading. Maximum stress is present over the center 1/3 portion of the beam

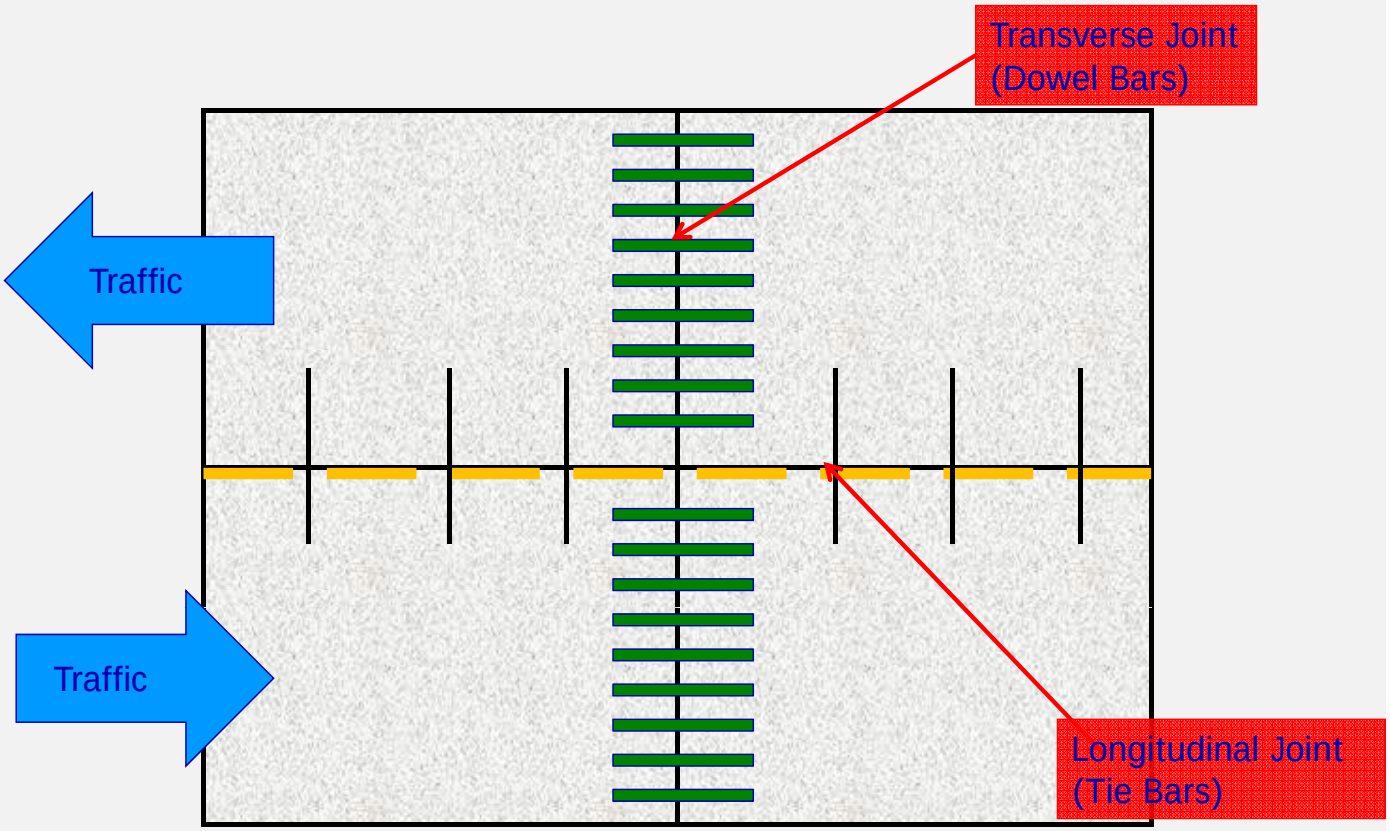
Third-Point loading at 28-days
Traditionally we use

S_c =710 psi

*Seeing current averages closer to **680psi***

256
547

JOINTS

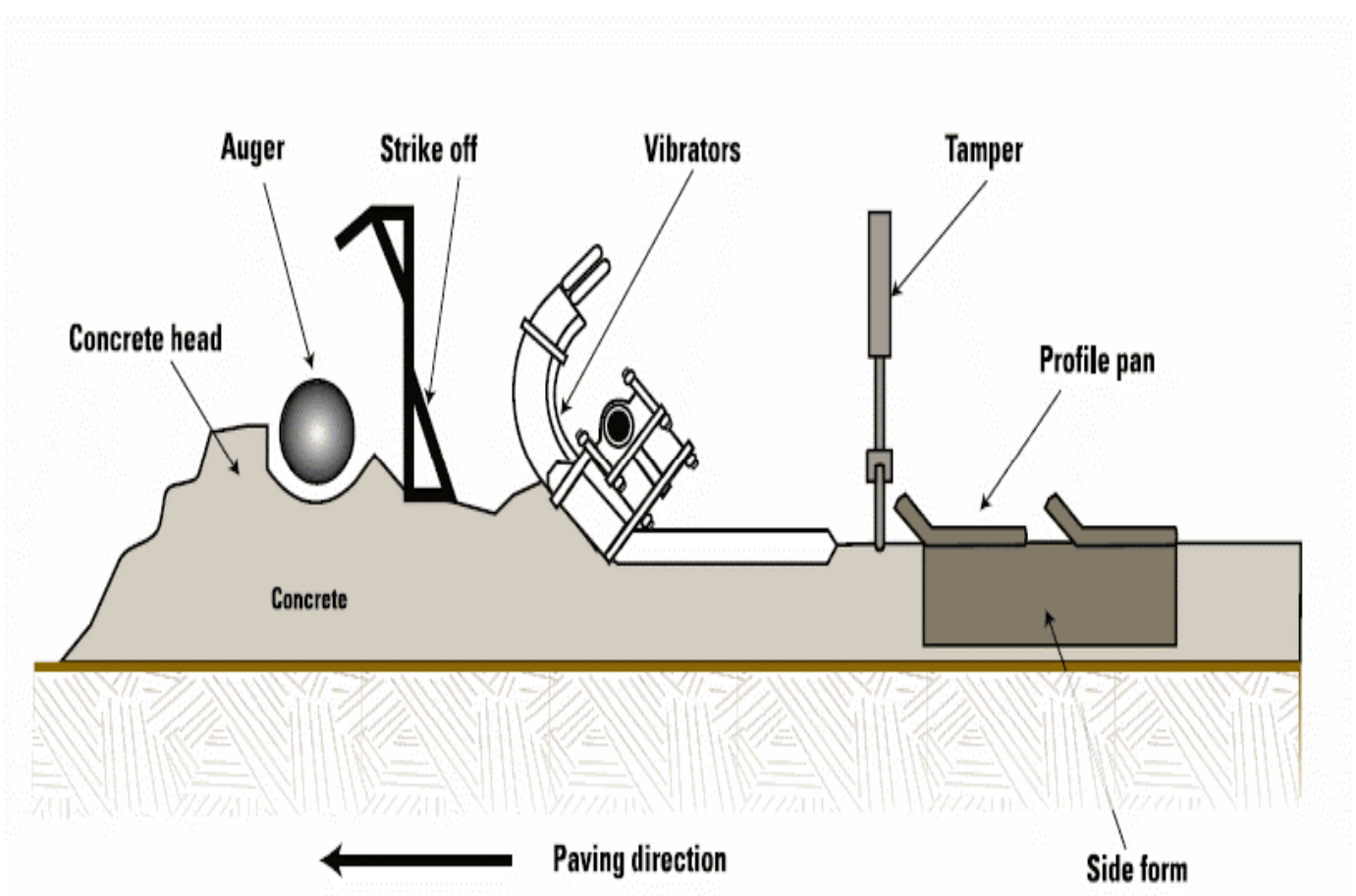

Transverse Joint
(Dowel Bars)
Traffic
Traffic
Longitudinal Joint
(Tie Bars)

Load Transfer Coefficient, J

Doweled PCC mainline w/tied Concrete Shoulder	3.0
Doweled PCC mainline w/widen section (28'-30')	3.1
Doweled PCC mainline w/asphalt or turf shoulder	3.2

~~Non-Doweled PCC mainline w/tied concrete shoulder~~	~~3.6~~
~~Non-Doweled PCC mainline w/asphalt or turf shoulder~~	~~4.1~~

Recommend using Doweled PCC For new build designs


Auger
Strike off
Vibrators
Tamper
Concrete head
Profile pan
Concrete
Paving direction
Side form

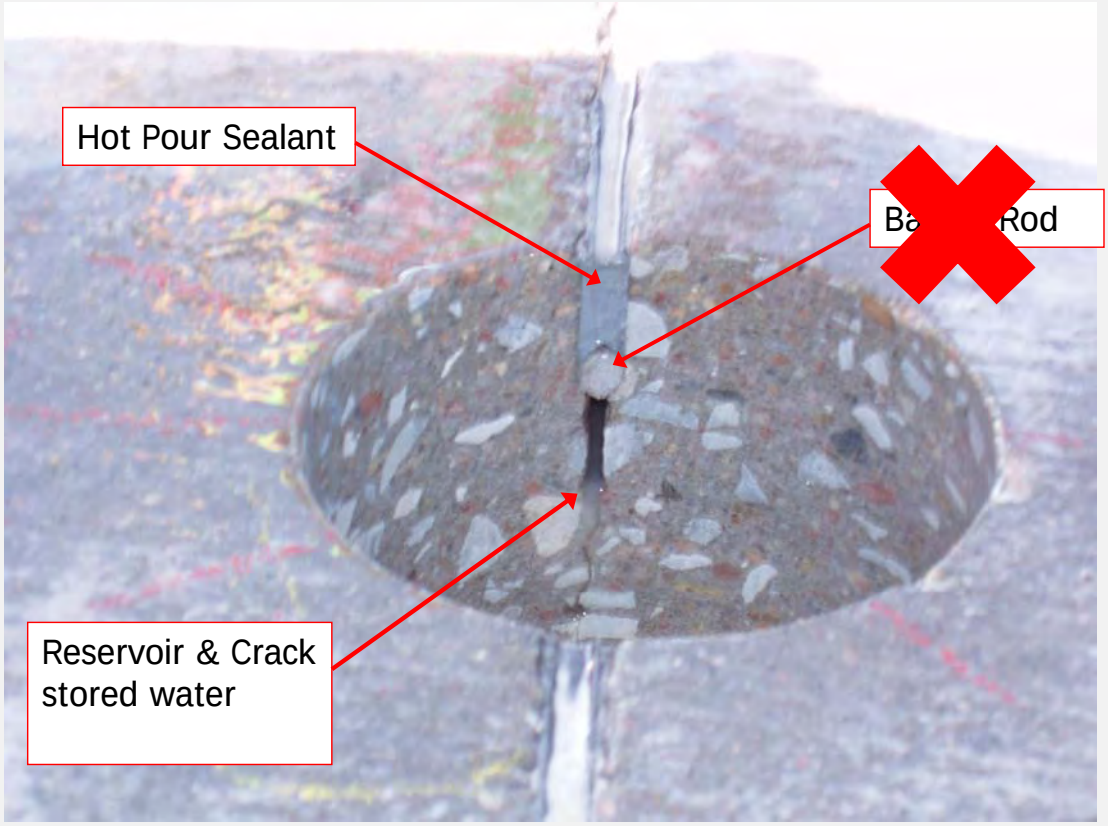
GOMACO

TARGET
TARGET
PRO 55 TF
60197

SOFF-CUT
18-138

60
FINES
DOUBLE

Joint Seal

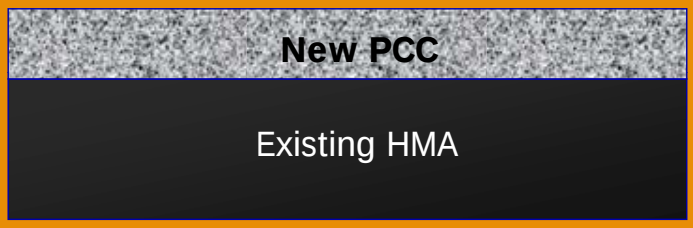


Joint Seal

WHITETOPPING
&
CONCRETE OVERLAYS

TERMINOLOGY

- WHITETOPPING
  Placing new Portland Cement Concrete over existing Hot-Mix Asphalt



TERMINOLOGY

- CONCRETE OVERLAY
  Placing new Portland Cement Concrete over existing Portland Cement Concrete

TERMINOLOGY

- ULTRA THIN
  Typically 2”-4”
  Bonded to existing surface

- CONVENTIONAL
  Typically 5” or more
  Not Bonded to existing surface

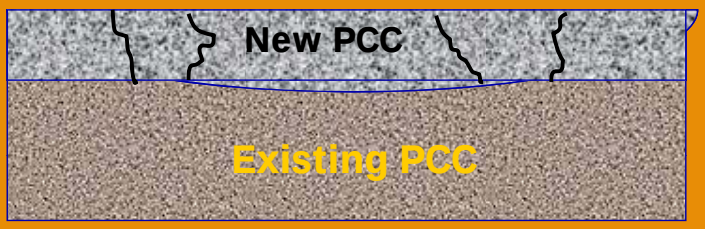
BONDED ULTRA THIN

BOND TO EXISTING PAVEMENT IS CRITICAL!

MUST BEHAVE MONOLITHICALLY

BONDED ULTRA THIN

CURLING



BONDED ULTRA THIN

LOAD STRESS

BONDED ULTRA THIN

GOOD BONDING TECHNIQUES

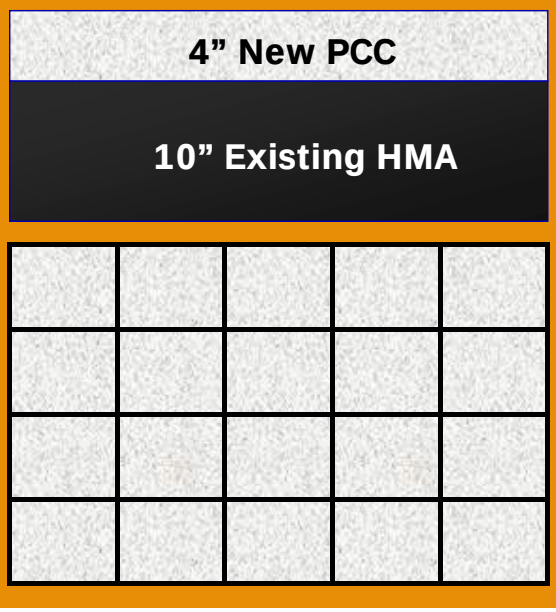
- MILL SURFACE
- APPLY BONDING AGENT (EPOXY OR GROUT)
- SHOTBLASTING SURFACE
- SURFACE MUST BE CLEAN

BONDED ULTRA THIN

JOINTS

WHITETOPPING

- 2'-6' SPACING



PCC OVERLAYING

- MATCH EXISTING

BONDED ULTRA THIN

FIBER REINFORCEMENT

- STEEL, POLYPROPYLENE AND OTHER SYNTHETICS
- INTENDED TO IMPROVE FLEXURAL STRENGTH
- MAY AID IN PLASTIC SHRINKAGE CRACKING
- CAN ADD UP TO $20/CY

BONDED ULTRA THIN

PERFORMANCE IN OTHER STATES

- MIXED PERFORMANCE
- SOME REFLECTIVE CRACKING
- CORNER CRACKING (LOST BOND)

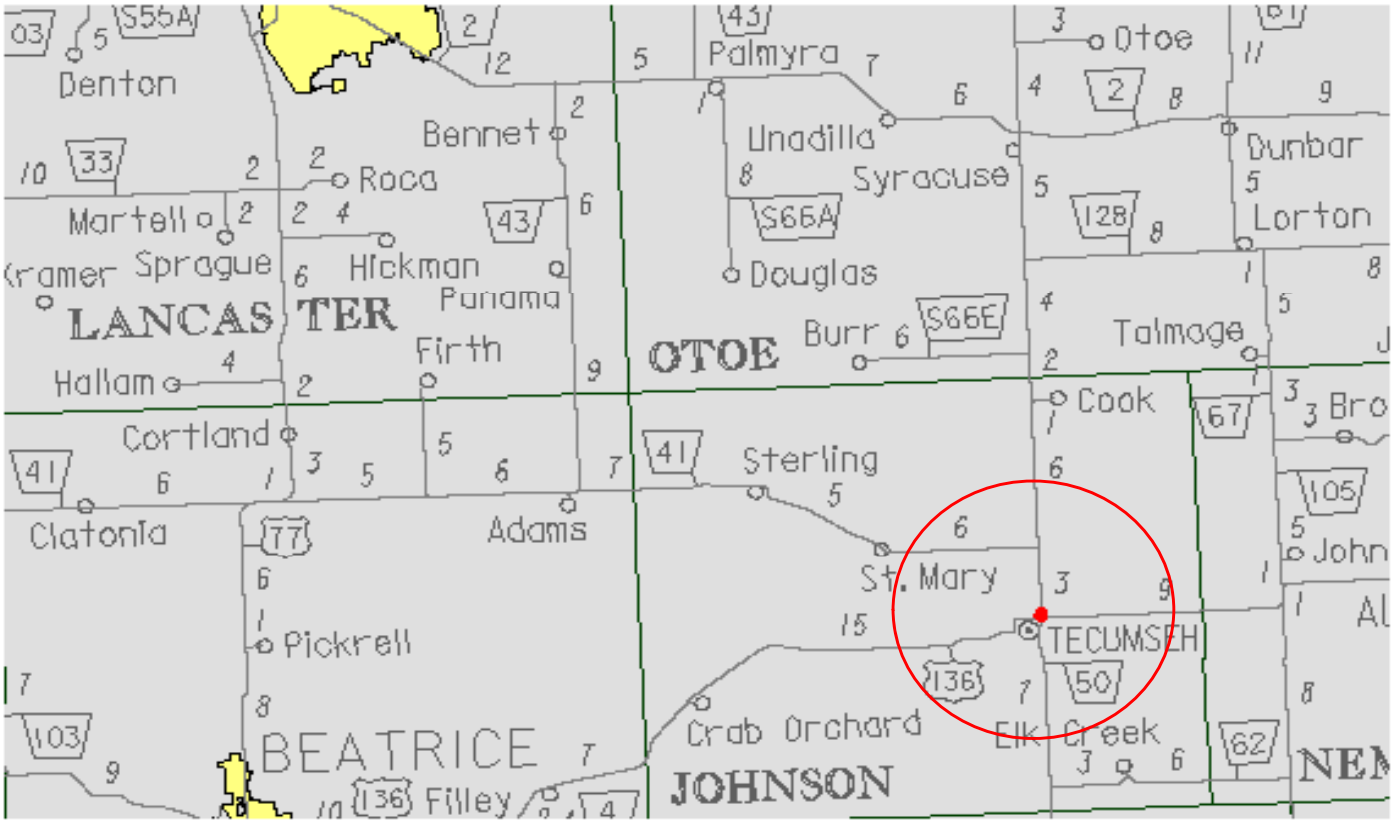
BONDED ULTRA THIN

BONDED ULTRA THIN

IN NEBRASKA

- N-50 NORTH OF TECUMSEH 2001
- MILLED EXISTING CONCRETE
- 4.5” UTW WITH FIBER REINFORCEMENT
- WIDENED 3’ x 12” EACH

BONDED ULTRA THIN



BONDED ULTRA THIN

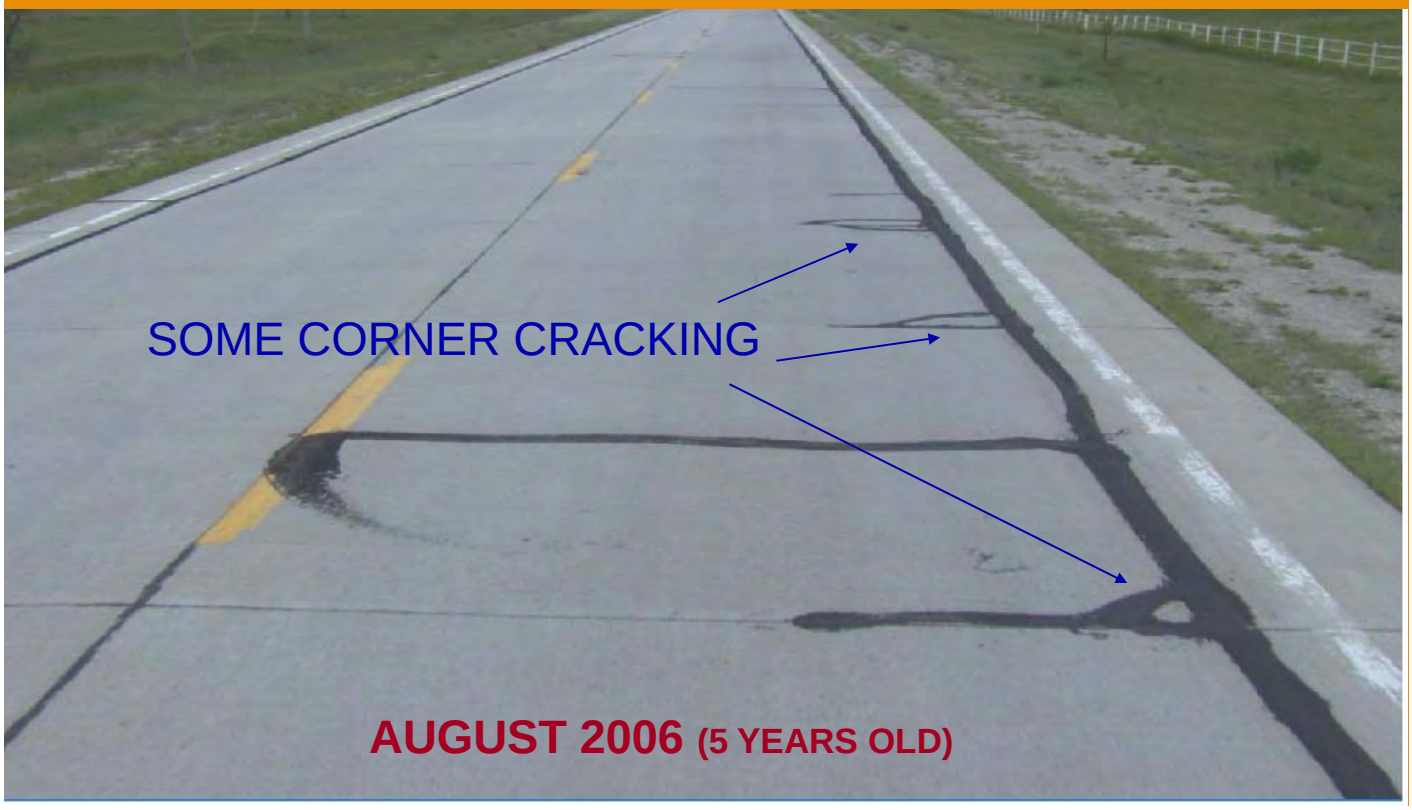
BONDED ULTRA THIN

BONDED ULTRA THIN

BONDED ULTRA THIN

BONDED ULTRA THIN

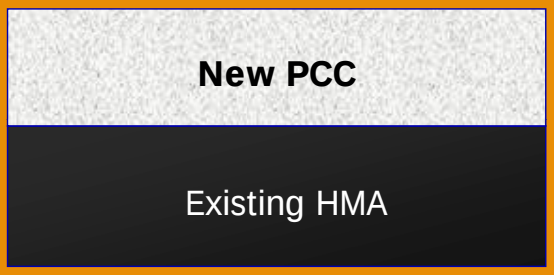
BONDED ULTRA THIN



COMMENTS

CONVENTIONAL

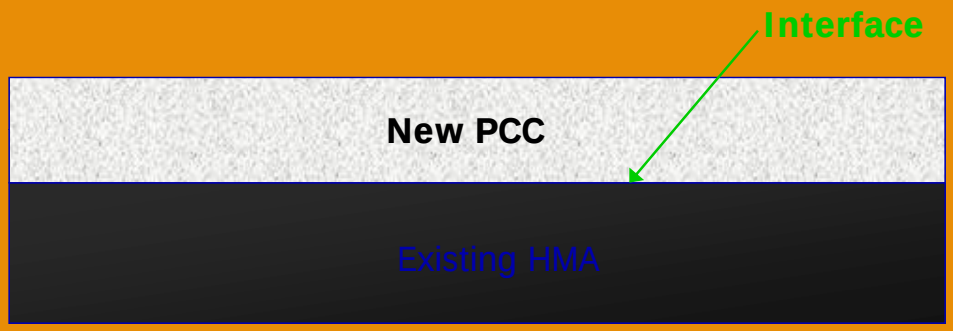
- TYPICALLY 5” – 12”
- NON-BONDED



CONVENTIONAL

WHITETOPPING

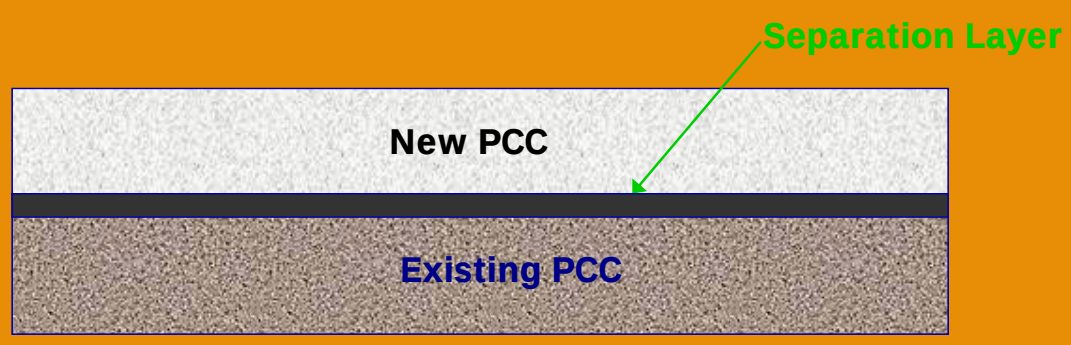
- Minimal surface preparation
- Uniform base = best performance



CONVENTIONAL

PCC OVERLAYING

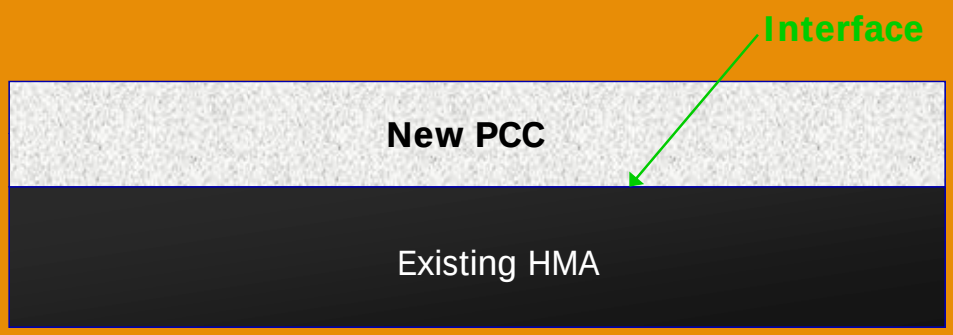
- Minimal surface preparation
- Separation Layer
- Uniform base = best performance



CONVENTIONAL JOINTS

WHITETOPPING

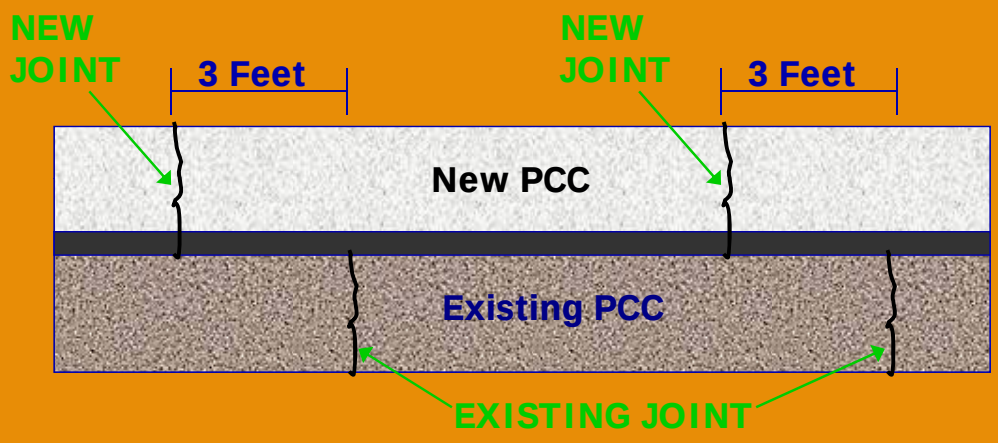
- 21 x Thickness (non-dowelled)
- NDOR currently uses 16.5' for dowelled



CONVENTIONAL JOINTS

PCC OVERLAYING

- Same 21 x thickness (non-dowelled)
- Offset existing joints by ±3'



GRADE RAISES

TRANSITIONS

CONVENTIONAL

PERFORMANCE IN OTHER STATES

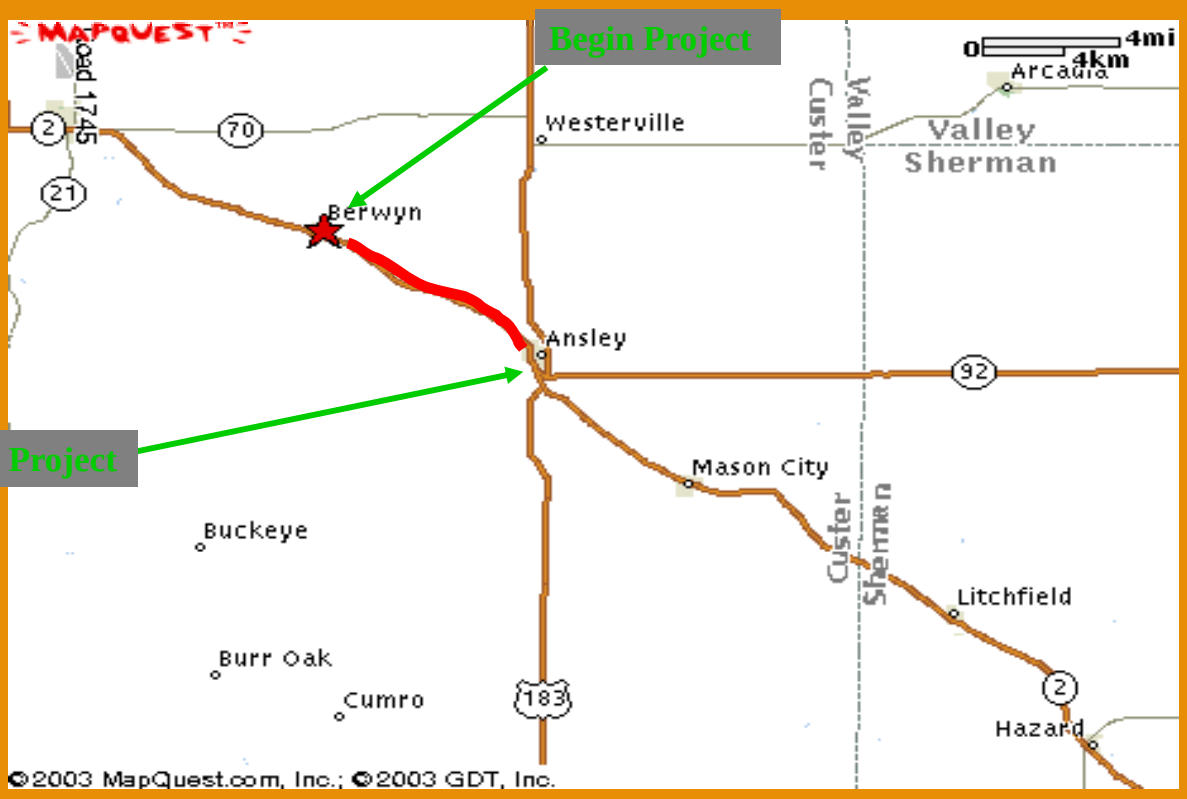
- OVERALL GOOD - EXCELLENT PERFORMANCE

CONVENTIONAL

IN NEBRASKA

- N-2, BERWYN to ANSLEY 2003
- MILLED EXISTING ASPHALT
  (Several inches to meet grade line)
- PLACED 8” DOWELLED PCC

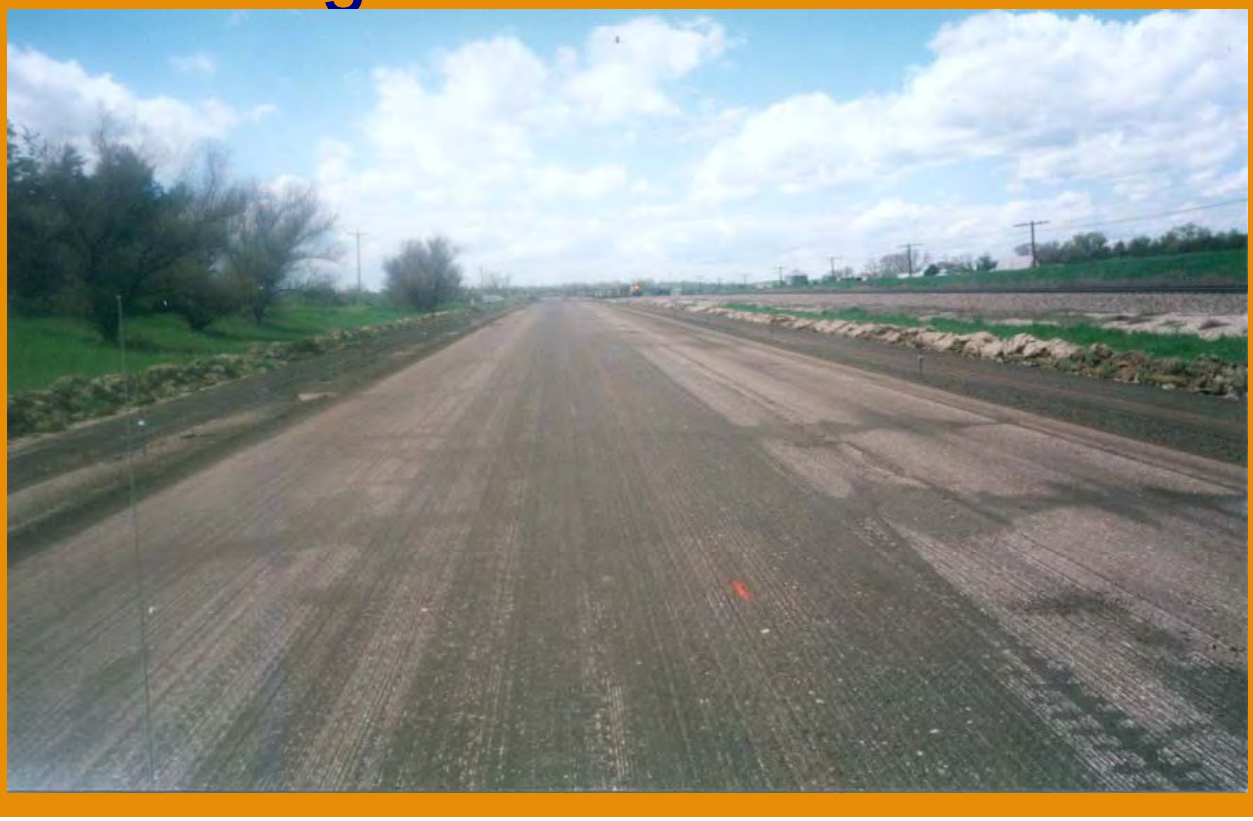
WHITETOPPING



Hwy 2 Berwyn – Ansley Pavement Section

Milled Roadway

Vertical and Horizontal Alignment Established



Dowels Installed and Ready to Start Paving Operations

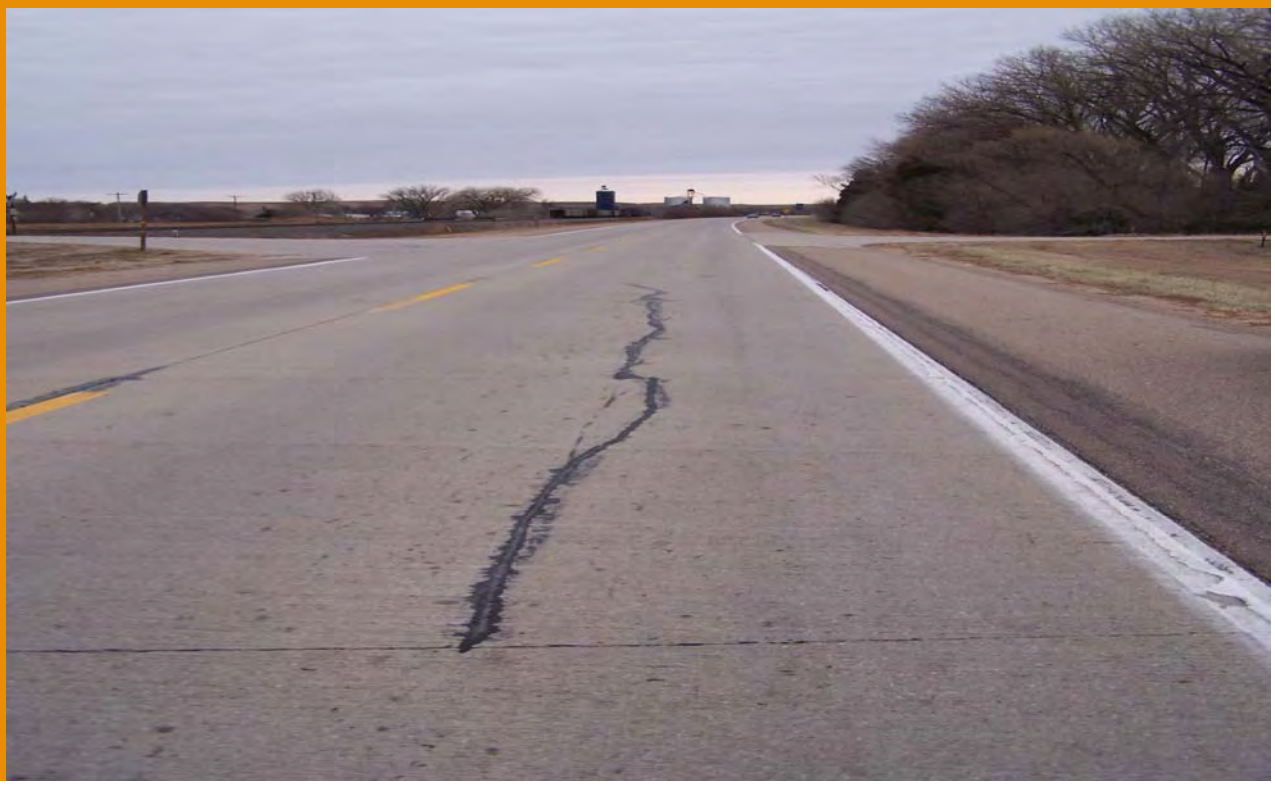
Paving

Applying Curing Compound

Asphaltic Concrete and Earth Shoulders

OPEN TO TRAFFIC

3 YEARS LATER



SOME ISSUES

- String line pins difficult to drive
- Dowel basket placement
  - Labor intensive
  - Different ties required to anchor
- Gradeline difficult to adjust
  - Variable Plan thickness vs. Bid item
  - Template checks need to be performed well in advance of paving operations
  - Thin cores, thick pavement

Positive Aspects of Whitetopping

- Provides stable paving platform
- Minimal weather delays
- No subgrade preparation or density requirements
- Trackline on milled surface exceptional for smoothness
- Minimal environmental impact
  - Dust
  - Waste materials

?

OUTLINE

- **Pavement, cont'd.**
  - **Asphalt (Flexible)**
    - **History of HMA**
    - **PG Binders**
    - **HMA Construction**
  - Recycling
    - Partial Depth HMA
    - Full Depth HMA
    - PCC Recycling
- Pavement Design
  - Traffic
  - Rigid Design
  - Flexible Design
- Review Deliverables
- NDOR Pavement Design Manual
  - Quick References
- Maintenance
  - Emulsions
  - HMA maintenance
  - PCC maintenance

ASPHALT

FLEXIBLE Pavement

Binder (asphaltic cement)

Aggregate (ledge rock, gravel, sand)

ASPHALT

PRIOR TO 1970's

Asphalt Cement

Penetration Test (40-50 = stiff)

Method Spec Mixes

Bituminous Sands & Soil Aggr. Bases

Bituminous Mats & Surface Course

ASPHALT

PRIOR TO 1970's

ASPHALT

1970's to early 1990's

Asphalt Cement

Viscosity Test (A-5, A-10, A-20)

Marshall Mixes

Type B, A, BC, BF, C, AX….

No angularity-round aggregate

Performed good through the 80's.

Tire Pressures 70psi

ASPHALT

1970's to early 1990's

ASPHALT

Early 1990's to 1999

Asphalt Cement
- Viscosity Test (A-5, A-10, A-20)

Marshall Mixes
- Type 7, 17, 4, 14, 11, 13….

Volumetrics
- VMA, VFA….still no angularity

Severe rutting

Tire Pressures 120psi

ASPHALT

1999 - Current

Performance Graded Binders
PG 58-28, 64-28, 70-28….

SuperPave Gyratory Mixes
SP-4, SP-5, SPS…
OGFC & GGCRM

Volumetrics & ANGULARITY
VMA, VFA, FAA, CAA

Performing very good
Tire Pressures 120psi, but may increase

Shell
Shell
Shell
Shell
ROAD
TRAIN

ASPHALT

1999 - Current

Volumetrics

VMA – Voids in Mineral Aggregate

VFA – Voids Filled with Asphalt

Air Voids – Voids not filled with asphalt

D/B – Dust to Binder ratio

FAA – Fine Aggregate Angularity

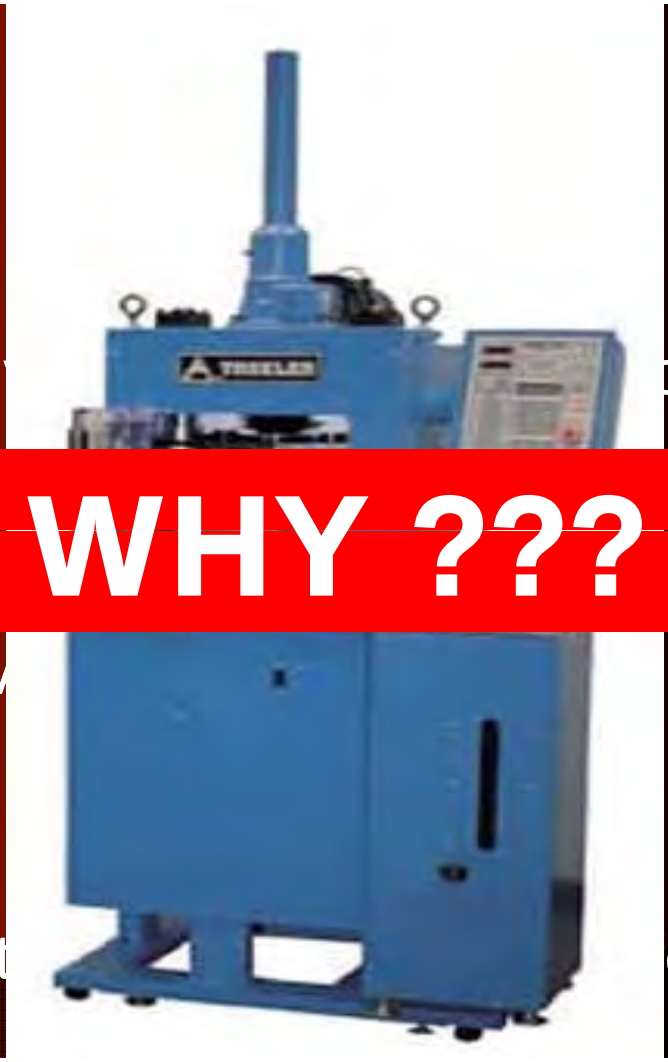
CAA – Coarse Aggregate Angularity

Vol

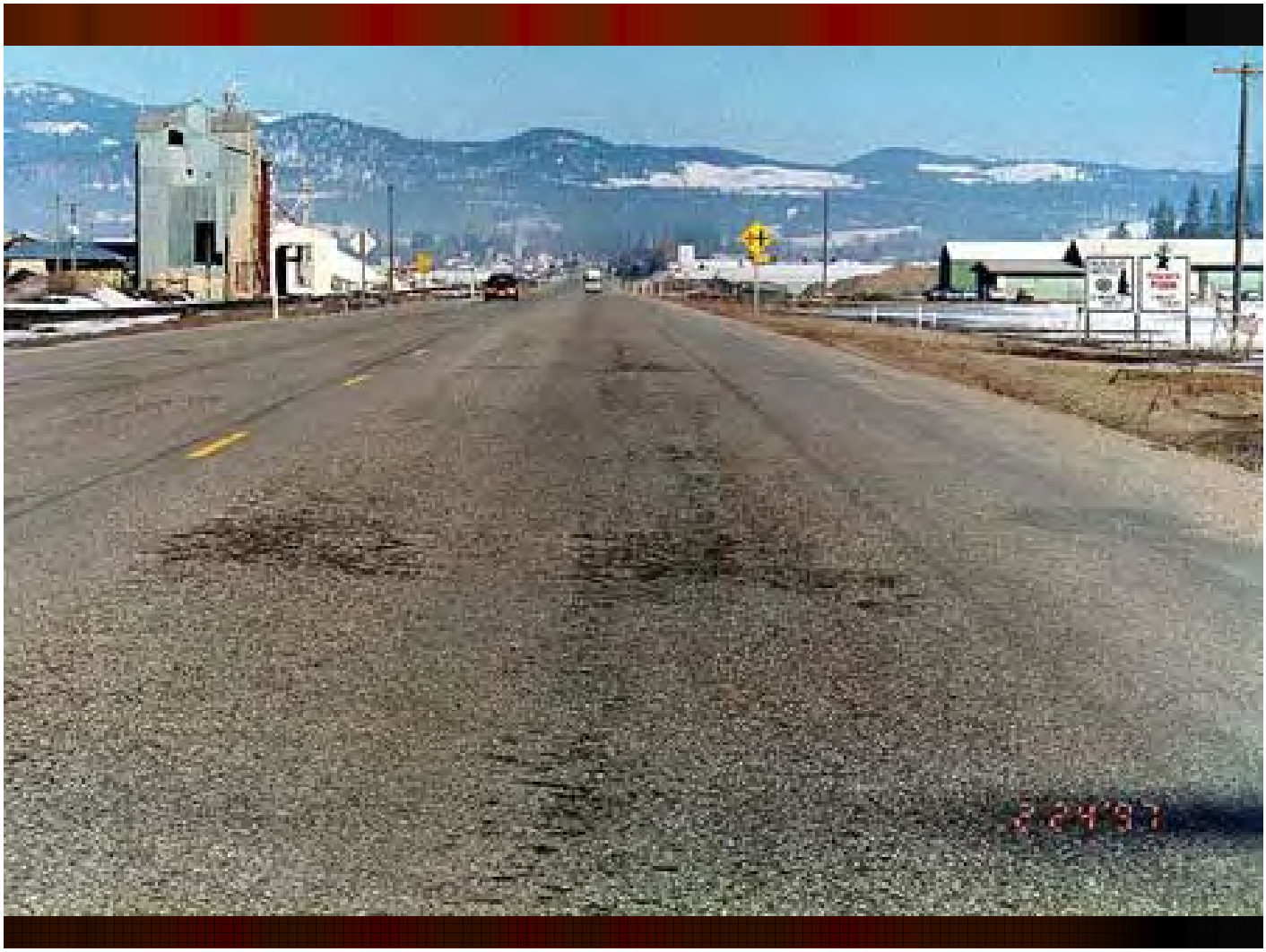
- N initial, 10
(# of blows to get on)

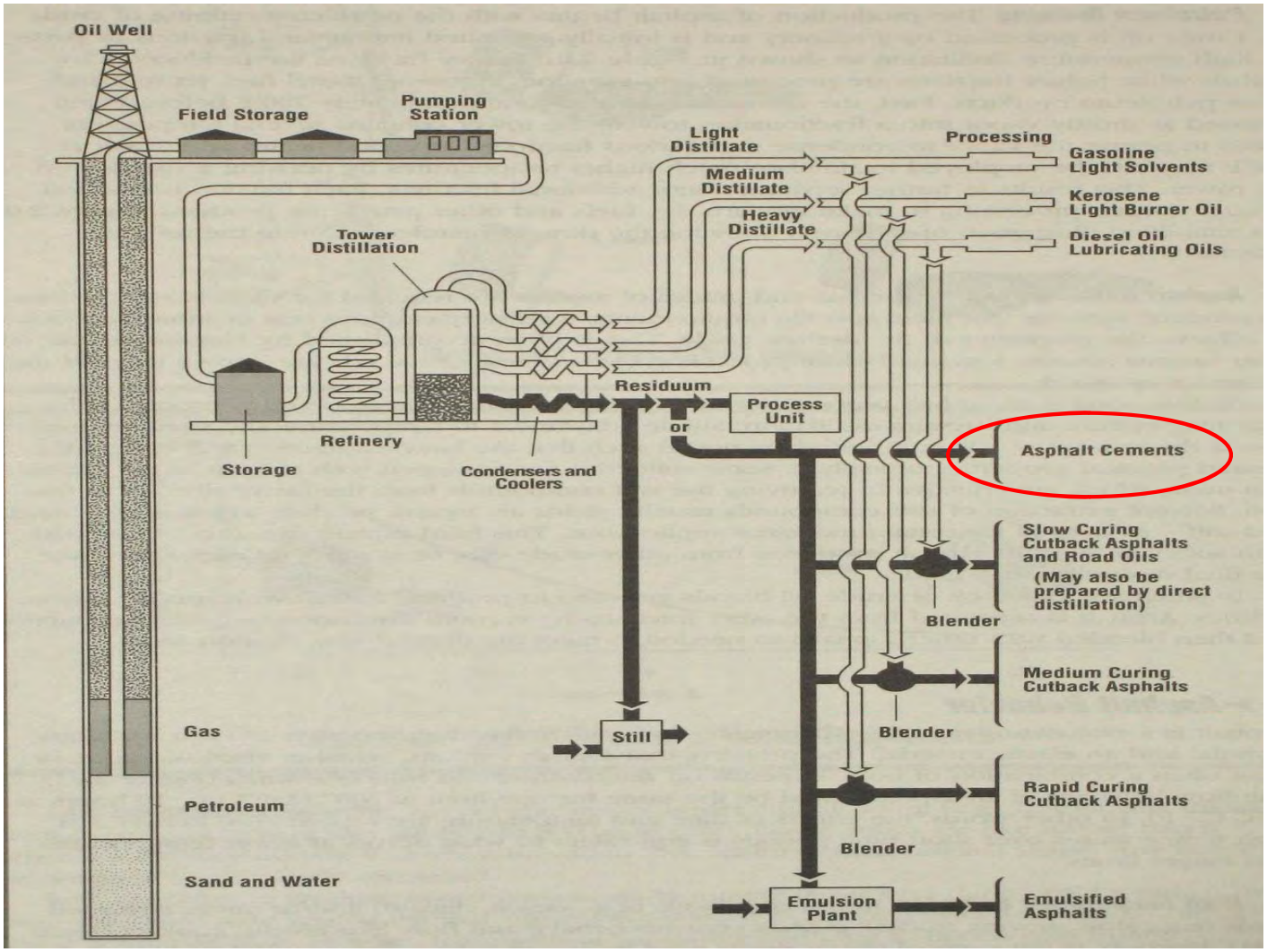
- N design, 96
(# blows to get v

- N max, 152
(blows to get to e)



WHY ???




Oil Well
Field Storage
Pumping Station
Light Distillate
Medium Distillate
Heavy Distillate
Processing
Gasoline Light Solvents
Kerosene Light Burner Oil
Diesel Oil Lubricating Oils
Tower Distillation
Residuum
Process Unit
or
Refinery
Storage
Condensers and Coolers
Asphalt Cements
Slow Curing Cutback Asphalts and Road Oils
(May also be prepared by direct distillation)
Blender
Medium Curing Cutback Asphalts
Blender
Gas
Still
Rapid Curing Cutback Asphalts
Petroleum
Blender
Sand and Water
Emulsion Plant
Emulsified Asphalts

PG 64-34

PG = Performance Graded

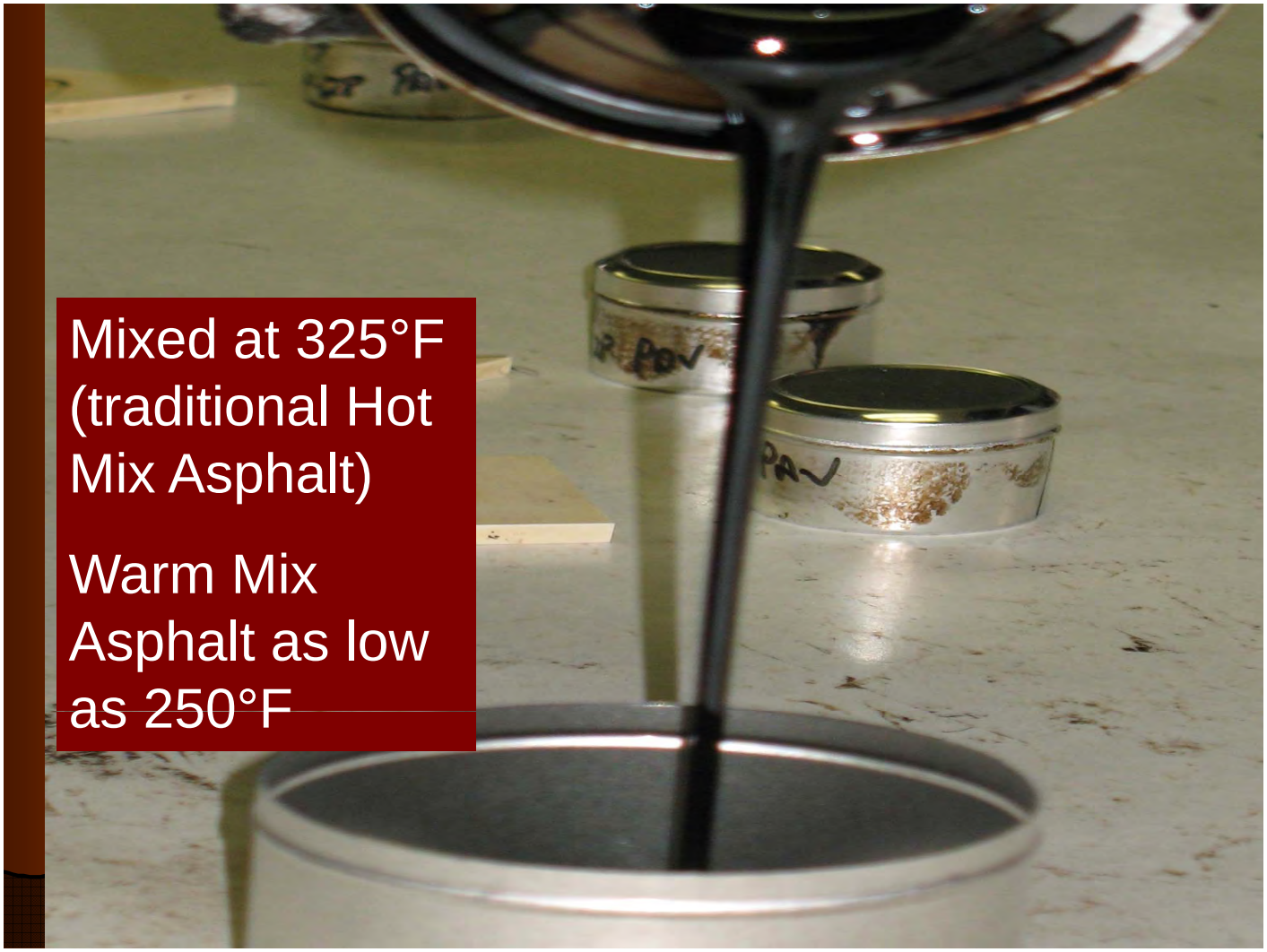
64 = 64°C (147°F)

-34 = -34°C (-29°F)

Base Oils: Was PG ~~58-28~~, but now is PG 52-34

(136-18)°F (126-29)°F

Modifications: SBS, SBR, crumb rubber (terminal & wet).....


Mixed at 325°F (traditional Hot Mix Asphalt)
Warm Mix Asphalt as low as 250°F

Gradations

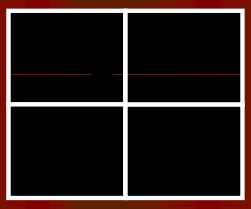
Gradation Bands
(Max Stone Size)

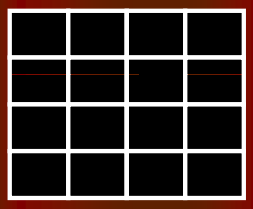
½" = 0.5" Band

$^{3}/_{8}$" = 0.375" Band

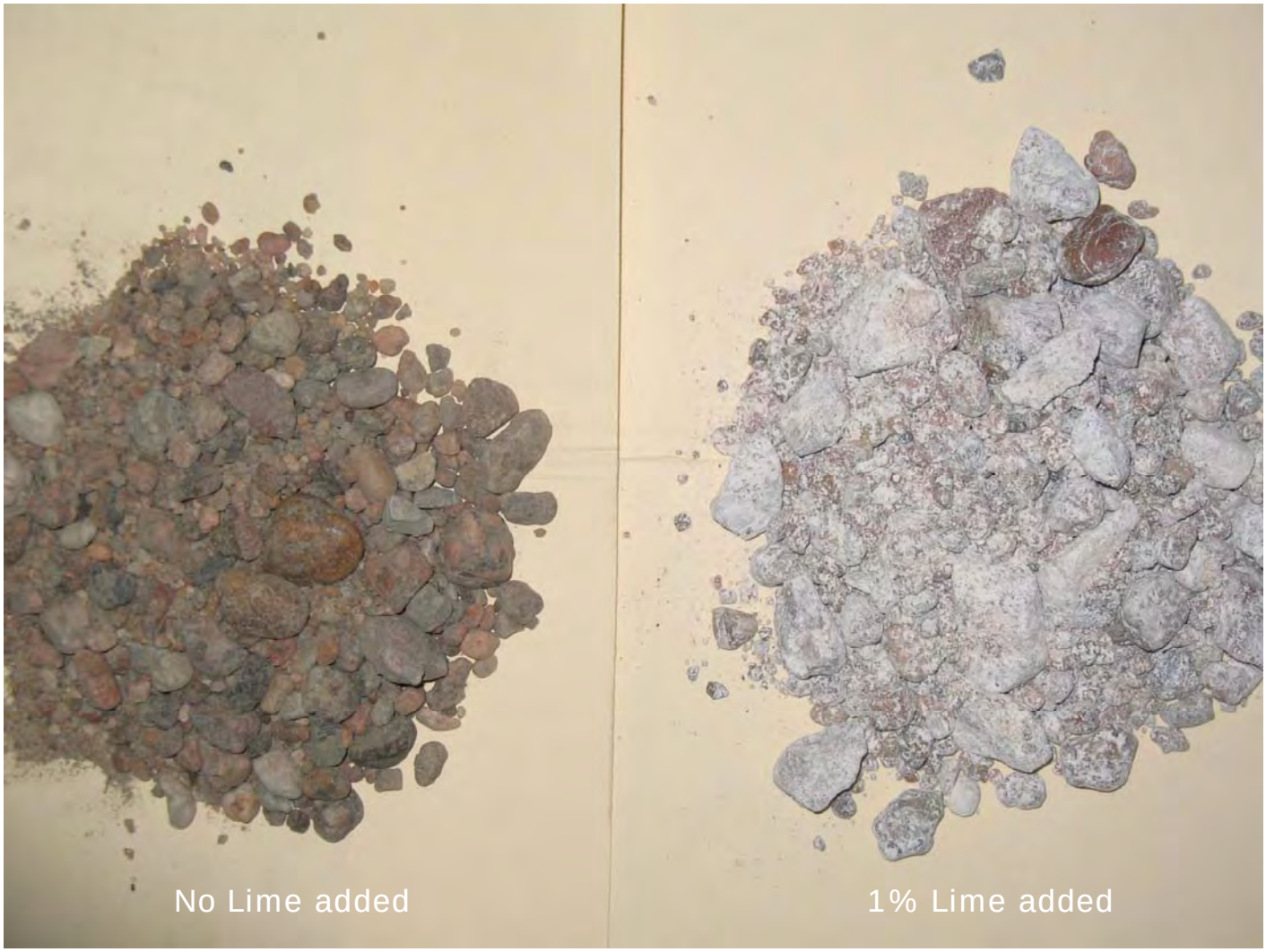
$^{3}/_{16}$" = 0.19" Band

Smaller the Stones = More Surface area =More Binder

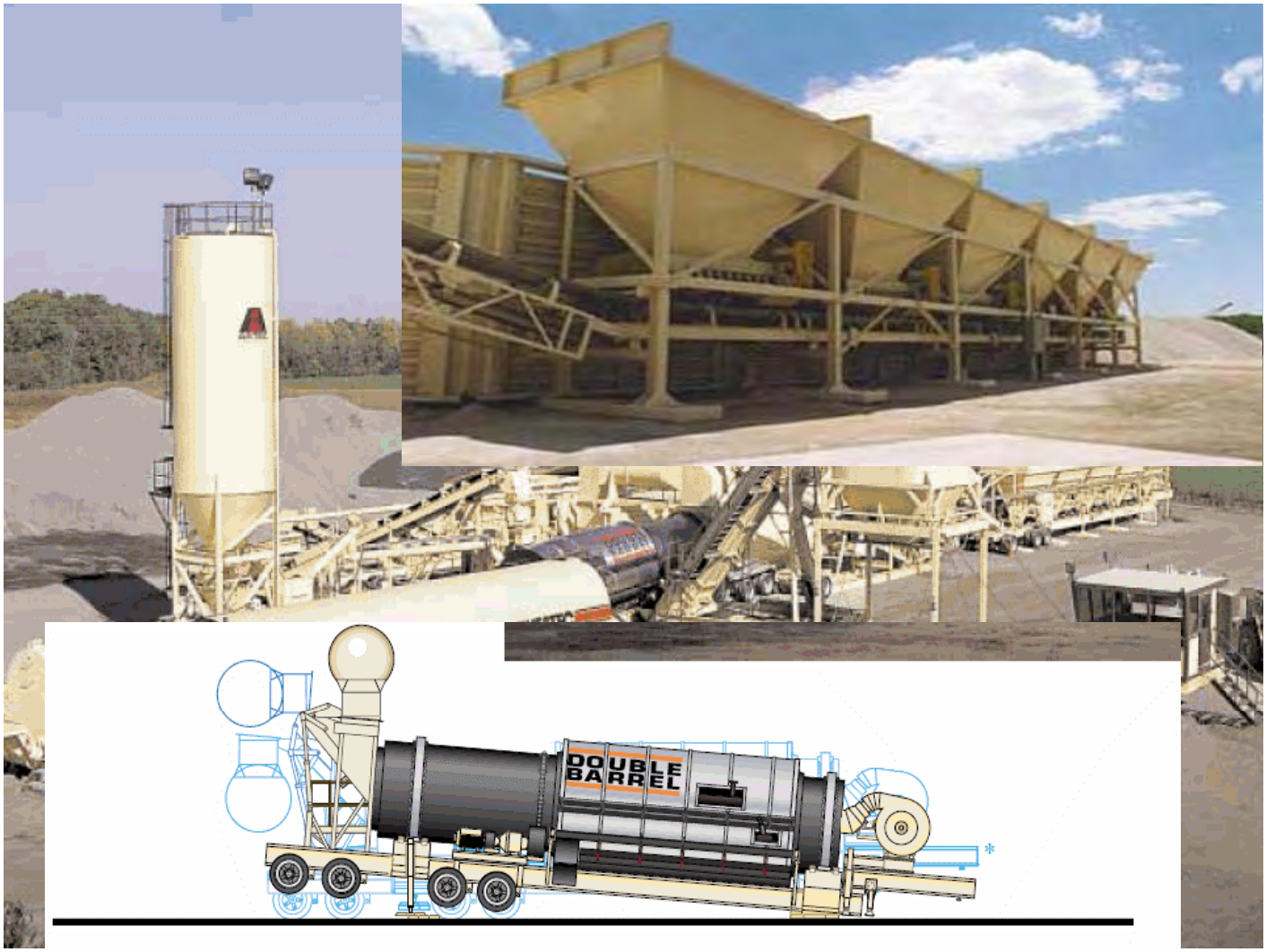




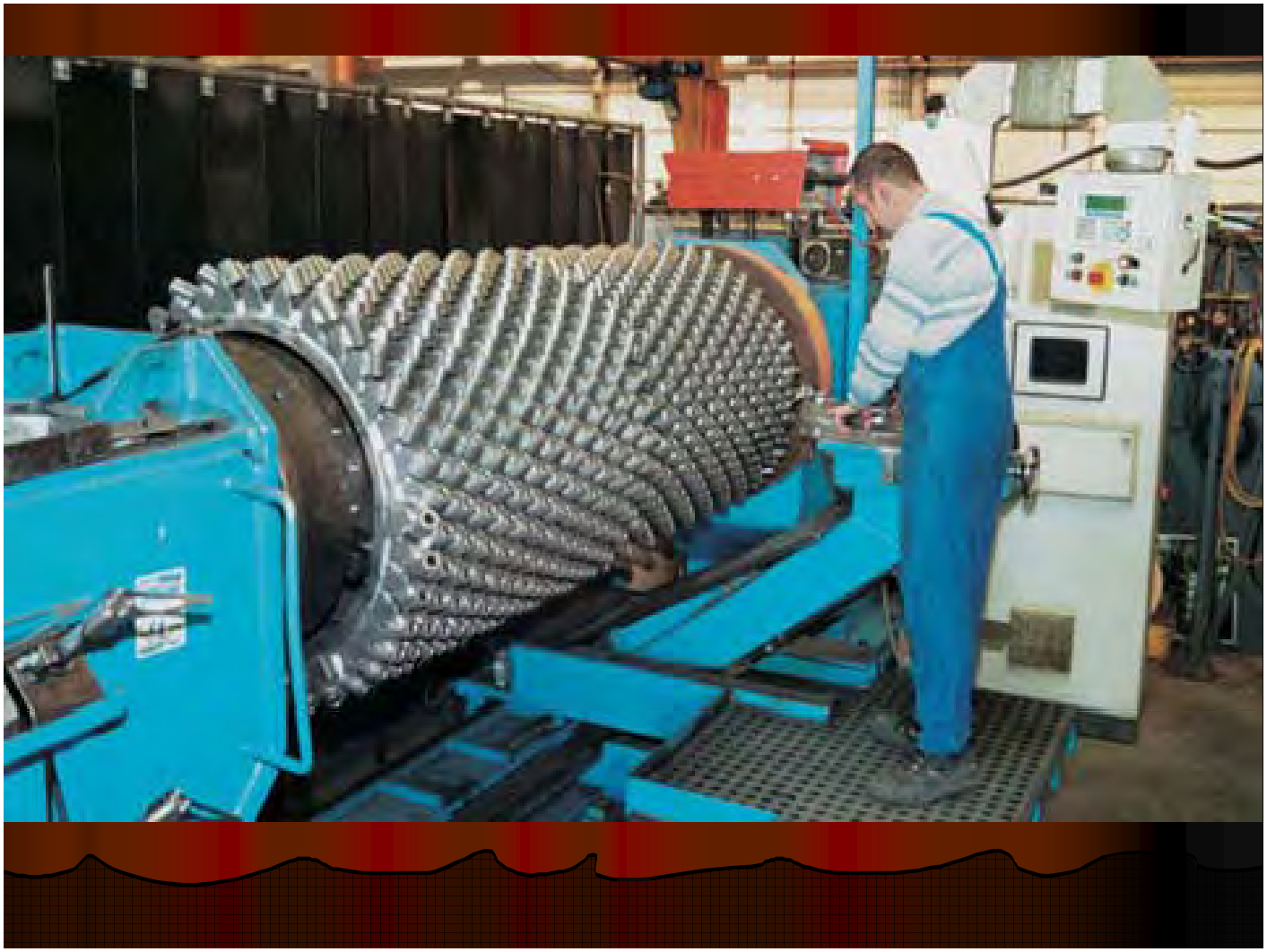
© 2002 WSDOT


No Lime added
1% Lime added

COLD FEED
INCLINE CONVEYOR
TURBO DOUBLE BARREL
RECYCLE BIN
BAGHOUSE


DOUBLE
BARREL

CATERPILLAR
PR-1000
NONPOTABLE WATER



CAT

CR451R
Cedarapids

20 12:26PM

18 3:20 PM

PAVERS
INGERSOLL-RAND
8531

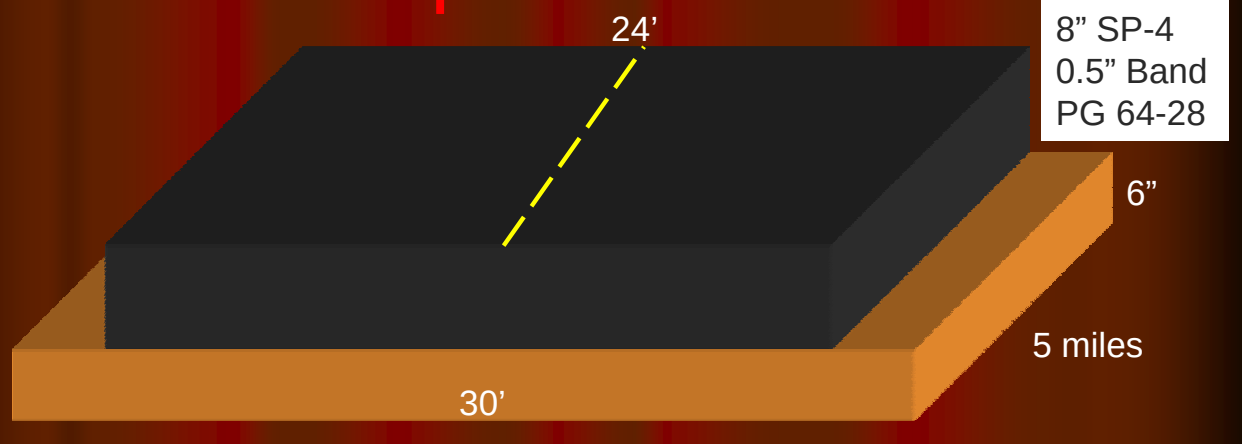
- Pavement Fabrics

Asphaltic Concrete

Pay Items

- Asphaltic Concrete, Type SP-4....
  Paid by the Ton
- Hydrated Lime for Asphalt Mixture
  Paid by the Ton
- Performance Graded Binder
  Paid by the Ton
- Tack Coat
  Paid by the Gallon

Asphaltic Concrete



Uniform pavement width 24' and (5 miles x 5280') 26,400' long

633,600 ft^2 x 8"= 422,400 ft^3

422,400 ft^3 x 143 lbs/ft^3 = 60,403,200 lbs = 30,202 Tons of SP-4

30,202 tons x 0.01 = 302 Tons of Lime

30,202 tons x 0.054 = 1631 Tons of PG 64-28

633,600 ft^2 = 70,400 yd^2

70,400 yd^2 x 0.05 Gal/yd^2 x 2 = 7,040 Gals of Tack Coat

OUTLINE

- **Pavement, cont'd.**
  - Asphalt (Flexible)
    - History of HMA
    - PG Binders
    - HMA Construction
  - **Recycling**
    - **Partial Depth HMA**
    - **Full Depth HMA**
    - **PCC Recycling**
- Pavement Design
  - Traffic
  - Rigid Design
  - Flexible Design
- Review Deliverables
- NDOR Pavement Design Manual
  - Quick References
- Maintenance
  - Emulsions
  - HMA maintenance
  - PCC maintenance

RECYCLING

TYPES OF RECYCLING

Partial Depth

Controlled Depth, typically 4” to 5”
Only want bound materials and not unbound base materials

Full Depth

Full depth of pavement structure
Typically includes a pre-determined amount of unbound base material, 1” to 2”

STABILIZING MATERIALS FOR RECYCLING

CHEMICAL

LIME

FLYASH

CEMENT

BITUMINOUS

ASPHALT EMULSIONS

EXPANDED ASPHALT

MECHANICAL

AGGREGATE

RECLAIMED ASPHALT

STRATEGY SELECTION

1)EXISTING PAVEMENT STRUCTURE

Type of pavement layer

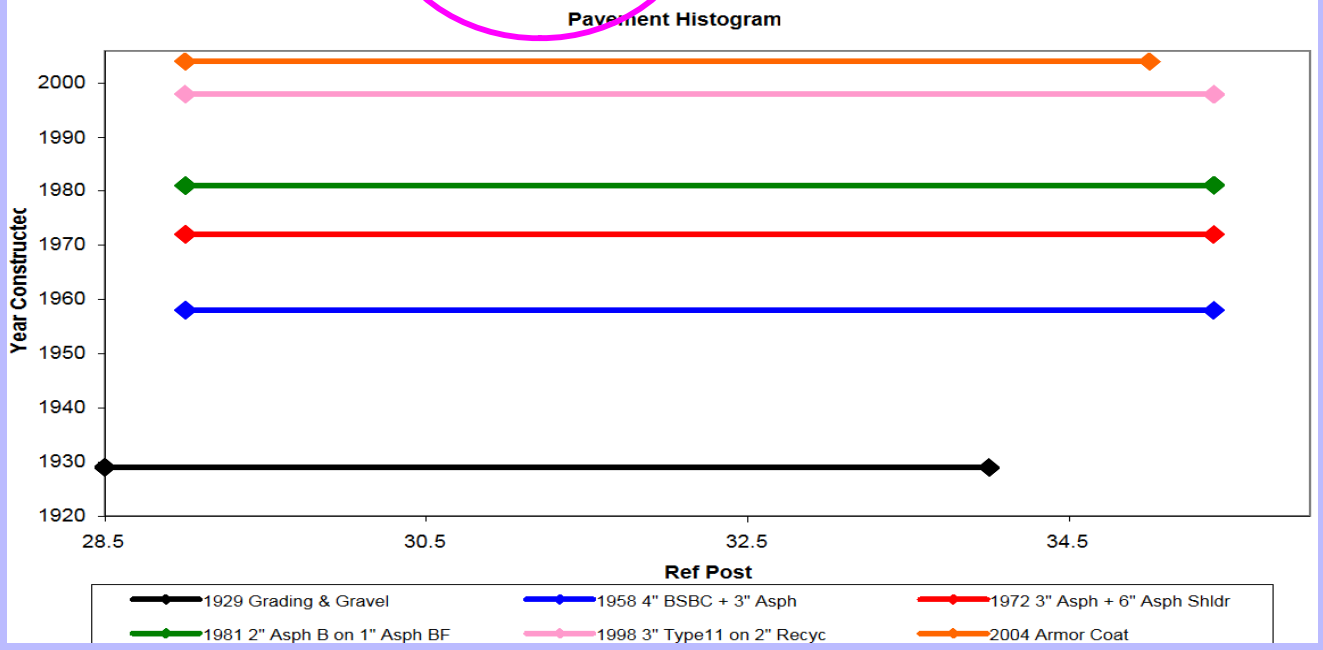
Age of each layer

Thickness of each layer

Other bound layers & unbound layers

HISTORY OF A ROADWAY

		Mainline Profile Summary:		Shoulder Profile Summary
Project #	STPD-9-4(113)			
C.N.	31512	2004 Armor Coat		
Location	In Emerson	1998 3" Type11 on 2" Recyc		
Hwy #	9	1981 2" Asph B on 1" Asph BF		
Ref Posts	29.00 - 35.00	1972 3" Asph + 6" Asph Shldr		
Date	1/8/2007	1958 4" BSBC + 3" Asph		
Prepared by	BV	1929 Grading & Gravel		1972 6" AC Shldr



Pavement Management

Pavement Management System

Pavement Management Data

Dist Num	HwyNum	Beg Ref Post	End Ref Post	Dir	Length	Type	Age	Lanes
06	002	228.140	238.680	B	10.55	1	6	2

Location Description: HALSEY-DUNNING

Trvlwy Wdth	shoulder TotWdth	SurfWdth	CondRtng	Slope
24	10	8	9	>4:1

Vert Curve Def

Exception
Design Except
Except Date

Strategy
Optimum Year: 2021
Critical Year: 2025
Under Const: NO
Pavement Status Indicator

Top
Next
Previous
Bottom
Find
Cross Section
Mandli Link
Map Section
Open Pathway Browser
Open Log Book
Return

NSI
NSI: 92
NSI Date: 5/4/2009
Low NSI: 96.85

Condition Ratings
PSI: 4.2
Rut Depth: 2.42
IRI: 0.95
Faulting: 0
Profile Date: 6/29/2009

Traffic
ADT: 1023
TADT: 191
20yr ADT: 1329
20yr TADT: 248

Cost/LnMile
5 Yr Ave: $273.00
Prev FY Cst: $553.00

Hwy 002 By Hwy ASC

Accidents

Previous Year	5 Year Avg
Fatal Acc: 0	Fatal Acc: 0
Injury Acc: 1	Injury Acc: 1
Property Acc: 0	Property Acc: 0

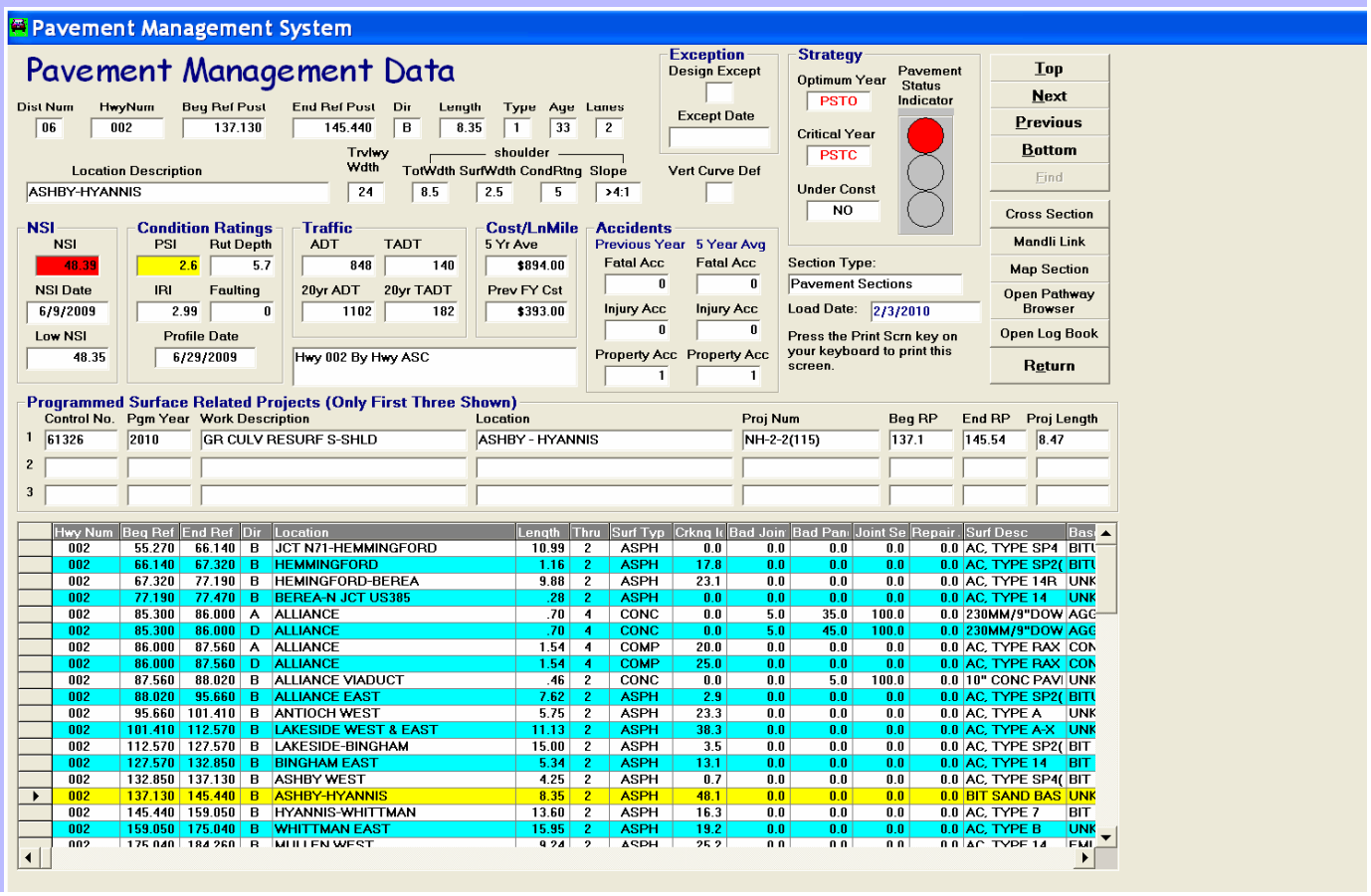
Section Type: Pavement Sections
Load Date: 2/3/2010
Press the Print Scrn key on your keyboard to print this screen.

Programmed Surface Related Projects (Only First Three Shown)

	Control No.	Pgm Year	Work Description	Location	Proj Num	Beg RP	End RP	Proj Length
1								
2								
3								

Hwy Num	Beg Ref	End Ref	Dir	Location	Length	Thru	Surf Typ	Crknq Ic	Bad Join	Bad Pan	Joint Se	Repair.	Surf Desc	Bas
002	112.570	127.570	B	LAKESIDE-BINGHAM	15.00	2	ASPH	3.5	0.0	0.0	0.0	0.0	AC, TYPE SP2(	BIT
002	127.570	132.850	B	BINGHAM EAST	5.34	2	ASPH	13.1	0.0	0.0	0.0	0.0	AC, TYPE 14	BIT
002	132.850	137.130	B	ASHBY WEST	4.25	2	ASPH	0.7	0.0	0.0	0.0	0.0	AC, TYPE SP4(	BIT
002	137.130	145.440	B	ASHBY-HYANNIS	8.35	2	ASPH	48.1	0.0	0.0	0.0	0.0	BIT SAND BAS	UNK
002	145.440	159.050	B	HYANNIS-WHITTMAN	13.60	2	ASPH	16.3	0.0	0.0	0.0	0.0	AC, TYPE 7	BIT
002	159.050	175.040	B	WHITTMAN EAST	15.95	2	ASPH	19.2	0.0	0.0	0.0	0.0	AC, TYPE B	UNK
002	175.040	184.260	B	MULLEN WEST	9.24	2	ASPH	25.2	0.0	0.0	0.0	0.0	AC, TYPE 14	EMU
002	184.260	184.890	B	MULLEN	.60	2	CONC	0.0	0.0	100.0	100.0	10.0	6" CONC PAVE	UNK
002	184.890	188.200	B	MULLEN EAST	3.32	2	ASPH	26.1	0.0	0.0	0.0	0.0	AC, TYPE 14	EMU
002	188.200	194.970	B	SENECA WEST	6.81	2	ASPH	13.0	0.0	0.0	0.0	0.0	AC, TYPE SP3(	BIT
002	194.970	202.090	B	SENECA EAST	7.10	2	ASPH	19.8	0.0	0.0	0.0	0.0	AC, TYPE B	UNK
002	202.090	203.520	B	RXR VIADUCT AREA	1.44	2	ASPH	17.0	0.0	0.0	0.0	0.0	AC, TYPE AX	BIT
002	203.520	206.750	B	THEDFORD WEST	3.23	2	ASPH	7.3	0.0	0.0	0.0	0.0	AC, TYPE SP2(	BIT
002	206.750	211.040	B	THEDFORD WEST & EAST	4.30	2	ASPH	19.4	0.0	0.0	0.0	0.0	AC, TYPE AX	BIT
002	212.200	222.100	B	THEDFORD EAST	9.86	2	ASPH	15.3	0.0	0.0	0.0	0.0	AC, TYPE 14	BIT
002	222.100	228.140	B	HALSEY WEST & EAST	6.10	2	ASPH	5.7	0.0	0.0	0.0	0.0	AC, TYPE SP3(	BIT
002	228.140	238.680	B	HALSEY-DUNNING	10.55	2	ASPH	0.4	0.0	0.0	0.0	0.0	AC, TYPE SP4(	BIT
002	238.680	247.310	B	DUNNING-CUSTER CL	8.61	2	ASPH	27.5	0.0	0.0	0.0	0.0	AC, TYPE A	UNK
002	247.310	258.040	B	CUSTER CL-ANSELMO	10.75	2	ASPH	1.3	0.0	0.0	0.0	0.0	AC, SP4 SP (3:	BIT

Pavement Management



STRATEGY SELECTION

STRATEGY SELECTION

4) FUNDING $$$$$$$$$$$$

Availability and Future programming

FURT[illegible]ION

Location	Distance Ft. Rt. or Lt. of CL	Field Depth inches	Remarks
R.P. 0.26	9 Rt.	7.0	
R.P. 1.04	6 Rt.	8.25	
R.P. 3.45	9' Lt.	7.25	
R.P. 4.12	6 Rt.	6.50	
R.P. 5.18	3 Rt.	5.75	
R.P. 6.04	9 Lt.	8.00	
R.P. 7.08	6 Rt.	7.25	
R.P. 8.09	3 Rt.	6.75	
R.P. 9.21	9 Rt.	6.75	
R.P. 10.27	6 Rt.	7.25	
R.P. 10.96	3 Rt.	6.25	

FLY ASH STABILIZED BITUMINOUS SMOOTHNESS

The Fly Ash Stabilized Bituminous surface shall be tested for smoothness as shown in the special provision titled Asphaltic Concrete Pavement Smoothness with the following exceptions:

1. This specification establishes a standard for Fly Ash Stabilized Bituminous smoothness, and defines defective pavement smoothness. The intent of the specification is to produce a finished Fly Ash Stabilized Bituminous pavement driving surface with a Profile Index no greater than 30 inches per mile.

2. Sections that are over 30.0 inches per mile that cannot be corrected by bump removal must be corrected by placing asphaltic concrete on that section.

3. Bumps will be corrected by cold milling or trimming. Milling or trimming on either or both side(s) of the dip will not be allowed. Dips can only be corrected by filling with asphaltic concrete.

4. Slope that is more than ± 1 inch different than the slope shown on the plans will be corrected by placing asphaltic concrete on that area.

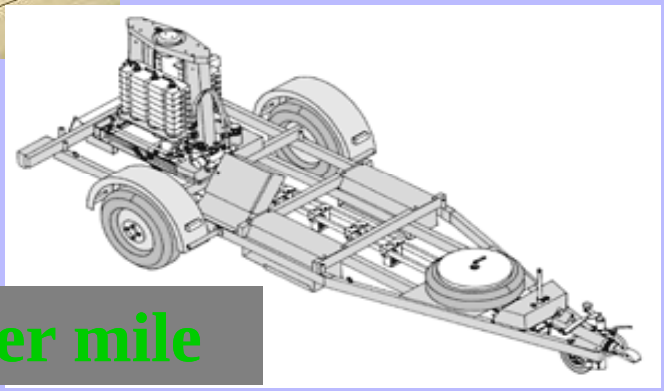
Method of Measurement

Fly Ash Stabilized Bituminous Smoothness or the work of correcting sections not in compliance including all required traffic control will not be measured and paid for but shall be considered subsidiary to the item "Fly Ash Stabilized Bituminous." Asphaltic Concrete used to correct sections not in compliance will not be measured and paid for but shall be considered subsidiary to the item "Fly Ash Stabilized Bituminous."

-136-

FURTHER INVESTIGATION

Falling Weight Deflectometer (FWD)

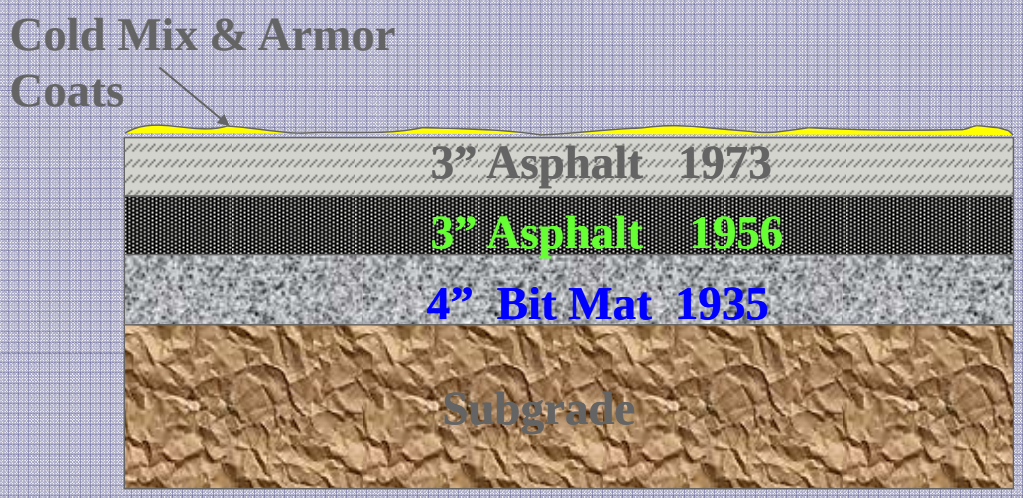


10 per mile

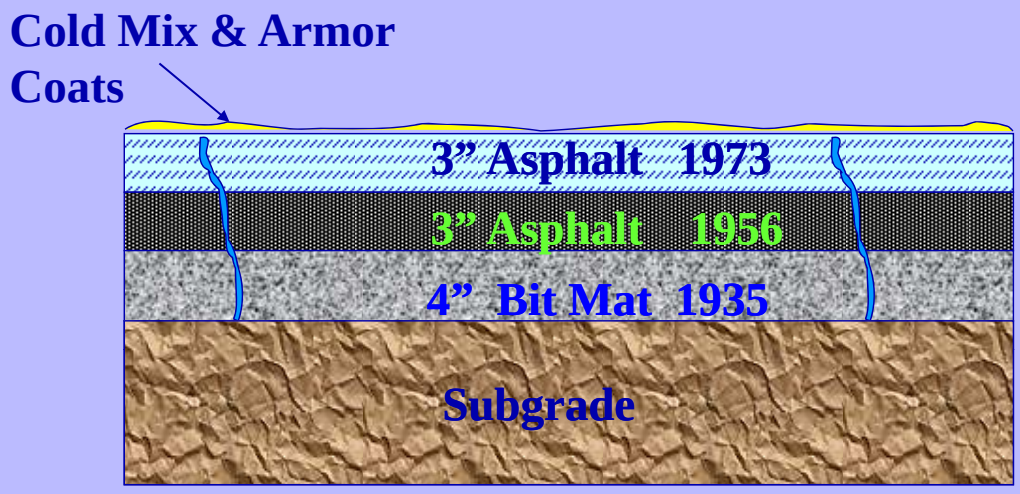
Project Information	Pavement Rating Scale		Subgrade Rating Scale	
Beatrice West	<150000	Very Weak	<2000	Very Weak
11981	150000-250000	Weak	2000-3000	Weak
Tested 8/14/06	250000-350000	Marginal	3000+	Strong
	350000-450000	Strong		
	>450000	Very Strong		

Reference Post	Pavement Modulus	Pavement Rating	Subgrade Modulus	Subgrade Rating
144.101	223952	Weak	3598	Strong
144.101	236789	Weak	3467	Strong
144.21	332965	Marginal	4226	Strong
144.21	335963	Marginal	4106	Strong
144.299	471798	VS	4579	Strong
144.299	459172	VS	4588	Strong
144.599	219403	Weak	4022	Strong
144.599	215260	Weak	3801	Strong

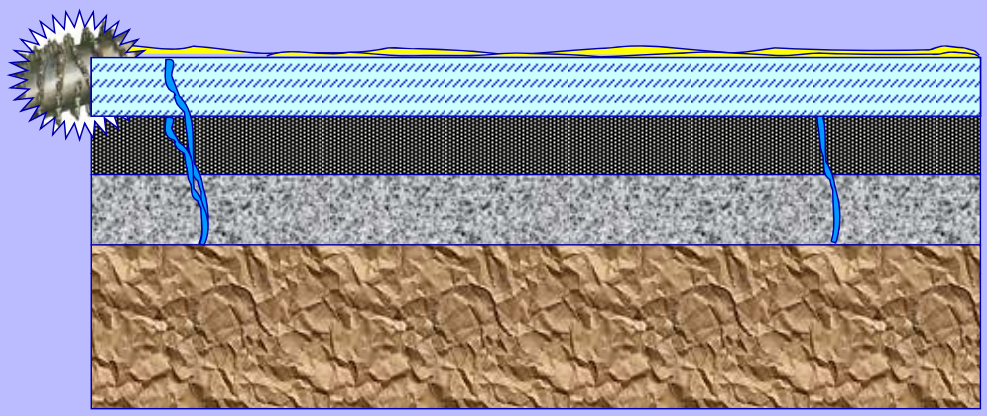
PARTIAL DEPTH RECYCLING



PARTIAL DEPTH RECYCLING



PARTIAL DEPTH RECYCLING



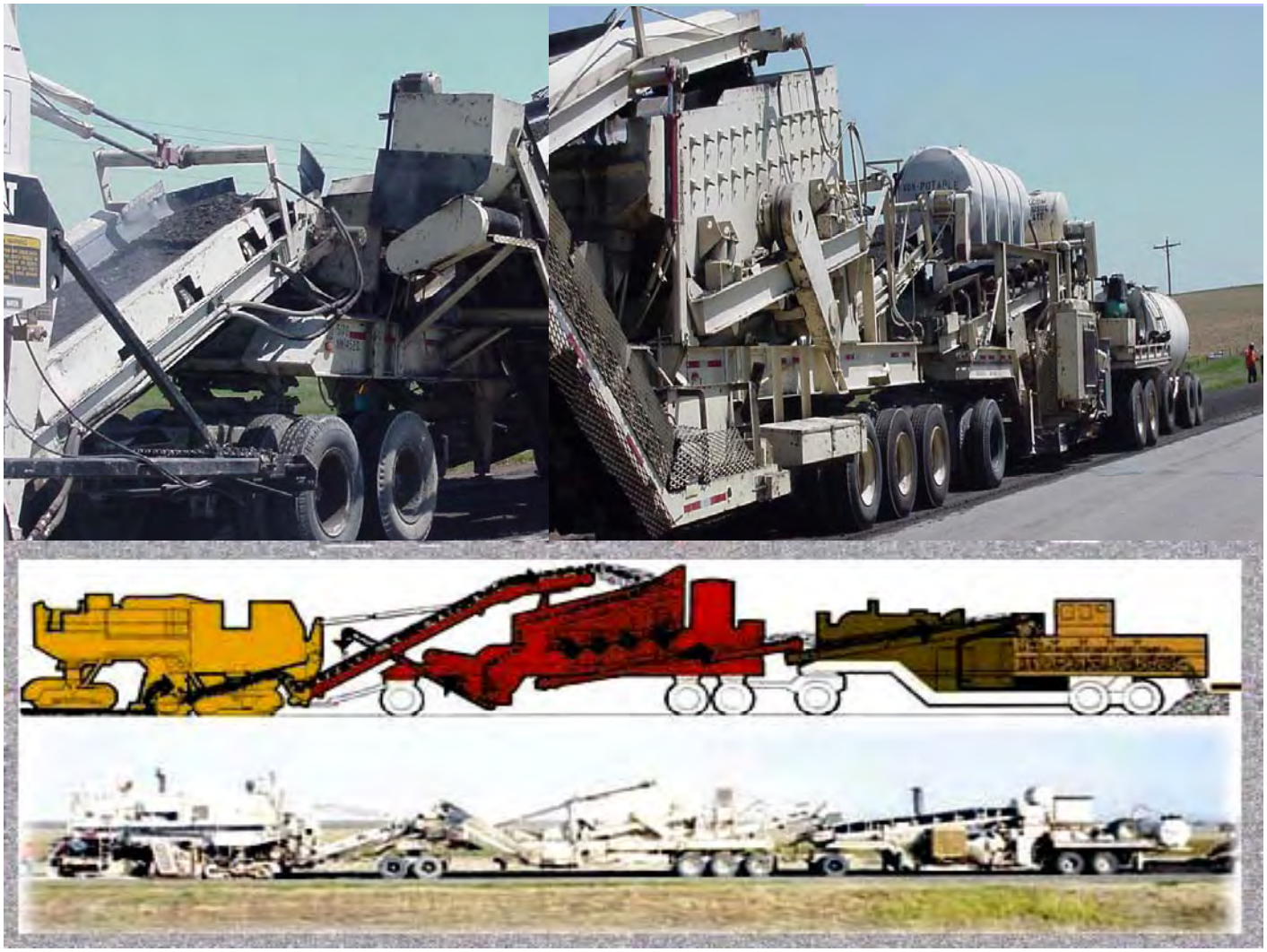
PARTIAL DEPTH RECYCLING

PARTIAL DEPTH STRATEGIES USED IN NEBRASKA

Hydrated Lime Slurry Stabilization

Blend of Chemical & Bituminous

- **Large/Heavy trains are used**
- **Strong base required!**
- **Adding Hydrated Lime & Emulsified Asphalt, then laying with paver**



NO
PASSING
ZONE

4005

Cedarapids
EAGLE
SINCE 1872
EIW
4203

LOAD

CATERPILLAR

CAT
DYNAPAC

Compute HLSS only for mainline

Test Report
50 Blow Marshall Design

Highway Number	N-40 Miller-Amherst
County	Buffalo
NDOR Project Number	EACSTPD-40-4(102)
Brown & Brown, Inc. Project Number	25-10

Sieve Analysis (%Passing) of Recycled Asphalt Pavement Millings
ASTM D 5444

Sieve Size	1-1/4"	1"	3/4"	1/2"	3/8"	#4	#8	#30	#200
1.5% Oil	100	100	92.6	83.5	78.0	64.7	28.7	5.4	0.1
2.25% Oil	100	100	93.0	83.9	78.2	65.4	32.5	6.1	0.0
3.0% Oil	100	100	93.1	83.7	78.2	65.2	34.7	8.6	0.0
Specification	100	100-90	98-78	85-65	75-55	52-32	40-20	15-0	10-0

Oil Content	Moisture Content	Lime Content	Average Density (pcf)	Marshall Stability (lbs)	Retained Stability (lbs)	% Retained
1.5%	1.0	1.5	129.8	1838	1353	73.6
2.25%	1.0	1.5	129.0	1848	1331	72.0
3.0%	1.0	1.5	129.0	1608	1129	70.2
Specification	1.0 %	1.0% min.		1250 lb min.		70 % min

Material used for Mix Design	Supplier
Asphalt Cores	Brown & Brown, Inc.
Emulsion Supplier	Monarch Oil
Lime Supplier	Chemical Lime Company

The mixing of samples was performed with a Hobart 20-quart mechanical mixer at room temperature. The samples were mixed thoroughly with the lime slurry added first and the emulsion added last. The emulsion temperature was 40 degrees C at the time it was added, and the mixing time after the emulsion was added was 60 seconds.

The specimens were compacted using Marshall Compaction equipment described in ASTM D 1559 Standard Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus. Specimens were cured to a constant weight at 60 degrees C in a forced draft oven with ventilation on the top and sides. The time for curing did not exceed 72 hours.

The Marshall Stability was determined according to ASTM D 1559 after the specimens had been heated at 40 degrees C in a forced draft oven for 2 hours. The Retained Stability specimens were placed in a water bath at 25 degrees C for 23 hours followed by a 1-hour soak at 40 degrees C. The Marshall Stability and Retained Stability was determined at the same time, and immediately after the soaking process was completed.

Some evidence of asphalt stripping after moisture conditioning was encountered in the samples, but all tests were within specifications.

GSI
3826 Arch Avenue, Grand Island, Nebraska 68803 (308) 381-1987

Project	Brown & Brown RAP QA/QC		
Location	Salina, Kansas		
Job No.	055432	Date	May 23, 2005

This Report not to be reproduced except in full as presented by GSI

Presented by J. Fred Jones, P.E.

Cold In Place Recycling
Density, Stability, Retained Stability Lab Calc Sheet

Curing of Sample after molding

Time	Wt. (g)	%Change
11:00	1120.3	
8:09	1079.8	3.75%
8:45	1077.9	0.18%
9:45	1077.9	0.00%

Cure Temp = 60C cure to constant wt (<72 hours)
Date Sample Collected
Brown & Brown Sample ID 25-10
Project Buffalo Co.
STA
1.5 % Emulsion
%Lime
% Slurry
% Add Water

Density

Dia top(in)	Dia bot(in)	Ht 1(in)	Ht 2(in)	Ht 3(in)	Wt(g)	Density(pcf)
3.989	3.995	2.519	2.525	2.528	1075.6	129.4
3.992	3.990	2.479	2.491	2.499	1069.3	130.5
3.986	3.993	2.504	2.507	2.512	1064.7	129.1
3.985	3.992	2.502	2.500	2.504	1072.2	130.3
3.988	3.996	2.503	2.502	2.506	1066.9	129.4
3.991	3.993	2.500	2.507	2.506	1071.5	130.0

Cured Marshall / Retained Stability

	Retained Stability	
40C (104F)	Date/Time @23C(73F) Start	5/19/2005 10:30
5/20/2005 8:30	Date/Time @23C(73F) End	5/20/2005 9:30
5/20/2005 10:30	Date/Time @40C (104F) Start	5/20/2005 9:30
	Date/Time @40C (104F) End	5/20/2005 10:30

all Stability

Ring Reading	Stability (pcf)
106	1736
120	1960
111	1816
Average	1838

Retained Stability

Puck ID		Ring Reading	Stability (pcf)
MD 1.5	-4	82	1353
	-5	82	1353
	-6	82	1353
	Average		1353

Results

Sample
129.8 pounds per cubic foot
1838 pounds
1353 pounds
73.6% percent

SI
nd NE 68803 308 381-1987

Project	Brown & Brown RAP QA/QC		
Location	Salina, Kansas		
GSI job number	055432	Date	5/20/2005

Hydrated Lime Slurry Stabilization

Weather and Liquidated Damages

Hydrated Lime Slurry Stabilization

How critical is the 60° specification?

WE WANT MOISTURE OUT AS SOON AS POSSIBLE

CHEMICAL REACTIONS DOUBLE FOR EVERY 10° CHANGE IN TEMPERATURE

Hydrated Lime Slurry Stabilization

How critical is the 7 days of cure?

OPTIMUM MOISTURE IS CRITICAL

Hydrated Lime Slurry Stabilization

Can or should the surface be fog sealed?

FOGGING WILL HELP WITH RAVELING

SHOULD BE USED TO SEAL SURFACE AFTER CURING

Hydrated Lime Slurry Stabilization

How critical is it to cover the roadway in 28 days?

INSUFFICIENT STRUCTURE AND MOISTURE

APR 24 2007

APR 24 2007

Hydrated Lime Slurry Stabilization

Pay Items

- Hydrated Lime Slurry Stabilization
  Paid by the Station
- Hydrated Lime (1.5%)
  Paid by the Ton
- Emulsified Asphalt (1.75%)
  Paid by the Gallon
- Fog Seal
  Paid by the Gallon

Hydrated Lime Slurry Stabilization

Uniform pavement width 24’ and 5 miles long

5 miles x 5280’ = 264 Stations of HLSS

264 Sta x 0.9 tons/sta = 238 Tons of Lime (4” depth)

264 Sta x 245 gal/sta = 64,680 Gals of Emulsified Asphalt

633,600 ft^2 = 70,400 yd^2

70,400 yd^2 x 0.10 Gal/yd^2 = 7,040 Gals of Fog Seal

Hydrated Lime Slurry Stabilization

Grade raises?

EXPECT ABOUT 20% GROWTH, TYPICALLY BETWEEN ¾" TO 1" GRADE RAISE

BENEFITS OF GROWTH

BENEFITS OF GROWTH

Roaming the Plains
4012

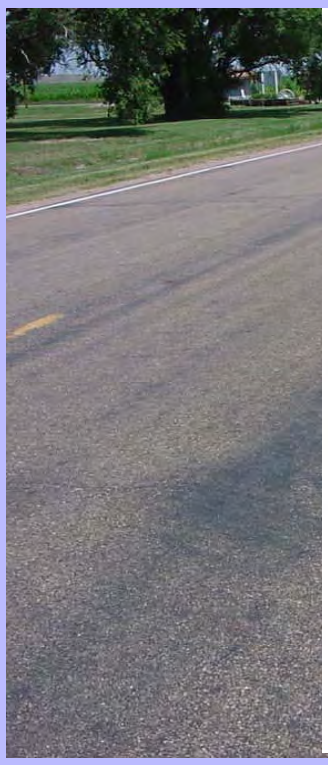
CATERPILLAR

TRENCH WIDENING

Trench Widened
28’ top

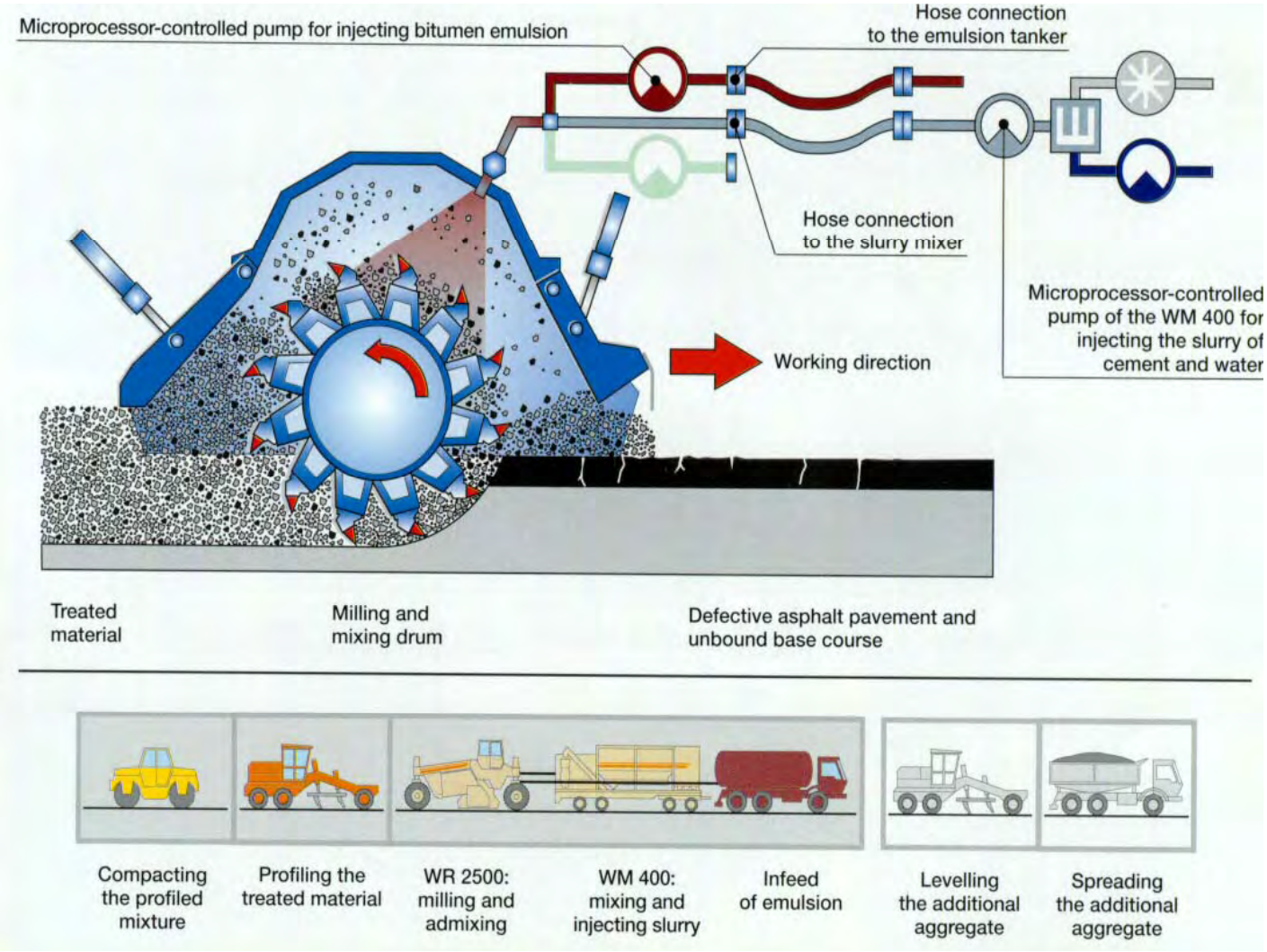
Before
After

END OF
PARTIAL DEPTHS STRATEGIES



16 2:39PM

FULL DEPTH RECYCLING


Microprocessor-controlled pump for injecting bitumen emulsion
Hose connection to the emulsion tanker
Hose connection to the slurry mixer
Microprocessor-controlled pump of the WM 400 for injecting the slurry of cement and water
Working direction
Treated material
Milling and mixing drum
Defective asphalt pavement and unbound base course
Compacting the profiled mixture
Profiling the treated material
WR 2500: milling and admixing
WM 400: mixing and injecting slurry
Infeed of emulsion
Levelling the additional aggregate
Spreading the additional aggregate

FULL DEPTH RECYCLING

Cold Mix & Armor Coats

FULL DEPTH RECYCLING

FULL DEPTH RECYCLING

COHESIVE SOILS UNDER PAVEMENT
(CLAYS – SILTS – LOESS)

FLY ASH OR CEMENT STABILIZATION

FLY ASH STABILIZED BITUMINOUS

- Pre-Milling is allowed and encouraged
- Fly Ash is uniformly spread
- A reclaimer is typically used to incorporate water & fly ash
- Recycled material is compacted & shaped with a blade
- Fog Seal

FLY ASH STABILIZED BITUMINOUS

Project Name: Milford Exit-US34
Project No.: 80-8(1029)
Control No.: 12780
Date: 8/16/2005

Full Depth Reclamation w/ FlyAsh

Unit Weights		Enter thicknesses(inches)
144 lbs/CuFt	Recycled Asphalt Pavement(RAP)	12
120 lbs/CuFt	Rock	0
110 lbs/CuFt	Soil	4
	Total Reclamation Depth	16 inches
	Water (4%of wt. of RAP + Ash)	
	Fly-Ash(Various % of Wt of RAP)	

Weight of tested samples= 2,500 grams

	Fly-Ash Blends(grams)			
	8% Ash	10% Ash	12% Ash	15% Ash
RAP	1,993 g	1,993 g	1,993 g	1,993 g
Rock	0 g	0 g	0 g	0 g
Soil	507 g	507 g	507 g	507 g
Fly-Ash	159 g	199 g	239 g	299 g
Water	86 g	88 g	89 g	92 g

Perform a 3-day and a 7-day break for each blend.

Materials and Research Division

NDOR
Nebraska Department of Roads

Fax

Date: 9/23/5

To: Proj. Manager

Fax: 462-1995

Phone: 462-1996

From: Mick Sysk

Pages (includes cover sheet): 2

Subject/Comments:

Project: Grand Island South
CN 42140, 5-1(104)

Use: 12% Fly-Ash
5.1% TOTAL Moisture
114.6 lb/ft³ Dry Density

☐ Urgent ☐ For Review ☐ Please Comment

☐ Please Reply ☐ Please Recycle ☐ Other _____

Nebraska Department of Roads
PO Box 94759
1400 Highway 2
Lincoln NE 68509-4759

Materials and Research Division
Telephone No.: (402) 479-4750
Fax No.: (402) 479-3975

Moisture

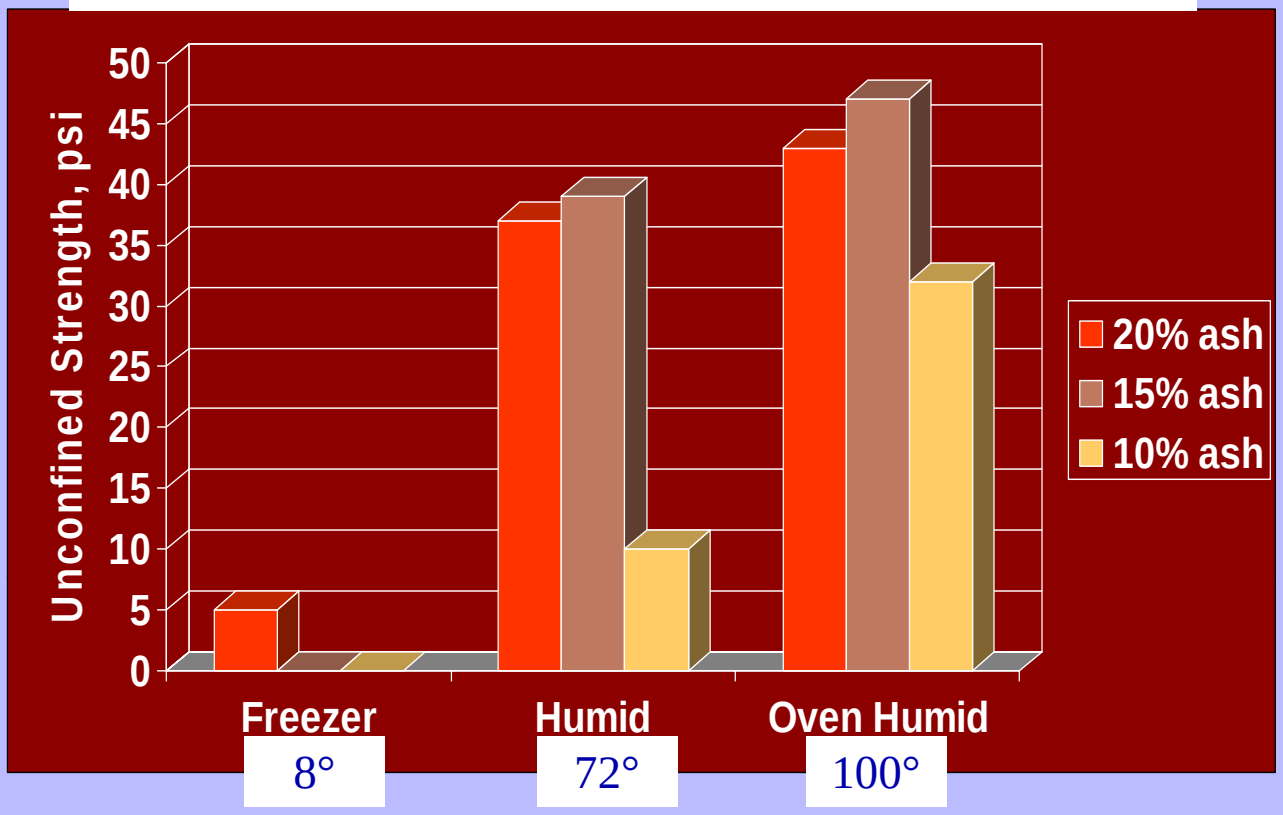
Spreading Fly Ash

Uniform

No Motor Graders

Temperature is important

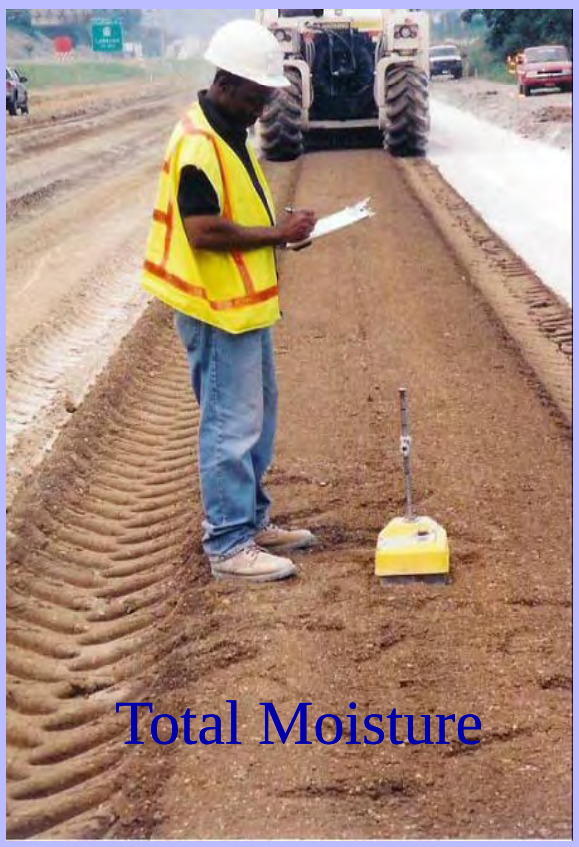
Iowa State University
Midwest Transportation Consortium
2002



Incorporating the Ash

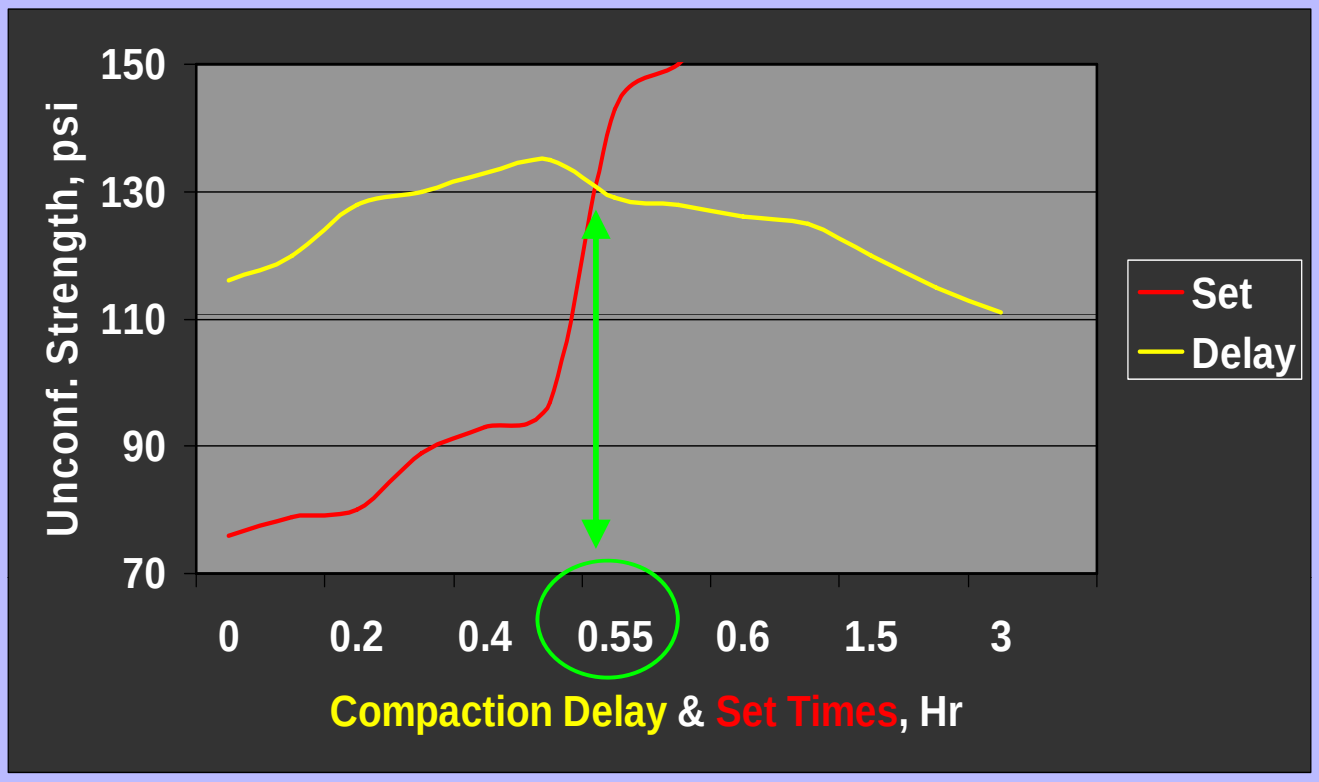
Required to be done in a single pass

Monitor Moisture



Compaction

Iowa State University
Midwest Transportation Consortium
2002



FR-100

10 15:04

HAMM
UNEVEN LANES

10 1991

Fly Ash Stabilized Bituminous

Pay Items

- **Fly Ash Stabilized Bituminous**
  Paid by the Station
- **Fly Ash**
  Paid by the Ton
- **Water**
  Paid by the MGallon
- **Fog Seal**
  Paid by the Gallon

Fly Ash Stabilized Bituminous

Uniform pavement width 24' and 5 miles long

5 miles x 5280' = 264 Stations of Fly Ash Stabilized Bituminous

633,600 ft^2 x 10" =528,000 ft^3

528,000ft^3 x 144 lbs/ft^3 =38,016 tons RAP

38,016 tons x 0.10 = 3,802 Tons of Fly Ash (10% ash used)

528,000ft^3 x 5%=26,400 ft^3 of Water

26,400ft^3 x 62.4 lbs/ft^3 = 1,648 MGallons of Water

70,400 yd^2 x 0.24 Gal/yd^2 = 16,895 Gals of Fog Seal

Fog Sealing

Fog Seal within 2 hours.

- **Continued hydration (strength gain)**
- **Better paint surface**
- **Reduces raveling,**
  BUT raveling WILL occur
- **Better surface for asphalt bond**

Fog Sealing

Adjust dilution?

- 1:1 can pick up under traffic, may need 2:1
- Keep application rate, material is absorptive
- Multiple applications may be necessary

FULL DEPTH PULVERIZATION

MOSTLY COHESIVE SOILS UNDER PAVEMENT
(CLAYS-SILTS, SOME GRANULAR)

LOW VOLUME ONLY

MECHANICAL STABILIZATION
(WATER & POSSIBLE AGGREGATE)

FULL DEPTH PULVERIZATION

- Pre-Milling is allowed and encouraged
- A reclaimer is used to incorporate WATER
- Additional aggregate may be brought in to adjust mix needs
- Recycled material is compacted
- Fog Seal
- Mixture is susceptible to moisture until covered with HMA (7 days must be coverd)

FULL DEPTH RECYCLING

GRANULAR SOILS UNDER PAVEMENT
(SAND)

BITUMINOUS STABILIZATION

COLD IN-PLACE RECYCLING BLADE LAYED

HIGH FLOAT EMULSIONS (HFE 300)

COLD IN-PLACE RECYCLING-BLADE LAYED

- Controlled depth milling is required
- A reclaimer is typically used to incorporate emulsified asphalt
- Recycled material is compacted
- 24 hours later, a full width mill is used to aerate and blend the mix uniformly
- Additional mixing until optimum moisture (2.5%) and uniformity are met

Trimming

Why such a concern?

SEP 6 2005

Trimming

- REMOVES VALUABLE STRUCTURE

Trimming

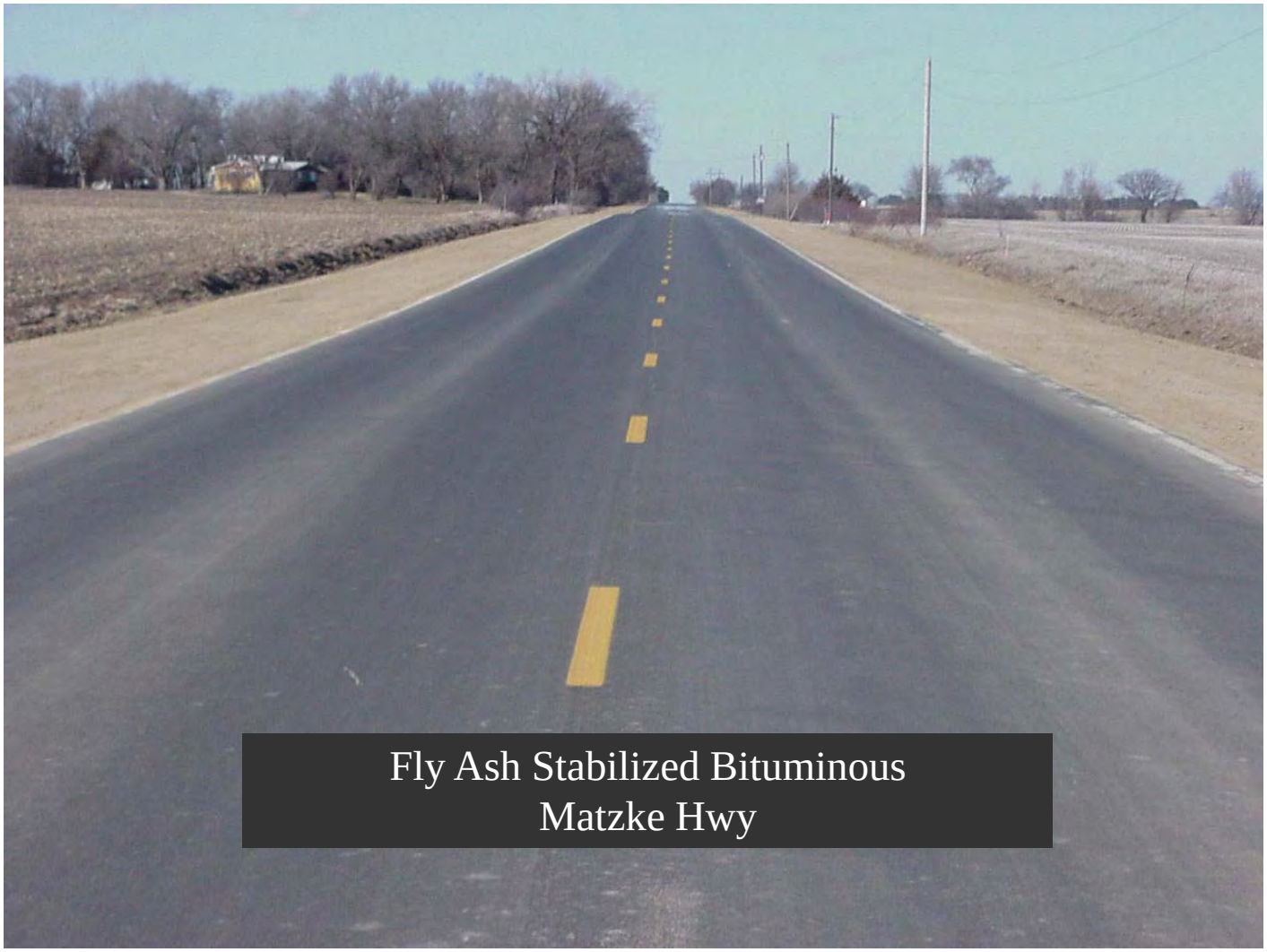
- CREATES A SLIP PLANE IF NOT DONE PROPERLY
  FOG SEAL AGAIN AND ALLOW TRAFFIC TO KNEAD

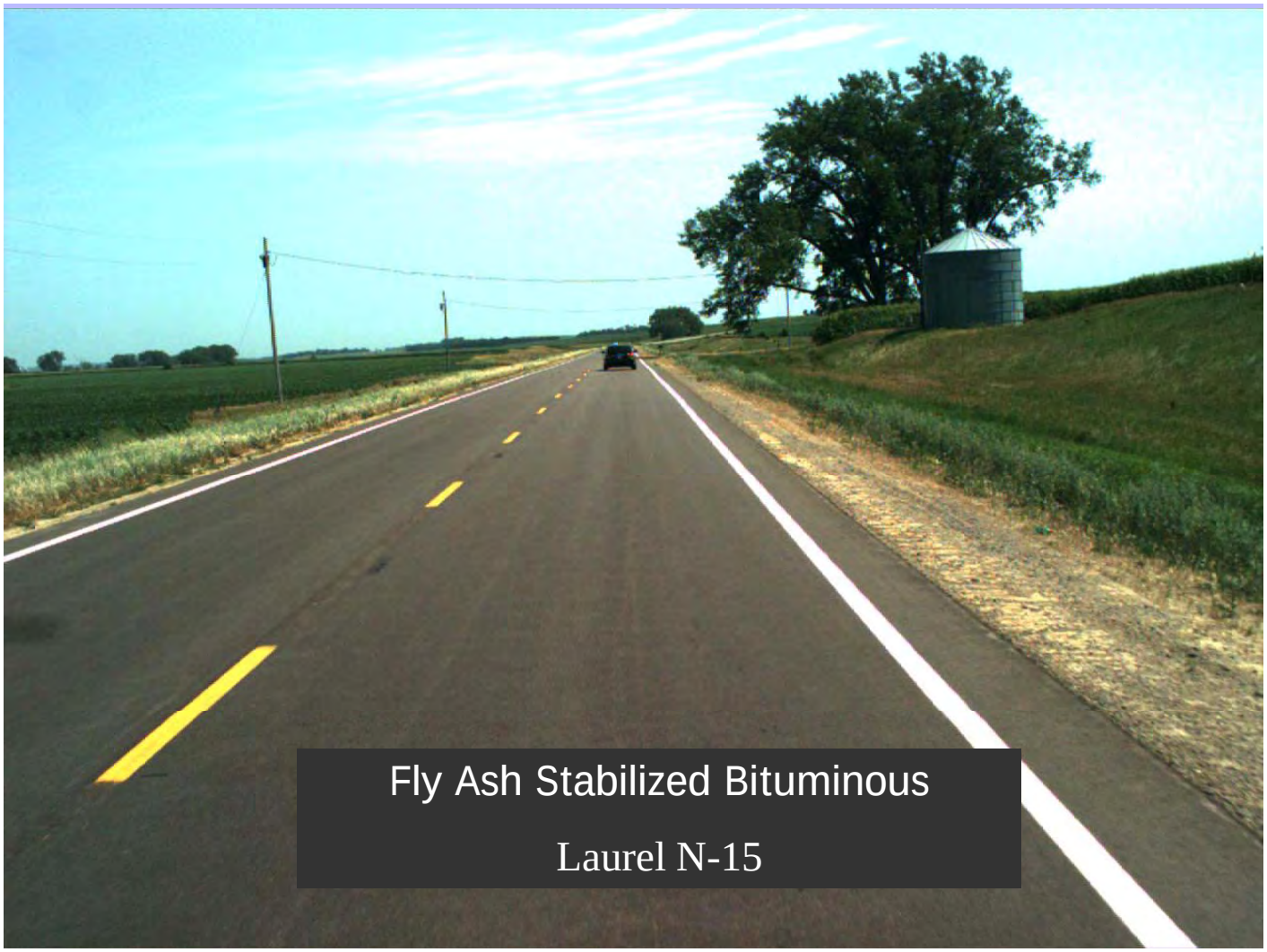
Trimming

- REMOVES EXPENSIVE MATERIAL

Trimming

- SOMETIMES WE HAVE TO TRIM DUE TO GRADE RAISES
- WHEN DESIGNED, TRIMMING WILL BE ALLOWED. BUT MUST BE DONE MINIMUM 2 DAYS PRIOR TO LAYDOWN. THE SURFACE NEEDS TO BE FOG SEALED AGAIN.


Fly Ash Stabilized Bituminous
Matzke Hwy


Fly Ash Stabilized Bituminous
Laurel N-15

4” Hydrated Lime Slurry Stabilization
N-20

PCC In-place Recycling

Crack and Seat
SEP 20 2004

SEP 20 2004

SEP 20 2004

SEP 20 2004

SEP 20 2004

SEP 20 2004

SEP 20 2004

SEP 20 2004

Rubbilizing Concrete

CONSTRUCTION
VEHICLE

CATERPILLAR

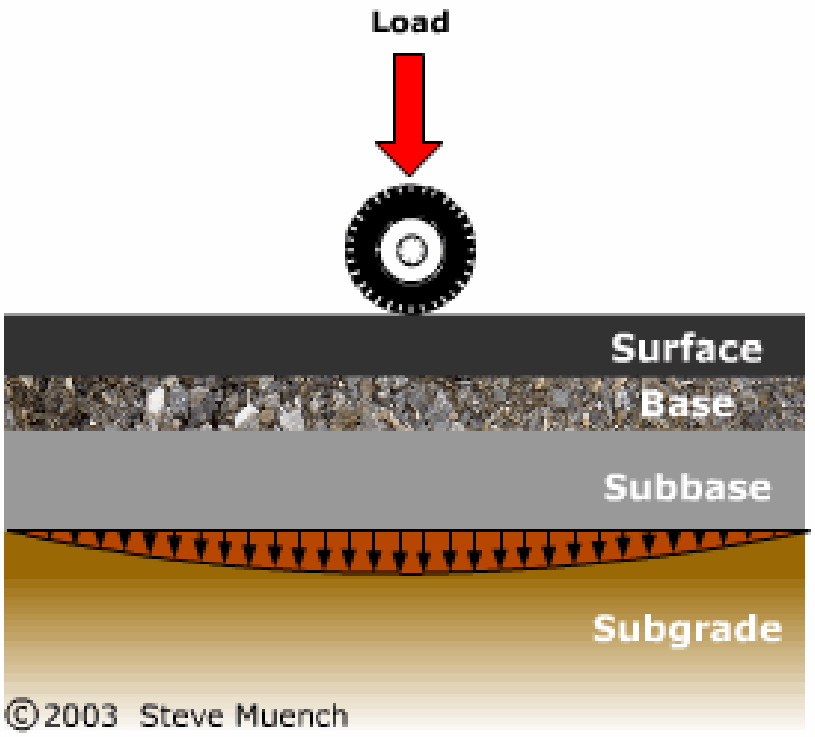
?

OUTLINE

- Pavement, cont'd.
  - Asphalt (Flexible)
    - History of HMA
    - PG Binders
    - HMA Construction
  - Recycling
    - Partial Depth HMA
    - Full Depth HMA
    - PCC Recycling
- **Pavement Design**
  - **Traffic**
  - **Rigid Design**
  - **Flexible Design**
- Review Deliverables
- NDOR Pavement Design Manual
  - Quick References
- Maintenance
  - Emulsions
  - HMA maintenance
  - PCC maintenance

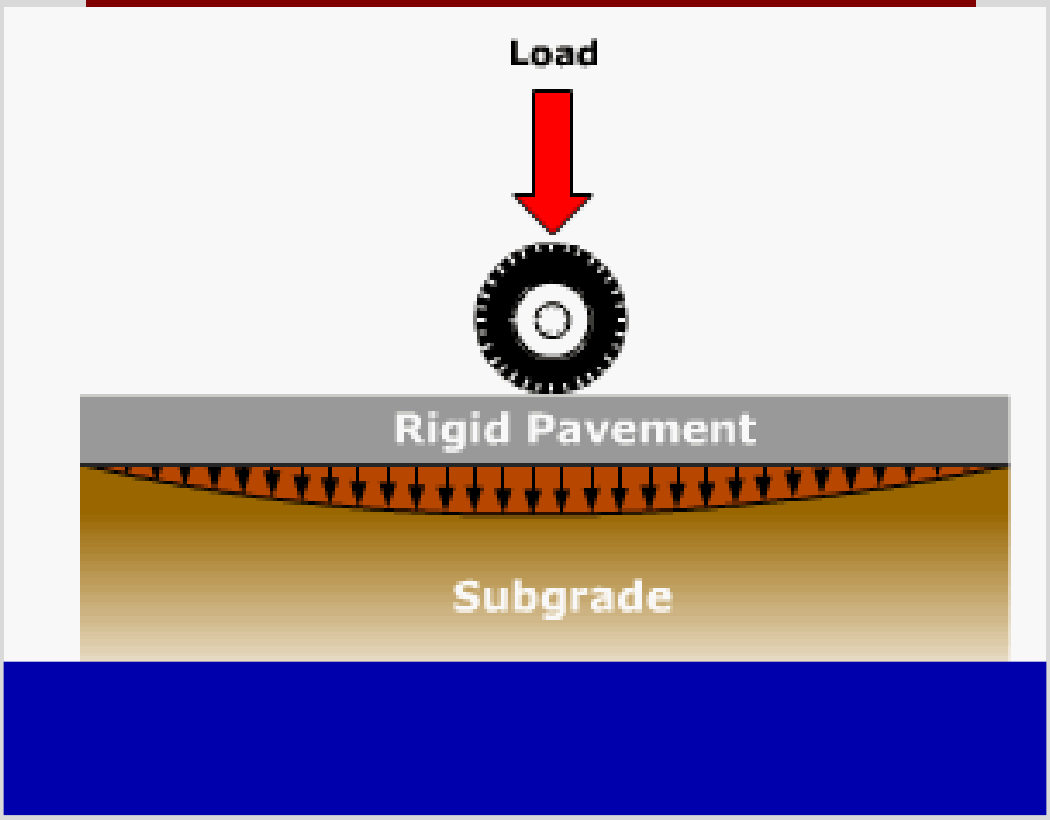
Pavement Design

Pavement Design



Flexible Pavement

Pavement Design



$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

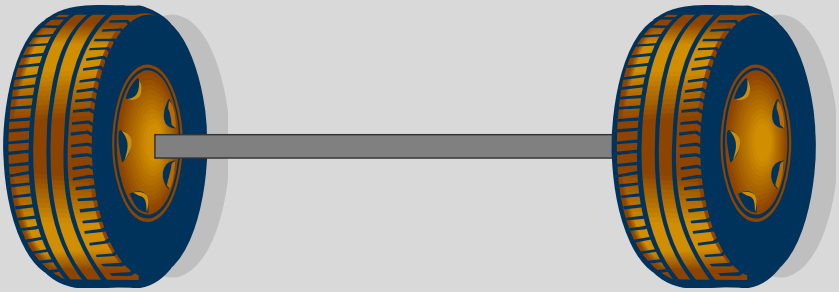
W_{18} = predicted number of 80 kN (18,000 lb.) ESALs

Z_R = standard normal deviate

S_o = combined standard error of the traffic prediction and performance prediction

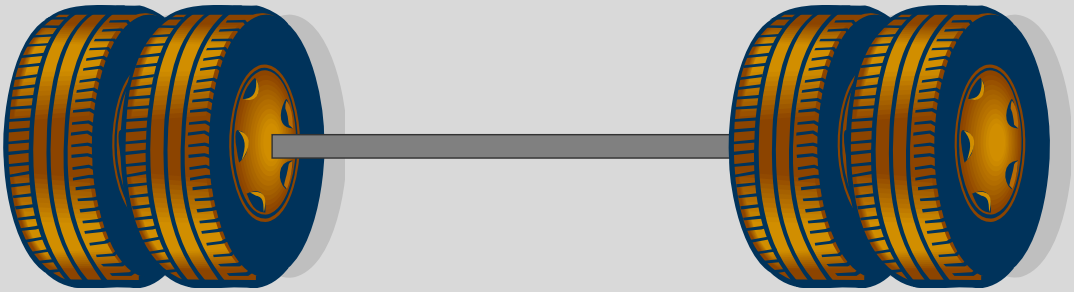
SN = Structural Number (an index that is indicative of the total pavement thickness required)

Axles



Single-Axle Single-Tire

Axles

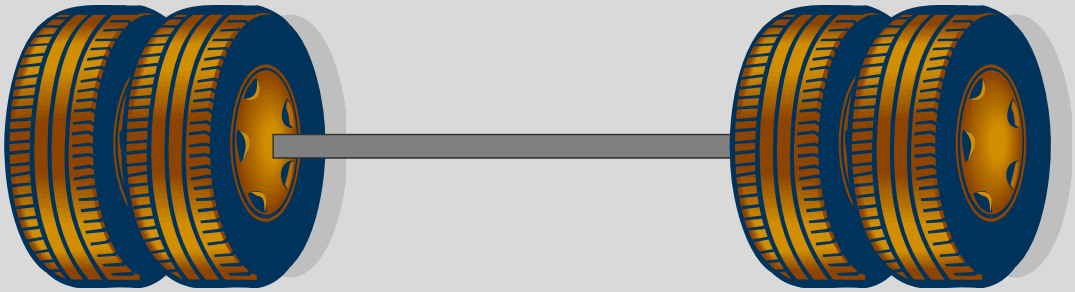


Single-Axle Dual-Tire

Equivalent Single-Axle Load (ESAL)

18,000 lbs

Load Equivalency Factors



Axle Load, lbs	Load Equiv. Factor (LEF)
<3,000	0.0002
8,000	0.0340
18,000	1.0000
28,000	5.3900

Truck Factors

Truck Type	Truck Factor
2-Axle, 4-Tire	0.0122
2-Axle, 6-Tire	0.1890
3-Axle Semi	0.8646
5-Axle Semi	2.3719

Traffic Growth Rate

$$\left[\frac{\text{Future ADT}}{\text{Current ADT}}\right]^{1/n}$$

(n = years)

Traffic Growth Factor

Table D.20. Traffic Growth Factors*

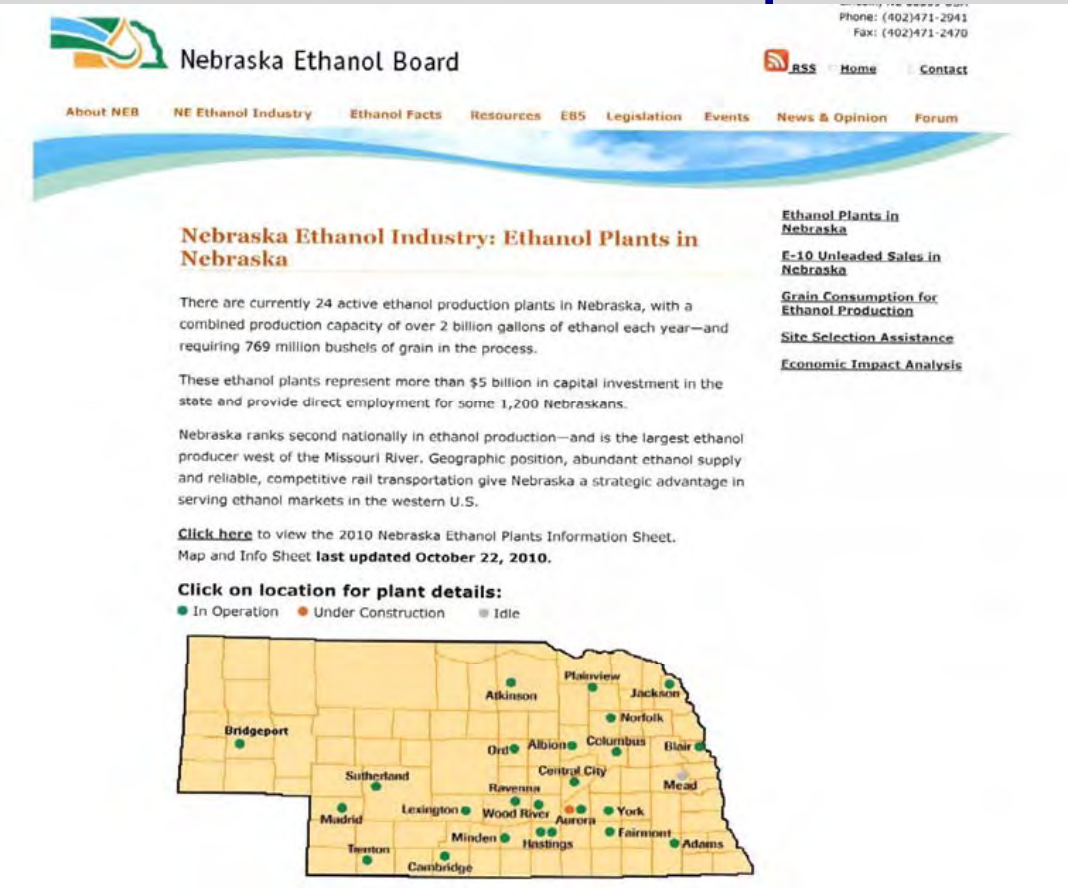
Analysis Period Years (n)	Annual Growth Rate, Percent (g)							
	No Growth	2	4	5	6	7	8	10
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	2.0	2.02	2.04	2.05	2.06	2.07	2.08	2.10
3	3.0	3.06	3.12	3.15	3.18	3.21	3.25	3.31
4	4.0	4.12	4.25	4.31	4.37	4.44	4.51	4.64
5	5.0	5.20	5.42	5.53	5.64	5.75	5.87	6.11
6	6.0	6.31	6.63	6.80	6.98	7.15	7.34	7.72
7	7.0	7.43	7.90	8.14	8.39	8.65	8.92	9.49
8	8.0	8.58	9.21	9.55	9.90	10.26	10.64	11.44
9	9.0	9.75	10.58	11.03	11.49	11.98	12.49	13.58
10	10.0	10.95	12.01	12.58	13.18	13.82	14.49	15.94
11	11.0	12.17	13.49	14.21	14.97	15.78	16.65	18.53
12	12.0	13.41	15.03	15.92	16.87	17.89	18.98	21.38
13	13.0	14.68	16.63	17.71	18.88	20.14	21.50	24.52
14	14.0	15.97	18.29	19.16	21.01	22.55	24.21	27.97
15	15.0	17.29	20.02	21.58	23.28	25.13	27.15	31.77
16	16.0	18.64	21.82	23.66	25.67	27.89	30.32	35.95
17	17.0	20.01	23.70	25.84	28.21	30.84	33.75	40.55
18	18.0	21.41	25.65	28.13	30.91	34.00	37.45	45.60
19	19.0	22.84	27.67	30.54	33.76	37.38	41.45	51.16
20	20.0	24.30	29.78	33.06	36.79	41.00	45.76	57.28
25	25.0	32.03	41.65	47.73	54.86	63.25	73.11	98.35
30	30.0	40.57	56.08	66.44	79.06	94.46	113.28	164.49
35	35.0	49.99	73.65	90.32	111.43	138.24	172.32	271.02

*Factor $= \frac{(1+g)^n - 1}{g}$, where g = [illegible] te is zero, the growth factor is equal to the analysis period.

GF=24.3

NOTE: The above growth factors multiplied by the first year traffic estimate will give the total volume of traffic expected during the analysis period.

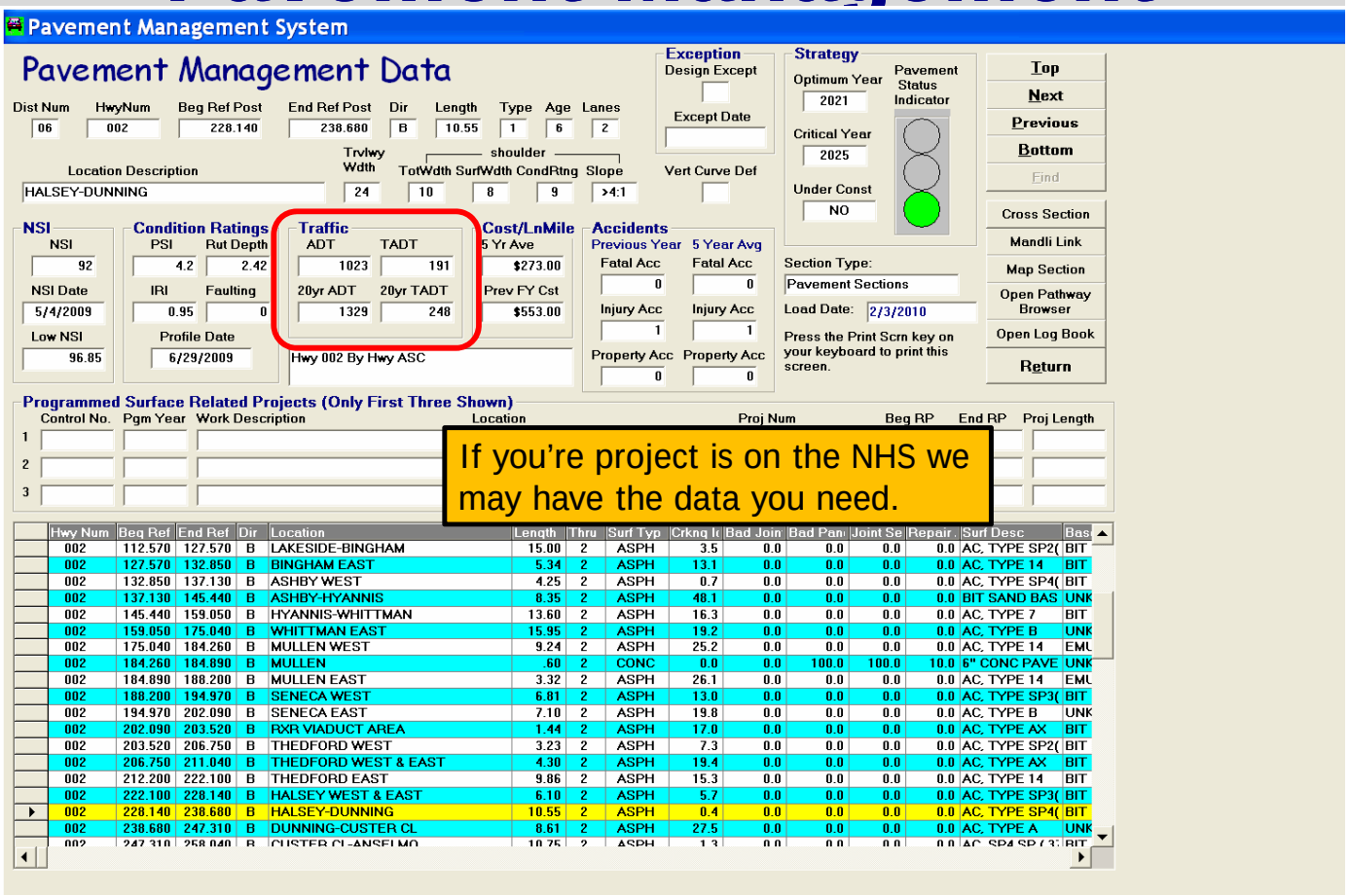
Traffic Generators to keep in mind



Example ESAL Calculation

Type Veh	ADT	% HT	Days Per yr	GF	20 yr Traffic	TF	ESALs
2-Axle 4 Tire	3,000	0.03	365	24.3	798,255	0.0122	9740
2-Axle 6 Tire	3,000	0.05	365	24.3	1,330,425	0.1890	251,450
4-Axle Semi	3,000	0.02	365	24.3	532,170	0.8646	460,114
5-Axle Semi	3,000	0.10	365	24.3	2,660,850	2.3719	6,311,270
							7,032,574

Pavement Management



RIGID
Pavement Design

k-Value

MODULUS OF SUBGRADE REACTION = k-Value

Combination of four different factors to calculate k-value:

1) Sub-base Types
The modulus for each layer of sub-base must be considered.
[Soil subgrades, foundation courses.....]

2) Sub-base Thickness
The thickness of each of the layers must also be identified

3) Loss of Support, LS
A value given for potential erosion of sub-base material.

4) Depth to rigid foundation
Typically in Nebraska, this value is much greater than 10-feet.
However, if within 10-feet; then needs to be design for.

k-Value

1) Recommend minimum of 4 composite k-Values be used:
   - Winter
   - Spring
   - Summer
   - Fall

k-Value

Season	Subgrade M_r Natural soils	Base M_r Foundation Course	Composite k-value Fig. 3.3	Relative Damage
Winter	20000 psi	22000 psi		
Spring	4500 psi	22000 psi		
Summer	6800 psi	22000 psi		
Fall	5600 psi	22000 psi		

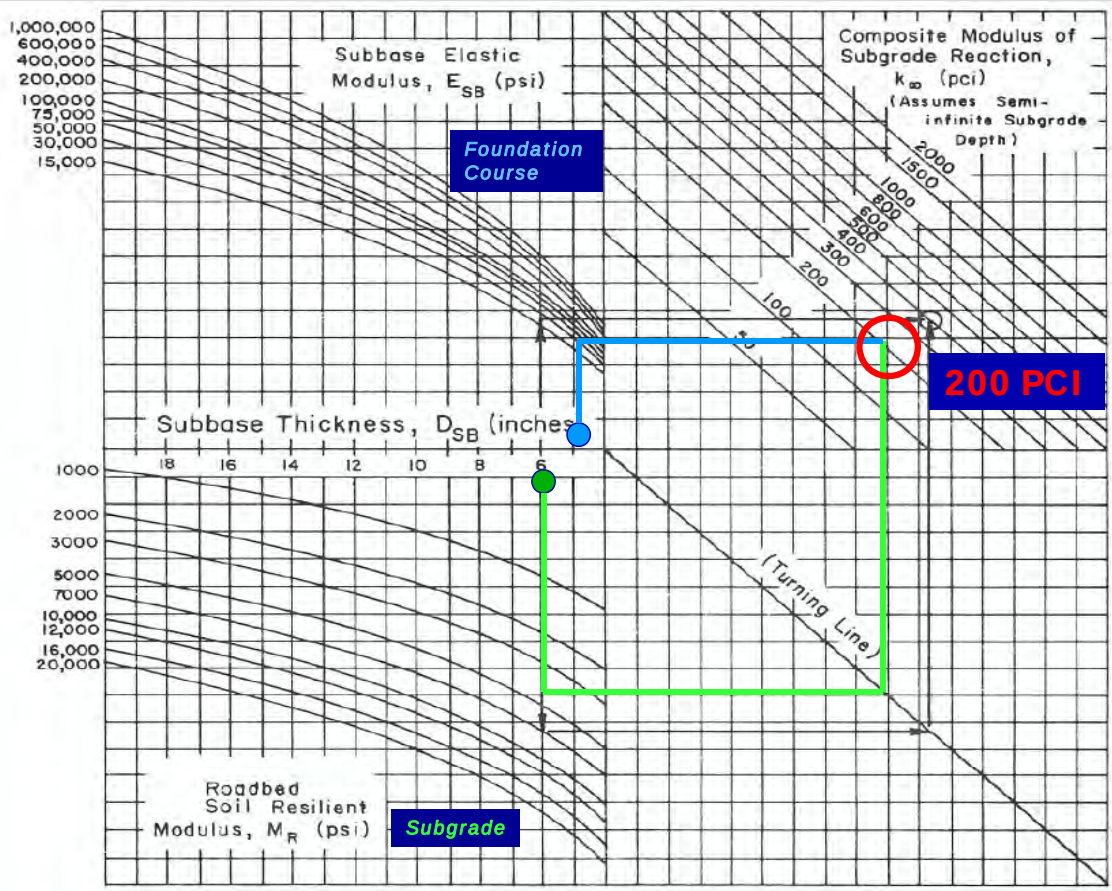


Figure 3.3. Chart for Estimating Composite Modulus of Subgrade Reaction, k_∞, Assuming a Semi-Infinite Subgrade Depth. (For practical purposes, a semi-infinite depth is considered to be greater than 10 feet below the surface of the subgrade.)

k-Value

Season	Subgrade M_r Natural soils	Base M_r Foundation Course	Composite k-value	Relative Damage
Winter	20000 psi	22000 psi	800 pci Fig. 3.3	
Spring	4500 psi	22000 psi	200 pci	
Summer	6800 psi	22000 psi	300 pci	
Fall	5600 psi	22000 psi	250 pci	

k-Value

1) Recommend minimum of 4 composite k-Values be used:

Winter
Spring
Summer
Fall

2) Determine Relative damage for each season based on projected slab thickness.

The higher the k-value (stronger base) the less damage allowed to the slab.

The thicker the slab the flatter the damage curve (slab can "bridge" over weaker sections)

k-Value

Season	Subgrade M_r Natural soils	Base M_r Foundation Course	Composite k-value	Relative Damage
Winter	20000 psi	22000 psi	800 pci *Fig. 3.3*	*Fig. 3.5*
Spring	4500 psi	22000 psi	200 pci	
Summer	6800 psi	22000 psi	300 pci	
Fall	5600 psi	22000 psi	250 pci	

Relative Damage

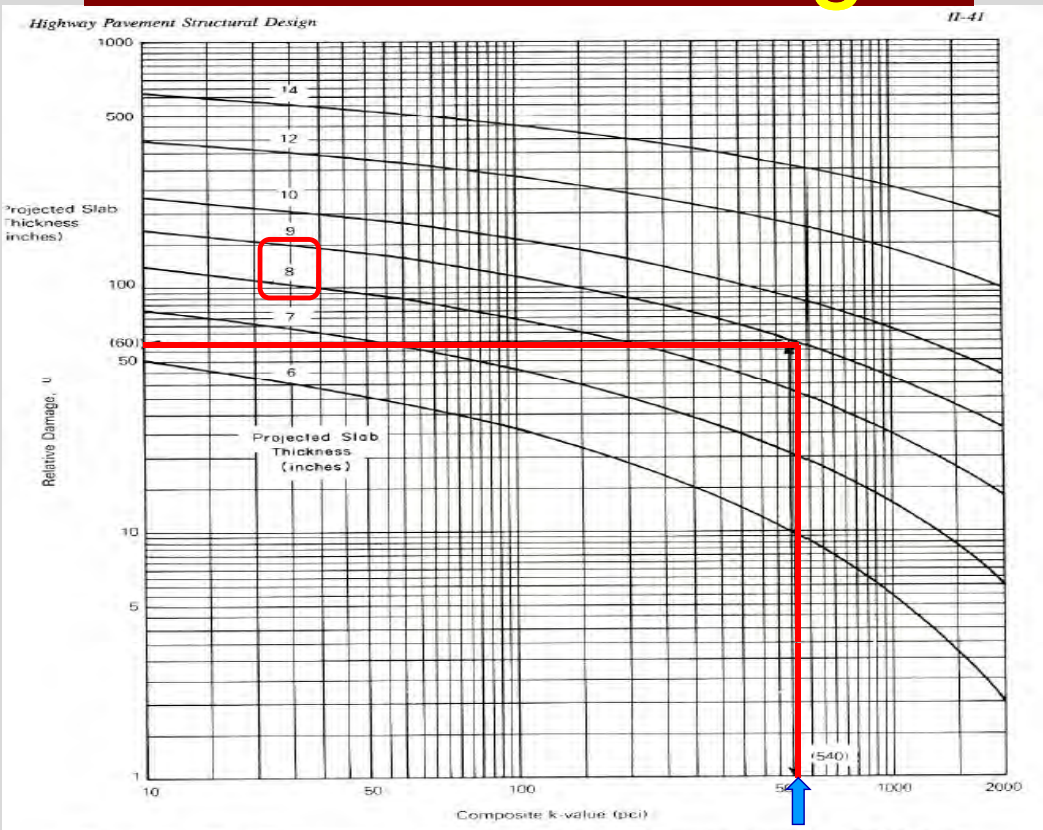


Figure 3.5. Chart for Estimating Relative Damage to Rigid Pavements Based on Slab Thickness and Underlying Support

k-Value

Season	Subgrade M_r	Base M_r	Composite k-value	Relative Damage
Winter	20000 psi	22000 psi	800 pci Fig. 3.3	28 Fig. 3.5
Spring	4500 psi	22000 psi	200 pci	60
Summer	6800 psi	22000 psi	300 pci	50
Fall	5600 psi	22000 psi	250 pci	55
				3÷4)

k-Value

1) Recommend minimum of 4 composite k-Values be used:
   - Winter
   - Spring
   - Summer
   - Fall

2) Determine Relative damage for each season based on projected slab thickness.
   - The higher the k-value (stronger base) the less damage [illegible] to the slab.
   - The thicker the slab the flatter the damage curve (slab can "bridge" over weaker sections)

3) Using average relative damage for all sections back calculate the k-value based on projected slab thickness.

Relative Damage

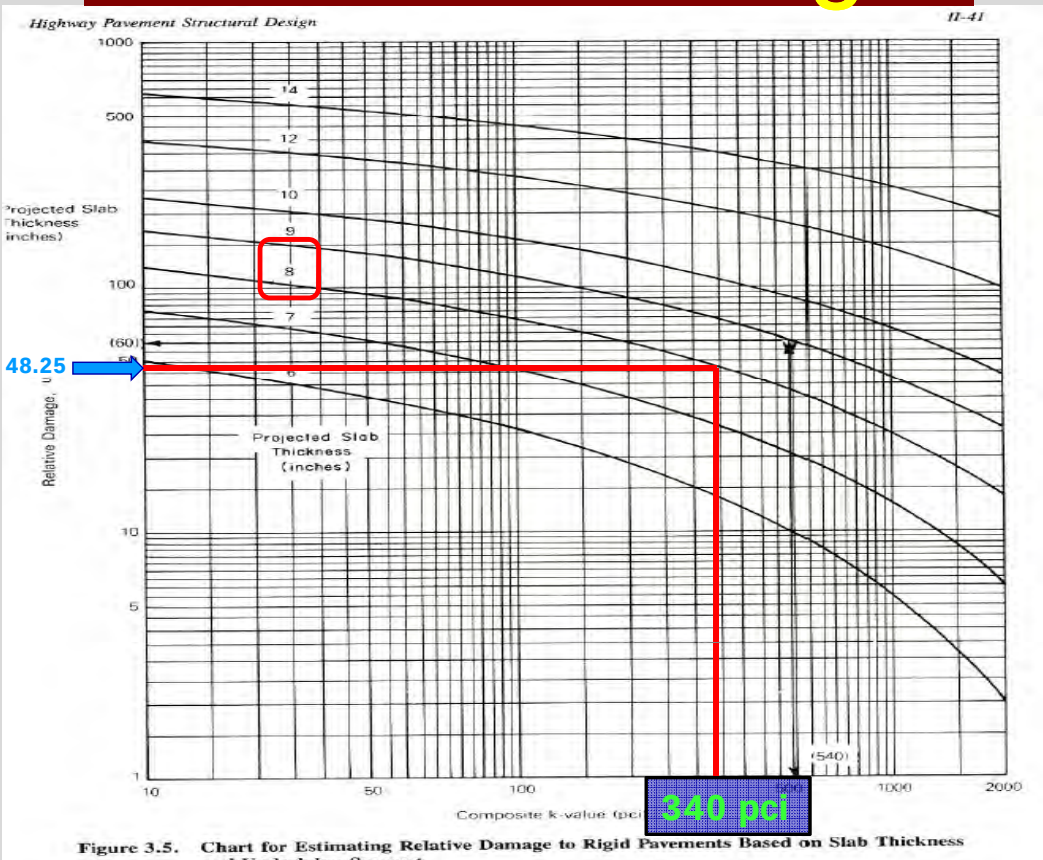


Figure 3.5. Chart for Estimating Relative Damage to Rigid Pavements Based on Slab Thickness and Underlying Support

k-Value

Season	Subgrade M_r	Base M_r	Composite k-value	Relative Damage
Winter	20000 psi	22000 psi	800 pci *Fig. 3.3*	28 *Fig. 3.5*
Spring	4500 psi	22000 psi	200 pci	60
Summer	6800 psi	22000 psi	300 pci	50
Fall	5600 psi	22000 psi	250 pci	55
			Sum Damage=	193
			Average Damage=	48.25 *(193÷4)*
	[illegible]			*3.5*

k-Value

1) Recommend minimum of 4 composite k-Values be used:
   - Winter
   - Spring
   - Summer
   - Fall

2) Determine Relative damage for each season based on projected slab thickness.
   - The higher the k-value (stronger base) the less damage [illegible] to the slab.
   - The thicker the slab the flatter the damage curve (slab can "bridge" over weaker sections)

3) Using average relative damage for all sections back calculate th[illegible] value.

4) Final step is to correct for Loss of Support due to erosion

k-Value

Season	Subgrade M_r	Base M_r	Composite k-value	Relative Damage
Winter	20000 psi	22000 psi	800 pci Fig. 3.3	28 Fig. 3.5
Spring	4500 psi	22000 psi	200 pci	60
Summer	6800 psi	22000 psi	300 pci	50
Fall	5600 psi	22000 psi	250 pci	55
			Sum Damage=	193
			Average Damage=	48.25 (193÷4)
	Back calculate k-value from average damage=			340 pci Fig. 3.5
	Correct for Loss of Support (LS=1.0)			Fig. 3.6

Loss of Support

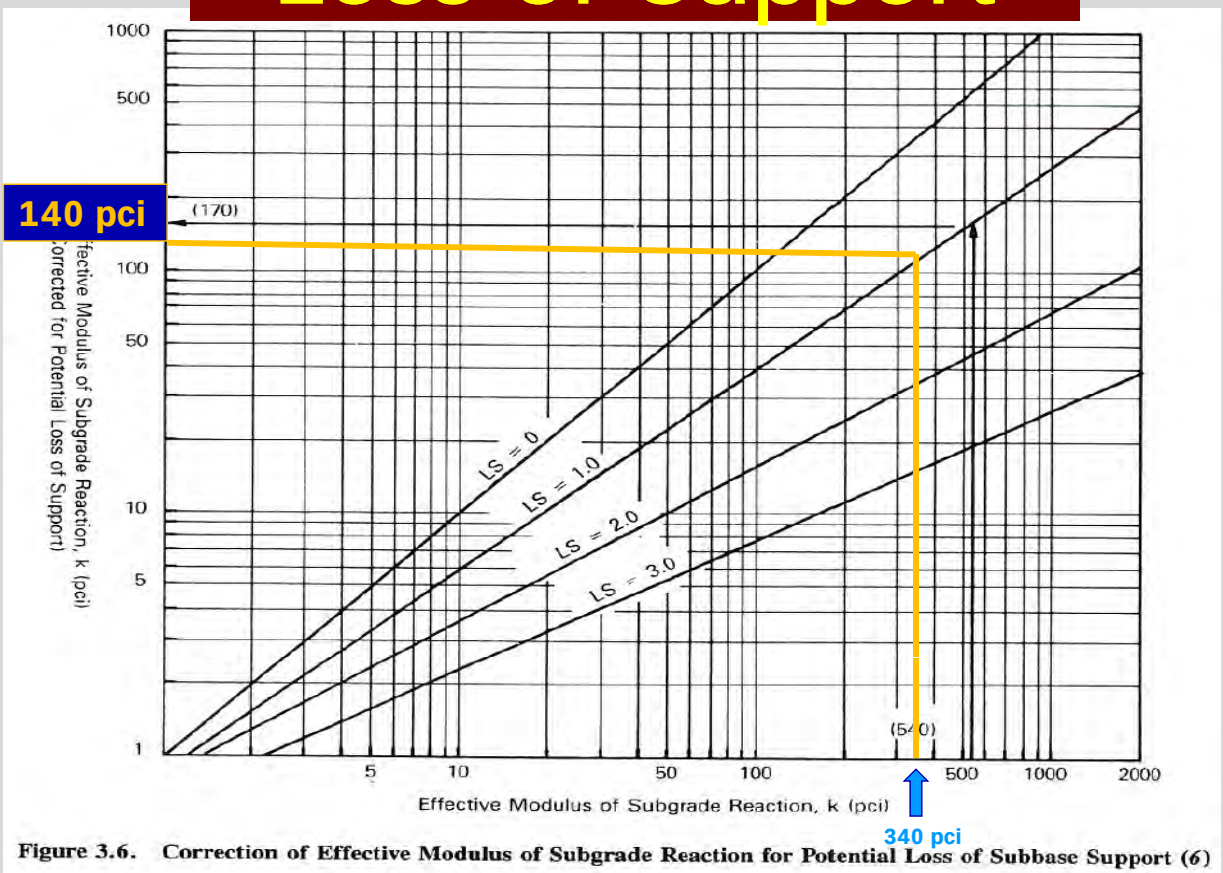


Figure 3.6. Correction of Effective Modulus of Subgrade Reaction for Potential Loss of Subbase Support (*6*)

k-Value

Season	Subgrade M_r	Base M_r	Composite k-value	Relative Damage
Winter	20000 psi	22000 psi	800 pci Fig. 3.3	28 Fig. 3.5
Spring	4500 psi	22000 psi	200 pci	60
Summer	6800 psi	22000 psi	300 pci	50
Fall	5600 psi	22000 psi	250 pci	55
			Sum Damage=	193
			Average Damage=	48.25 (193÷4)
	Back calculate k-value from average damage=			340 pci Fig. 3.5
	Correct for Loss of Support (LS=1.0)			Fig. 3.6

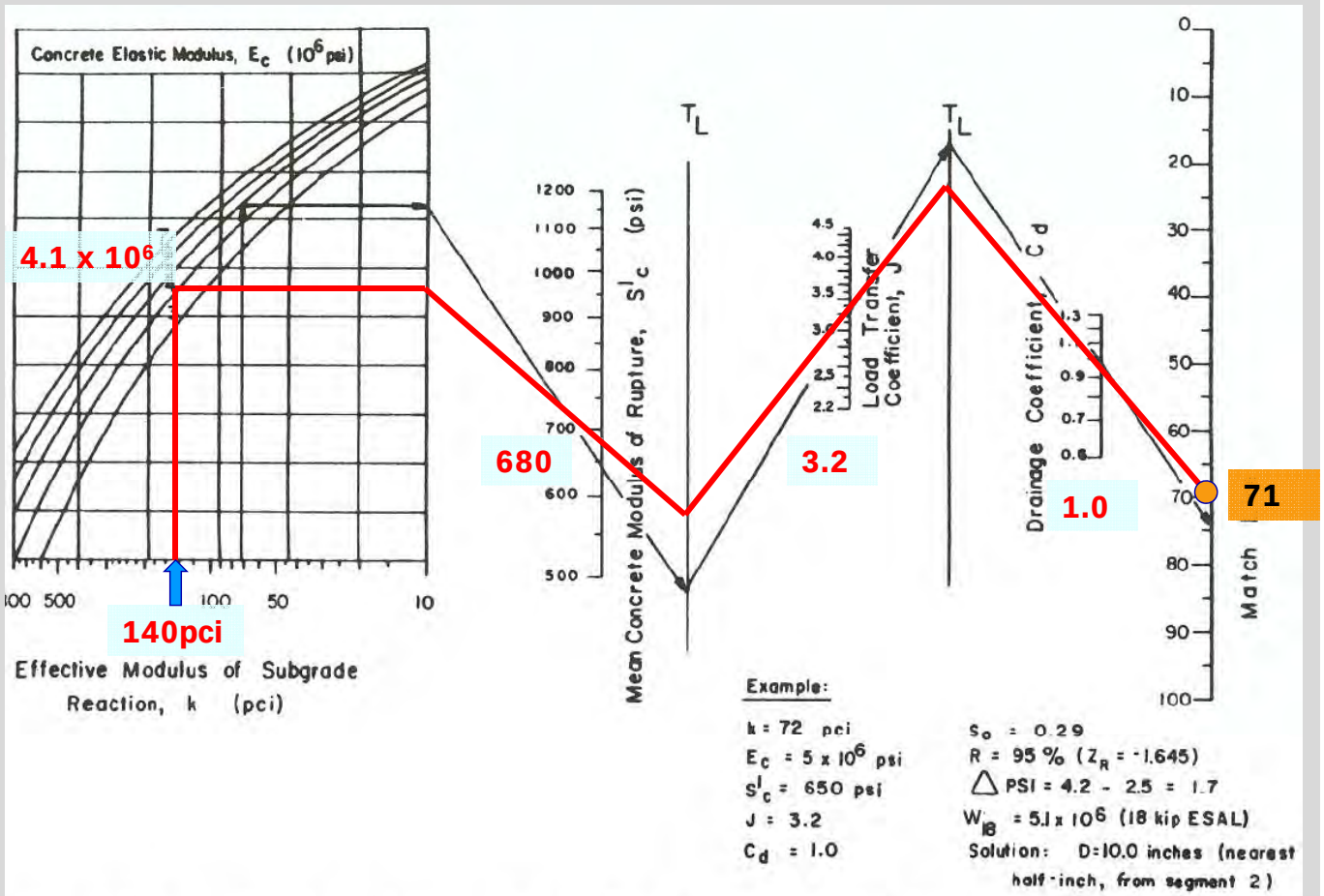


Figure 3.7. Design Chart for Rigid Pavement Based on Using Mean Values for Each Input Variable (Segment 1)

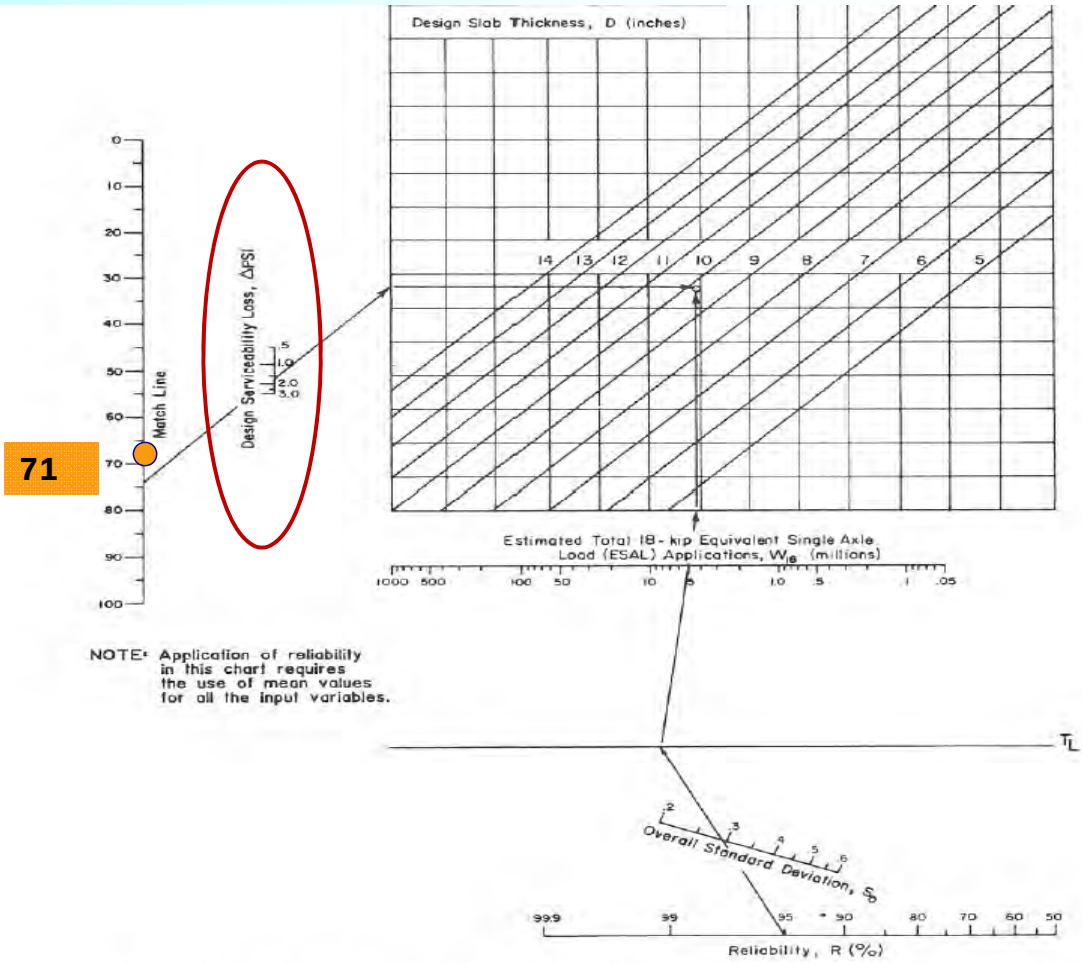


Figure 3.7. Continued—Design Chart for Rigid Pavements Based on Using Mean Values for Each Input Variable (Segment 2)

Serviceability

The ability of the pavement to provide service for the users.

Initial Serviceability, established at the AASHTO test sight

PCC = 4.5

HMA = 4.2

Terminal Serviceability, lowest value tolerated before rehabilitation

3.0 12% people object

2.5 55% people object Recommend for higher volumes

2.0 85% people object Recommend for lower volumes

Design Serviceability Loss

ΔPSI = Initial – Terminal

= 4.5 – 2.0

= 2.5

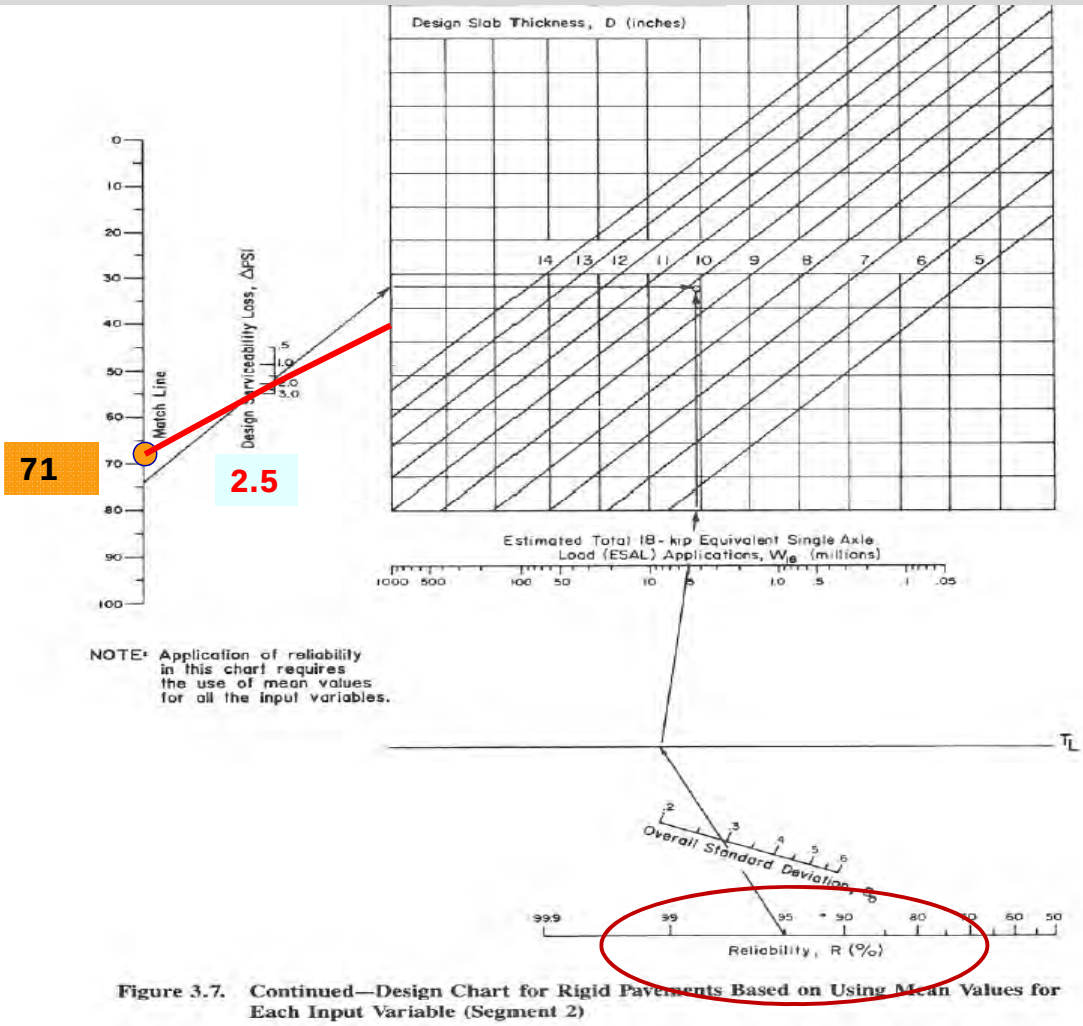


Figure 3.7. Continued—Design Chart for Rigid Pavements Based on Using Mean Values for Each Input Variable (Segment 2)

Reliability

A predetermined level of assurance that the pavement will survive the design period.
Typically use functional classification to determine % Reliability

Table 2.2. Suggested Levels of Reliability for Various Functional Classifications

Functional Classification	Recommended Level of Reliability	
	Urban	Rural
Interstate and Other Freeways	85–99.9	80–99.9
Principal Arterials	80–99	75–95
Collectors	80–95	75–95
Local	50–80	50–80

NDOR Uses:
85% Interstate
80% Expressway
75% Highway >3000 ADT
70% Highway <3000 ADT

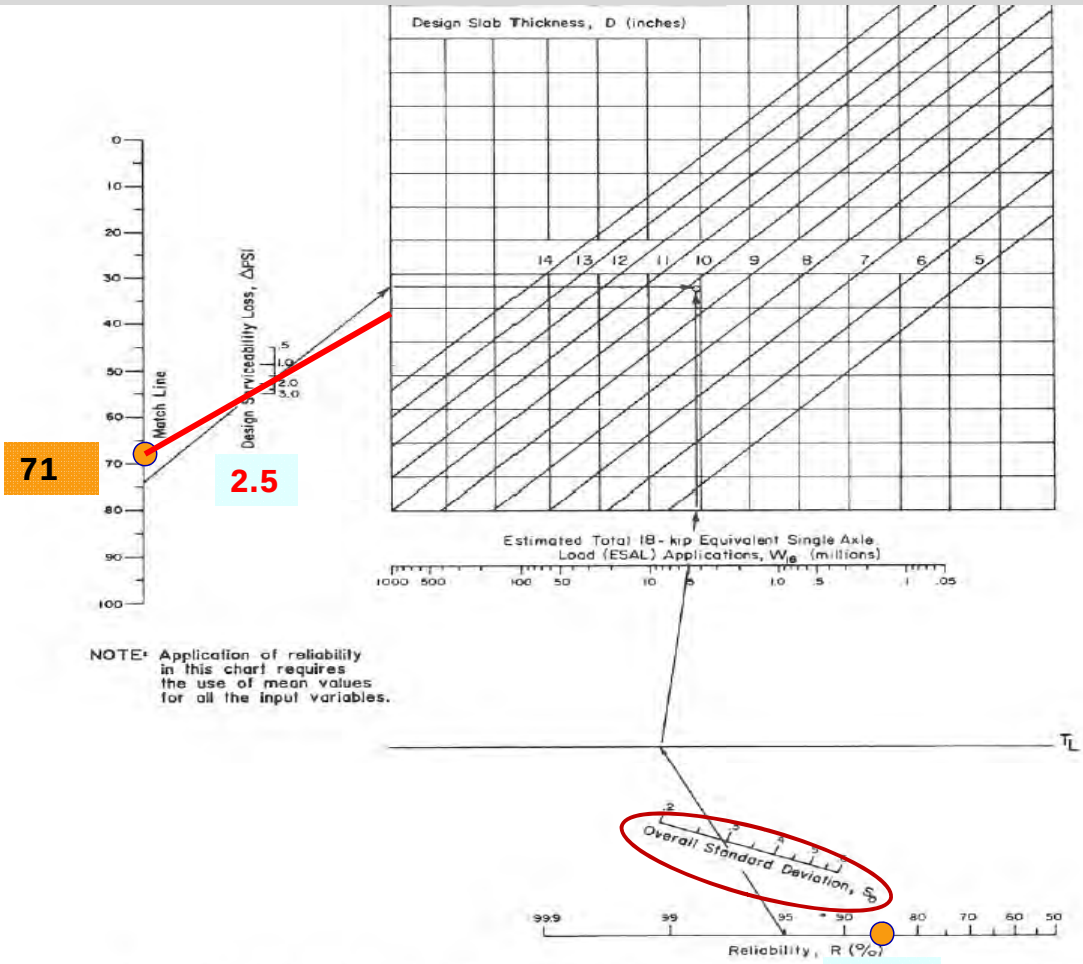
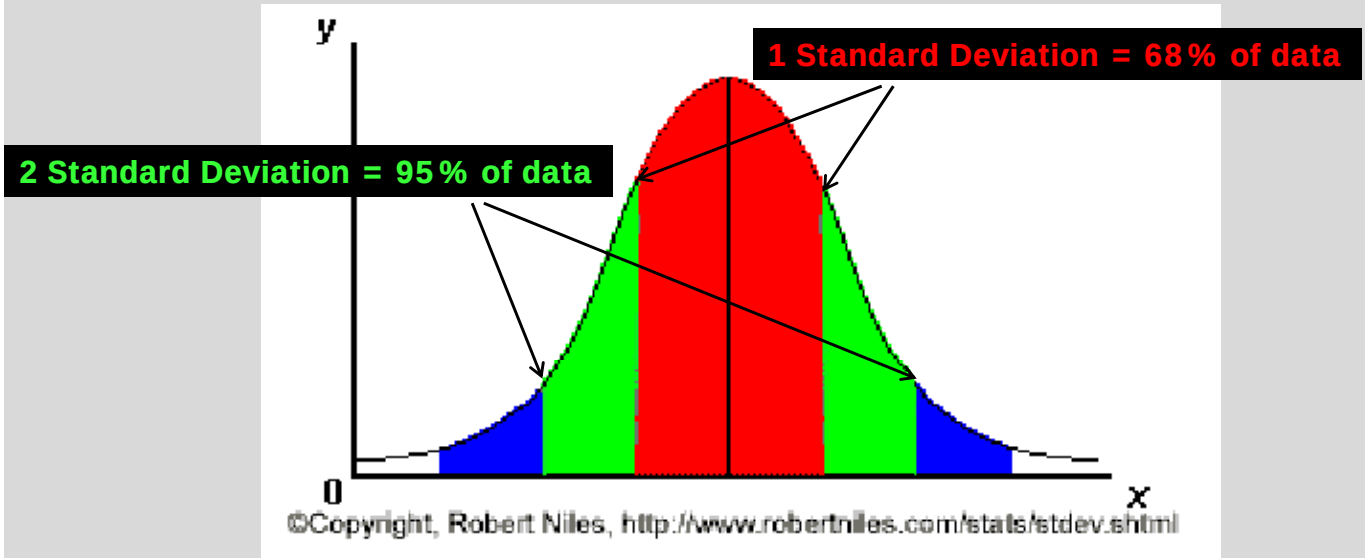


Figure 3.7. Continued—Design Chart for Rigid Pavements Based on n Values for Each Input Variable (Segment 2)

Standard Deviation

The are several references of standard deviations for each level of reliability, but we want to use the

Overall Standard Deviation



Standard Deviation

The are several references of standard deviations for each level of reliability, but we want to use the

Overall Standard Deviation

Rigid Pavements	0.30 – 0.40
Flexible Pavements	0.40 – 0.50

Future Traffic Considered

Future Traffic Not Considered

NDOR Uses:

Rigid	**0.35**
Flexible	**0.45**

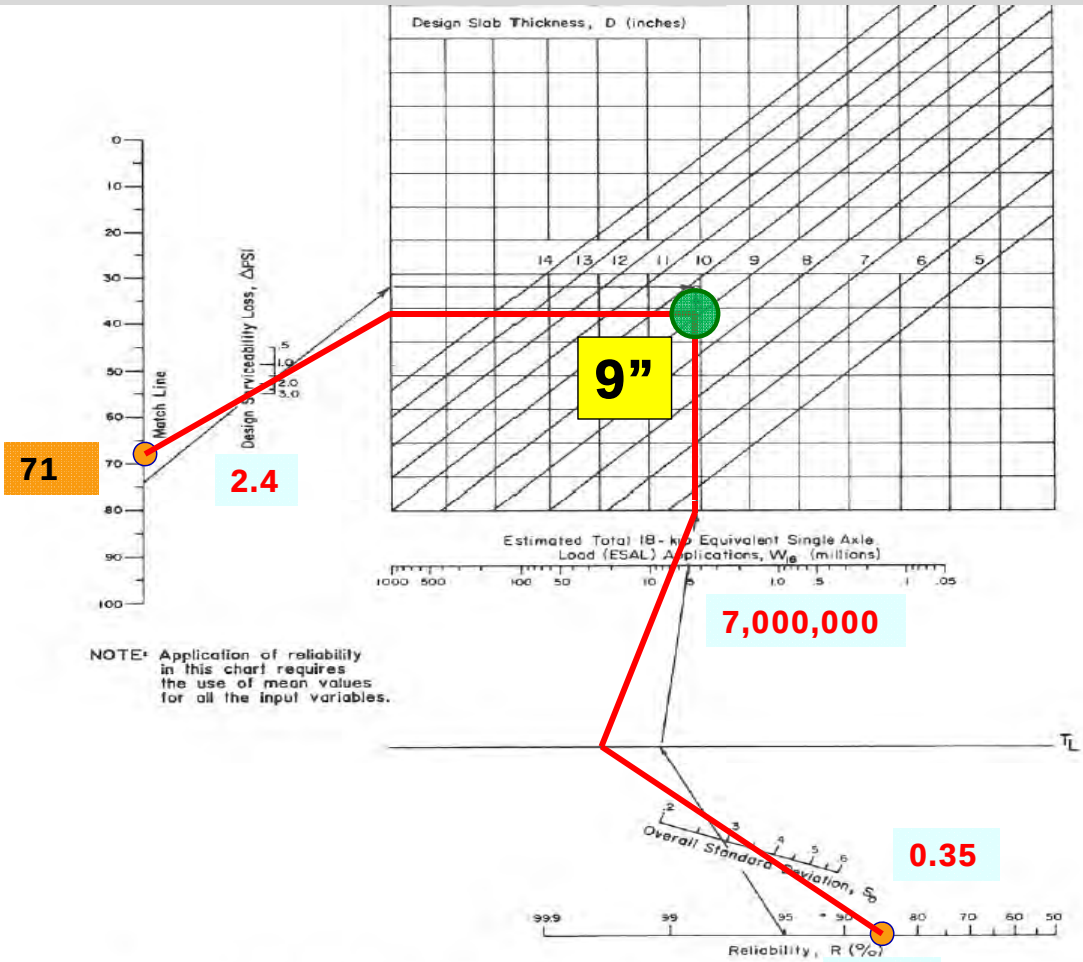


Figure 3.7. Continued—Design Chart for Rigid Pavements Based on n Values for Each Input Variable (Segment 2)

Rigid Design Inputs

Thickness based off ESAL's

Use this method for New Build design or for establishing Residual thickness for conversion to Rehabilitation design.

Expected Performance Years	
No. lanes	
% Trucks in Design Lane	
% Trucks in Design Direction	
Ave. Initial Truck Factor	
Annual Truck Factor Growth Rate	
Annual Truck Volume Growth Rate	
Growth Rate Method	
Intial Serviceability	
Terminal Serviceability	
28-Day Mean PCC Modulus Rupture	
28-day Mean PCC Elastic Modulus of Slab	

Base Type	
Base Thickness	
Depth to Bedrock	
Project Slab Thickness	
Loss of Support	
Reliability Level	
Overall Standard Deviation	
Load Transfer Coefficient	
Drainage Coefficient	
Thickness Required (D_r)	

9”

Use these inputs & the Rigid Pavement Nomograph (Figure 3-7, pg. 45)

PCC Condition Survey Method (Rehabilitation)

Use for Rehabilitation of HMA overlay for existing concrete roadways

$$D_{ovl} = A\left(D - D_{eff}\right)$$

$$A = 2.2231 - 0.0099\left(D - D_{eff}\right)^2 + 0.1537\left(D - D_{eff}\right)$$

$$D_{eff} = F_{jc} \times F_{fat} \times F_{dur}$$

Definitions:

D_{ovl} = HMA overlay thickness (inches)

D = PCC required thickness (inches) based on ESAL's

D_{eff} = Condition Survey or Factor of existing PCC as thickness (inches)

A = Conversion number for PCC to HMA

F_{jc} = Joint & Crack adjustment factor (1.0 - 0.5)

F_{fat} = Fatigue Damage adjustment factor (1.0 - 0.3)

F_{dur} = Durability Factor (1.0 - 0.8)

F_{jc}=	
F_{fat}=	
F_{dur}=	
D_{eff} =	

A=	

D_{ovl}=	

Comments:

Rigid Design Inputs

Thickness based off ESAL's

Use this method for New Build design or for establishing Required thickness for comparison to Rehabilitation design.

Expected Performance Years		Base Type	
No. lanes		Base Thickness	
% Trucks in Design Lane		Depth to Bedrock	
% Trucks in Design Direction		Project Slab Thickness	
Ave. Initial Truck Factor		Loss of Support	
Annual Truck Factor Growth Rate		Reliability Level	
Annual Truck Volume Growth Rate		Overall Standard Deviation	
Growth Rate Method		Load Transfer Coefficient	
Intial Serviceability		Drainage Coefficient	
Terminal Serviceability			
28-Day Mean PCC Modulus Rupture		Thickness Required (D_r)	9”
28-day Mean PCC Elastic Modulus of Slab			

Use these inputs & the Rigid Pavement Nomograph (Figure 3.7, pg.II-45)

PCC Condition Survey Method (Rehabilitation)

Use for Rehabilitation(HMA overlay) for existing concrete roadways

$$D_{ovl} = A\left(D_r - D_{eff}\right)$$

$$A = 2.2233 + 0.0099\left(D_r - D_{eff}\right)^2 - 0.1534\left(D_r - D_{eff}\right)$$

$$D_{eff} = F_{jc} \times F_{fat} \times F_{dur}$$

Definitions:

D_{ovl} = HMA overlay thickness (inches)
D_r = PCC required thickness (inches) based on ESAL's
D_{eff} = Condition Survey or Factor of exsting PCC as thickness (inches)
A= Conversion number for PCC to HMA
F_{jc} = Joint & Crack adjustment factor (1.0 - 0.5)
F_{fat} = Fatigue Damage adjustment factor(1.0 - 0.9)
F_{dur} =Durability Factor (1.0 - 0.8)

F_{jc}=	
F_{fat}=	
F_{dur}=	
D_{eff} =	

A=	

D_{ovl}=	

Comments:

EXISTING PCC ASSESSMENT

D_{eff} - Remaining Effect Life of the existing pavement

$$D_{eff} = F_{jc} \times F_{dur} \times F_{fat} \times D$$

EXISTING PCC ASSESSMENT

$$D_{eff} = F_{jc} \times F_{dur} \times F_{fat} \times D$$

F_{jc} – Adjustment Factor for joints and cracks that reflect through

Assuming that all joints/cracks are repaired then a factor of 1.0 should be used.

Use Fig. 5.12 for PCC slabs where not all the cracks/joints will be repaired.

This is NOT a factor for material distresses such as ASR.

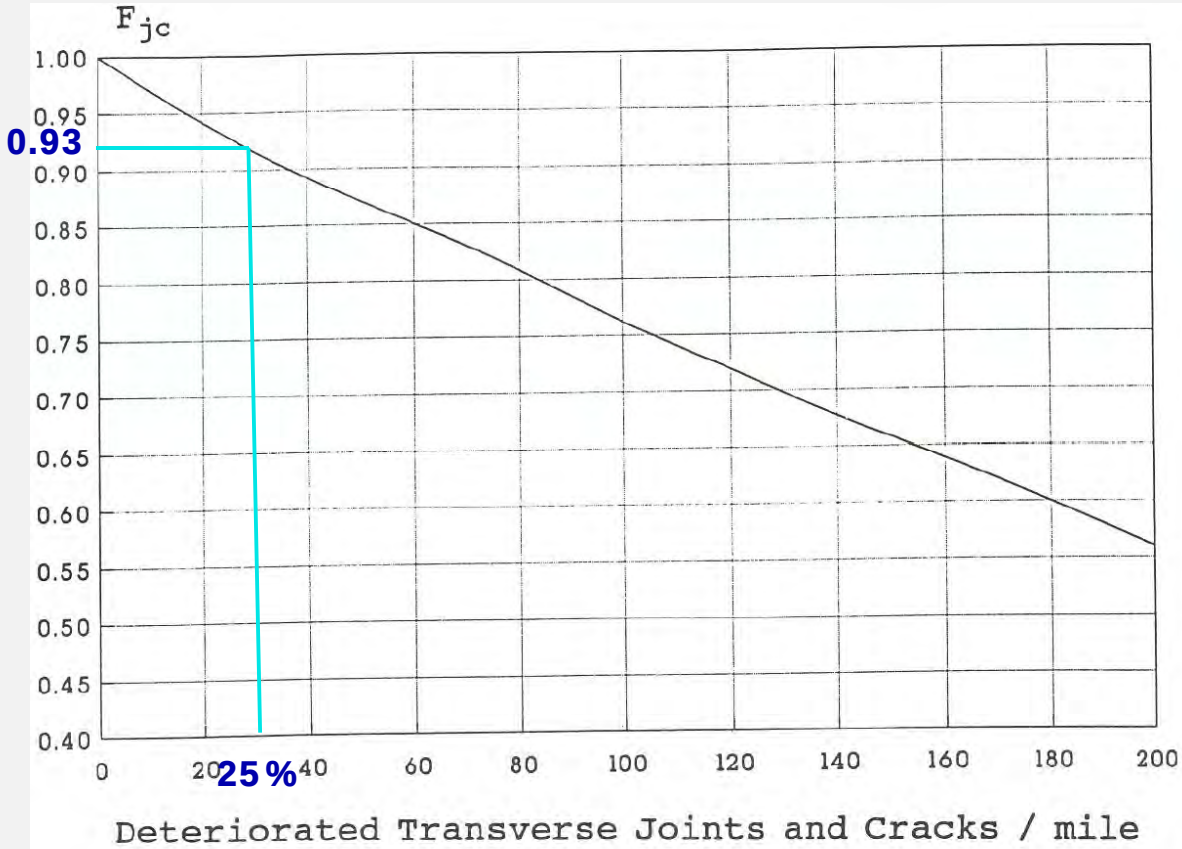
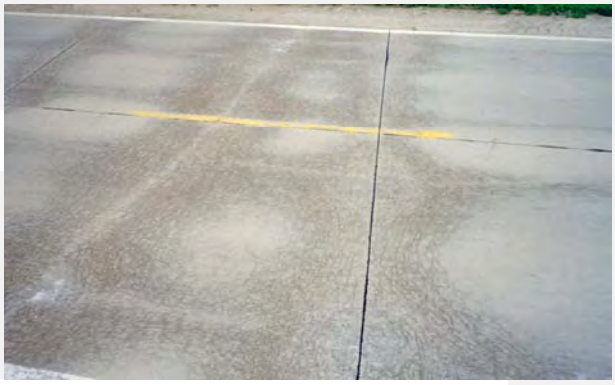


Figure 5.12. F_{jc} Adjustment Factor

EXISTING PCC ASSESSMENT



$D_{eff} = F_{jc} \times F_{dur} \times F_{fat} \times D$

F_{dur} – Adjustment Factor for Durability

Use this factor for assessing pavements with ASR, D-Cracking…..

1.0	No durability issues
0.96 – 0.99	Some cracking, no spalling
0.88 – 0.96	Cracking & Spalling
0.80 – 0.88	Severe cracking & Spalling

EXISTING PCC ASSESSMENT

$D_{eff} = F_{jc} \times F_{dur} \times F_{fat} \times D$

F_{fat} – Adjustment Factor for Fatigue

Use this factor for assessing pavements for deterioration due to repeated loading such as punch outs or large working joints

0.97 - 1.0	Few
0.94 – 0.97	Several
0.90 – 0.94	Significant

EXISTING PCC ASSESSMENT

$$D_{eff} = F_{jc} \times F_{dur} \times F_{fat} \times D$$

Example:

Original thickness 8” PCC, D=8

All joints repaired, F_{jc} = 1.0

Bad ASR, F_{dur}=0.85

Some loading failures, F_{fat}=0.95

$$D_{eff} = F_{jc} \times F_{dur} \times F_{fat} \times D$$

$$1.0 \times 0.85 \times 0.95 \times 8$$

$$D_{eff} = 6.46$$

EXISTING PCC ASSESSMENT

A= Conversion factor for concrete to asphalt

$= 2.2233 + 0.0099(D_r - D_{eff})^2 - 0.1534(D_r - D_{eff})$

$= 2.2233 + 0.0099(9-6.46)^2 - 0.1534(9-6.46)$

A= 1.90

D_{ovl} = Asphalt overlay thickness

$= A\,(D_r - D_{eff})$

$= 1.9(9 - 6.46)$

D_{ovl} = 4.8”

FLEXIBLE Pavement Design

Flexible Design Inputs

Structural Number based off ESAL's

Use this method for New Build design or for establishing Required structure number for comparison to rehabilitation design.

Expected Performance Years	
No. Lanes	
% Trucks in Design Lane	
% Trucks in Design Direction	
Ave. Initial Truck Factor	
Annual Truck Factor Growth Rate	
Annual Truck Volume Growth Rate	
Growth Rate Method	
Intial Serviceability	
Terminal Serviceability	
Reliability Level	
Overall Standard Deviation	
Structure Number Required	

Use these inputs & the Flexible Pavement Nomograph (Figure 1-1, pg.II-12).

HMA Condition Survey Method (Rehabilitation)

Use this method for Rehabilitation of existing asphalt roadways or for bituminous recycling strategies

Surface Course

Type		
Depth (D_1,inches)		
Layer Coefficient (a_1)		
Structure No. for Layer(SN_1)		$SN_1=D_1 \times a_1$

Base Layer

Type		
Depth (D_2,inches)		
Layer Coefficient(a_2)		
Drainage Coefficient(m_2)		
Structure No. for Layer(SN_2)		$SN_2=D_2 \times a_2 \times m_2$

Sub-Base Layer

Type		
Depth (D_3,inches)		
Layer Coefficient(a_3)		
Drainage Coefficient(m_3)		
Structure No. for Layer(SN_3)		$SN_3=D_3 \times a_3 \times m_3$

Total Structure Provided ($SN_1 + SN_2 + SN_3 + ...$)

Add or subtract layers as needed

Comments:

Flexible Design Inputs

Structural Number based off ESAL's	
Expected Performance Years	
No. Lanes	
% Trucks in Design Lane	
% Trucks in Design Direction	
Ave. Initial Truck Factor	
Annual Truck Factor Growth Rate	
Annual Truck Volume Growth Rate	
Growth Rate Method	
Intial Serviceability	
Terminal Serviceability	
Reliability Level	
Overall Standard Deviation	
Structure Number Required	

Use this method for New Build design or for establishing Required structure number for comparison to Rehabilitation design.

Use these inputs & the Flexible Pavement Nomograph (Figure 3.1, pg.II-32)

Different Output than Rigid Design

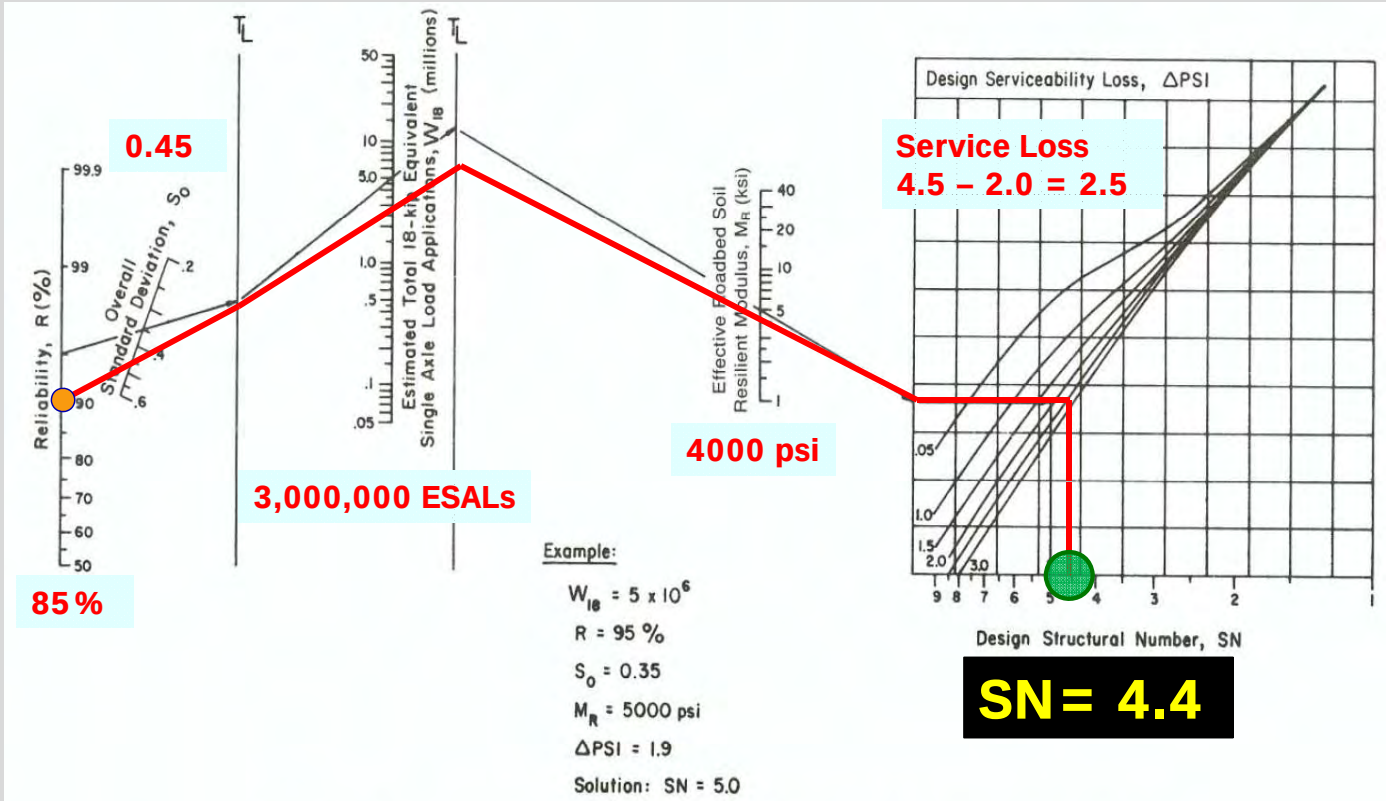


Figure 3.1. Design Chart for Flexible Pavements Based on Using Mean Values for Each Input

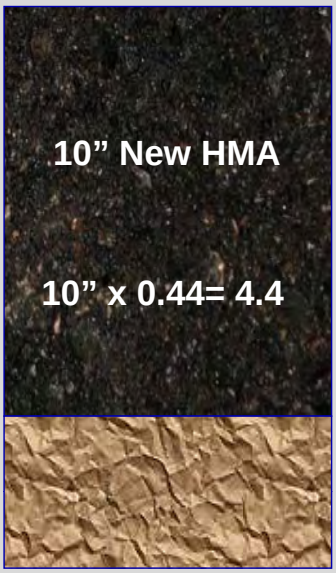
Structural Number

The Structural Number is an abstract number expressing the structural strength of a pavement required for given **combinations** of **soil support**, total **traffic** loading, **layer** coefficients, terminal **serviceability** and effects from the **environment**.

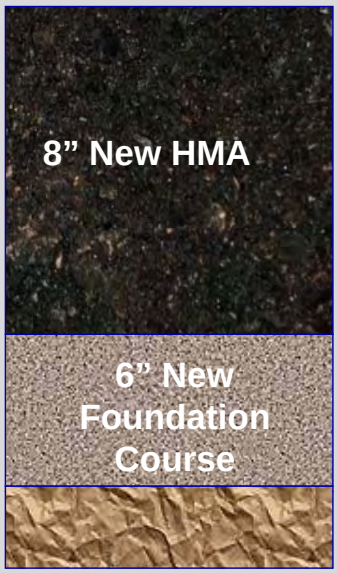
Layer Coefficients

Foundation Course	0.20
SABC	0.14
Bit Millings Base	0.20
Existing AC	0.24-0.35
New AC	0.44
Existing Bit Sand	0.20
Cold-In-Place Recycle	0.25
FDR w/ash	0.25
FDR w/water	0.14
HLSS	0.25
HRB	0.40
Stabilized Subgrade	0.22

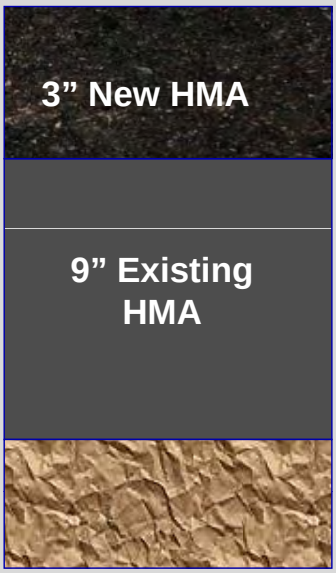
Structural Number
(Layer Coefficients)



SN = 4.4



SN = 4.4



SN = 4.4

Structural Number

SN = 4.4

Structural Number

Higher SN = More Structure

HMA Condition Survey Method (Rehabilitation)

Use this method for Rehabilitation of existing asphalt roadways or for Bituminous Recycling Strategies

Surface Course		
Type		
Depth (D_1,inches)		
Layer Coefficient (a_1)		
Structure No. for Layer(SN_1)		$SN_1=D_1 \times a_1$
Base Layer		
Type		
Depth (D_2,inches)		
Layer Coefficient(a_2)		
Drainage Coefficient(m_2)		
Structure No. for Layer(SN_2)		$SN_2=D_2 \times a_2 \times m_2$
Sub-Base Layer		
Type		
Depth (D_3,inches)		
Layer Coefficient(a_3)		
Drainage Coefficient(m_3)		
Structure No. for Layer(SN_3)		$SN_3=D_3 \times a_3 \times m_3$
Total Structure Provided ($SN_1 + SN_2 + SN_3$+...)		

Add or Subtract Layers as needed

Comments:

Flexible Design Inputs

Structural Number based off ESAL's

Expected Performance Years
No. Lanes
% Trucks in Design Lane
% Trucks in Design Direction
Ave. Initial Truck Factor
Annual Truck Factor Growth Rate
Annual Truck Volume Growth Rate
Growth Rate Method
Intial Serviceability
Terminal Serviceability
Reliability Level
Overall Standard Deviation
Structure Number Required **4.4**

HMA Condition Survey Method (Rehabilita

Surface Course

Type
Depth (D_1,inches)
Layer Coefficient (a_1)
Structure No. for Layer(SN_1) $SN_1=D_1 \times a_1$

Base Layer

Type
Depth (D_2,inches)
Layer Coefficient(a_2)
Drainage Coefficient(m_2)
Structure No. for Layer(SN_2) $SN_2=D_2 \times a_2 \times m_2$

Sub-Base Layer

Type
Depth (D_3,inches)
Layer Coefficient(a_3)
Drainage Coefficient(m_3)
Structure No. for Layer(SN_3) $SN_3=D_3 \times a_3$

Total Structure Provided ($SN_1 + SN_2 + SN_3 + ...$) **4.4**

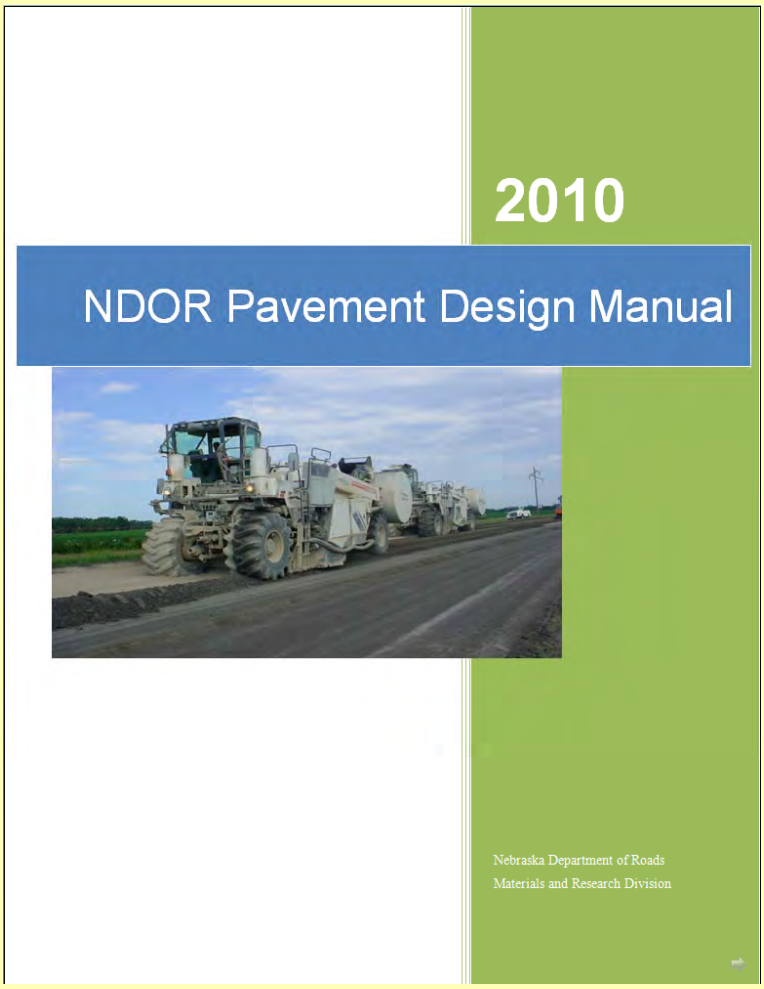
Comments:

Does the rehabilitation design meet the required structure number?

If not, you would need to adjust the design.

OUTLINE

- Pavement, cont'd.
  - Asphalt (Flexible)
    - History of HMA
    - PG Binders
    - HMA Construction
  - Recycling
    - Partial Depth HMA
    - Full Depth HMA
    - PCC Recycling
- Pavement Design
  - Traffic
  - Rigid Design
  - Flexible Design
- **Review Deliverables**
- **NDOR Pavement Design Manual**
  - **Quick References**
- Maintenance
  - Emulsions
  - HMA maintenance
  - PCC maintenance


2010
NDOR Pavement Design Manual
Nebraska Department of Roads
Materials and Research Division

2.2h DARWIN Rigid Design Inputs

Date: Revised 9/25/07
Source: Pavement Design Section

The following inputs are values typically recommended by NDOR. Values may be adjusted as needed based on specific project details and in accordance with the 1993 *AASHTO Guide for Design of Pavement Structures.*

Description:

- Project Number
- Project Title
- Control Number
- Designer
- Date

18-kip ESALs Over Initial Performance Period Calculation (Simple Tab):

- Performance Period (years) ---------- 35
- Two-way Daily Traffic (ADT) ---------- Current ADT
- Number of Lanes in Design Direction ---------- 1 or 2 (usually)
- % of All Trucks in Design Lane ---------- 100 % (2-lanes)
  80 % (Expressway and Interstate)
  60 % (6-lanes)
- % Trucks in Design Direction ---------- 50 % (always)
- % Heavy Trucks (of ADT) ---------- Current % of ADT
- Average Initial Truck Factor (ESALs/Truck) ------- See Summary of ESAL Values
- Annual Truck Factor Growth Rate (%) ---------- 0 % (always)
- Annual Truck Volume Growth Rate (%) ---------- $((\text{Future TADT}/\text{Present TADT})^{(1/\text{yrs})}-1) \times 100$
- Growth Rate ---------- Compound
- Initial Serviceability ---------- 4.4
- Terminal Serviceability ---------- 3.0 (Interstate System)
  2.5 (All other Highway Systems)
- 28-Day Mean PCC Modulus of Rupture ---------- 710 psi
- 28-Day Mean Elastic Modulus of Slab ---------- 4,100,000 psi

Mean Effective k-value:

Seasons:	Roadbed Soil Resilient Modulus (psi):	Base Elastic Modulus (psi):
Frozen (Dec – Feb)	20,000	22,000
Wet (Mar-May)	Soils Data	22,000
Optimum (Jun-Aug)	Soils Data	22,000
Dry (Sept-Nov)	Soils Data	22,000

- Base Type ---------- Foundation Course
- Base Thickness ---------- 4" (usually)
- Depth to Bedrock ---------- 20 ft
- Projected Slab Thickness ---------- 10 in.
- Loss of Support---------- 1
- Reliability Level (%) ---------- 85 (Interstate System)
  80 (Expressway System)
  75 (Highways w/Future ADT over 3000)
  70 (Highways w/Future ADT under 3000)
- Overall Standard Deviation ---------- 0.35
- Load Transfer Coefficient, J ---------- 3.0 (Doweled conc. w/tied conc. shlds.)
  3.1 (Doweled conc., 30' top)
  3.2 (Doweled conc. w/asph. or no shlds.)
  3.6 (Non-doweled conc. w/tied conc. shlds.)
  4.1(Non-doweled conc. w/asph. or no shlds.)
- Overall Drainage Coefficient, Cd ---------- 1

2.2i DARWIN Flexible Design Inputs

Date: Revised 9/30/08
Source: Pavement Design Section

The following inputs are values typically recommended by NDOR. Values may be adjusted as needed based on specific project details and in accordance with the 1993 *AASHTO Guide for Design of Pavement Structures.*

Description:

- Project Number
- Project Title
- Control Number
- Designer
- Date

18-kip ESALs Over Initial Performance Period Calculation (Simple Tab):

- Performance Period (New Build) ---------- 20 yrs
- Performance Period (Overlay Design Module Only)
  - 4" HRB w/2" AC & 4" AC over PCC ---------- 20 yrs
  - HLSS, Fly Ash, & CIR w/ 3" AC, Mill 4"/Fill 4"--- 15 yrs
- Two-way Daily Traffic (ADT) ---------- Current ADT
- Number of Lanes in Design Direction ---------- 1 or 2 (usually)
- % of All Trucks in Design Lane ---------- 100 % (2-lanes)
  80 % (Expressway and Interstate)
  60 % (6-lanes)
- % Trucks in Design Direction ---------- 50 % (always)
- % Heavy Trucks (of ADT) ---------- Current % of ADT
- Average Initial Truck Factor (ESALs/Truck) ------- See Summary of ESAL Values
- Annual Truck Factor Growth Rate (%) ---------- 0 % (always)
- Annual Truck Volume Growth Rate (%) ---------- ((Future TADT/Present TADT)$^{(1/yrs)}$ -1) x 100
- Growth Rate ---------- Compound
- Initial Serviceability ---------- 4.4
- Terminal Serviceability ---------- 3.0 (Interstate System)
  2.5 (All other Highway Systems)
- Reliability Level ---------- 85 (Interstate System)
  80 (Expressway System)
  75 (Highways w/Future ADT over 3000)
  70 (Highways w/Future ADT under 3000)
- Overall Standard Deviation ---------- 0.45

Effective Roadbed Soil Resilient Modulus Calculation:

Season:	Roadbed Soil Resilient Modulus (psi):
• Frozen (Dec – Feb)	20,000
• Wet (Mar-May)	Soils Data
• Optimum (Jun-Aug)	Soils Data
• Dry (Sept-Nov)	Soils Data

- Number of Construction Stage---------- 1

Thickness Design (Specified)

Material Description		Struct Coeff.	Drain Coeff.	Thickness	One Direct. Width
• Asphalt	0.44	1	1st Guess	Proposed Design	

Summary of ESAL Values

Rigid Pavement

National Functional Classification	2-year Average	1997	1998	Adjusted B. Rea Peak (use this)
01	1.5328	1.3474	1.7183	1.8013
02	1.1736	1.2754	1.0718	1.3392
06	1.0580	1.0901	1.0260	1.2810
07	0.7642	0.7910	0.7373	0.8295
11	0.7470	0.8080	0.6861	0.8715
14	0.6202	0.5953	0.6451	0.9282
16	0.2961	0.3064	0.2857	0.6657

Flexible Pavement

National Functional Classification	2-year Average	1997	1998	Adjusted B.Rea Peak (use this)
01	0.8585	0.8364	0.8806	1.1390
02	0.7350	0.7949	0.6750	0.8823
06	0.6687	0.6923	0.6451	0.8680
07	0.4661	0.4795	0.4527	0.5611
11	0.4775	0.5055	0.4495	0.5816
14	0.4084	0.3934	0.4233	0.6859
16	0.2401	0.2455	0.2348	0.4817

Recommended Truck Factors based on NE Traffic and National Functional Classification

See http://www.nebraskatransportation.org/maps/highway/nat-func.pdf for National Functional Classification map

3.1 Asphalt Mix, Binder, Gradation & Minimum Thickness Policy

Date: Revised 11/10/10
Source: Syslo

Mix Selection

Heavy Trucks Per Day	Surface Mix Type	Base Mix Type
0 – 200	SPR (some SPL & SP4 Spcl)	SPR, SPL or HRB
200 –500	SP-4 Special *(some SPR)*	SP-4 Special, SPR, SPL or HRB
500-1500	SP-4	SP-4, SPR *(may consider HRB)*
1500+	SP-5	SP-5
Shoulders	SPS	SPS
Parking/temporary/Maint.	SPL or SPR	SPL or SPR

Performance Graded Binders

Interstate/Expressway Mainline (SP-5)	PG 70-28
Leveling Course, Type LC	PG 70-28 *(Interstate)* PG 64-34 *(All Others)*
Mainline Top Lifts (SP-4 Special, SP-4)	PG 64-34 (*Some 70-28*)
Mainline Top Lift Low Volume w/High Recycle (SPR)	PG 64-34
Mainline Bottom Lift w/High Recycle (HRB, SPL, SPR)	PG 64-34
Shoulder Mix (SPS)	PG 52-34
Temporary Interstate/Some Expressway	PG 70-16 *(Or better)*
Temporary for all other highways	PG 64-22 *(Or better)*

PG 70-28: Resists deformation up to 70°C (158°F) and Cracking to -28°C(-82°F)

Gradation

$^{3}/_{16}$" (0.19) gradation band for thicknesses less than 1",
$^{3}/_{8}$" (0.375) gradation band for thicknesses 1" or greater
½" (0.5) gradation band for thicknesses 1 $^{3}/_{8}$" or greater

New Construction Minimum Thickness

Heavy Trucks per Day	Minimum Thickness**
0 – 200	8" (6" in pure sand regions)
200 – 1600	10" (8" in pure sand regions)
1600+	12" (10" in pure sand regions)

**AASHTO 93 currently used to determine structural thickness

These changes are due to the use of higher RAP percentages in all HMA (RAP incentive & increase in the allowable percentage used) and the use of high RAP mixes being used in base lifts.

9.1 Estimated Costs Per Mile

Date: Revised 5/5/10
Source: Debutts

Updated Costs 5/5/10

ESTIMATED COSTS PER MILE

Costs include a 1.32 factor (E&C)
Asphalt quantities are SP-4 w/PG 64-28 Binder, except

PG 52-34 $575/ton
PG 64-28 & 58-34 $630/ton
PG 70-28 $700/ton

Interstate is SP-5 w/PG 70-28
Shoulders are SPS w/PG 52-34
HRB/SPL/SPR uses PG 58-34 or 64-34

No.	STRATEGY DESCRIPTION		COST /MILE
1.	4" Hydrated Lime Slurry w/3" Overlay		$299K
	4" HLSS w/Trench Widening & 3" overlay (28' top)		$342K
2.	Mill 1.5", Place 2"		$148K
3.	Class 1 Mill, Place 4"		$283K
4.	Class 3 Mill 2", Place 4"		$286K
5.	Class 3 Mill 4", Place 4"		$281K
	Class 3 Mill 4", Place 2" HRB + Place 2" SP-4		$257K
6.	10" Fly Ash Bituminous Stabilization w/ 3" overlay		$315K
7.	Dowel Bar Retrofit & Diamond grind driving lanes, then joint seal (14' width one direction)		$186K
8.	Interstate- Mainline 30', Cold Milling 4" and place 4" SP-5. Outside shoulder 7' Cold Milling 1.5" and place 1.5"		$396K x 2 for 4-lane
9.	New Build HMA on stabilized subgrade 24' wide	6" thick	$497K
		8" thick	$610K
		9" thick	$672K
		10" thick	$734K
10.	New Build Dowelled PCC 30'	($31.5/sy) 8" thick	$952K
	(includes 4" F.C., Prep, 6" surf shldr, shldr constr)	($32.5/sy) 9" thick	$975K
		($33.5/sy) 10" thick	$999K
		($37/sy) 12" thick	$1,080K
		($40/sy) 14" thick	$1,150K
11.	4" HRB w/2" SP-4 Overlay		$363K
12.	8" Cold In-place Recycling (CIR) *no overlay included*		$202K
13.	24' x 5" Non Doweled PCC Whitetopping ($25/sy) no special traffic control or bond breaker included		$512K
14.	Hot In-Place Recycling + Armor Coat ($21K/mi)		$116K
15.	Mill 1", Hot In-Place 2" and place 1.5" SPR		$210K

Crack & Seat PCC= $0.50/sy
Stabl Subgrade=$1.90/sy,$550/sta
Sub Prep=$1.00/sy, $200/sta

Rubblize PCC=$2.30/sy
Granular Subdrains=$58/ea
4" Perf. Underdrain=$6/lf

Fnd Course=$2.50/sy
Rubblization=$2.00/sy

(6%)]

"Bituminous Sand Base Course" – Station

"Mineral Filler for Bituminous Sand Base Course – Cubic Yard (cubic meter) **10 CuYds/Sta for (5"x24') **25 m^3/Sta for (130mmx7.3m)

"Mineral Aggregate" – Cubic Yard (cubic meter) Do not use for estimate.

"Water" – MGallon (kiloliter) 1 Mga/Sta (12 kL/Sta)

"Fog Seal" – Gallon (liter) 0.15 Gal/yd^2 (0.68 L/m^2)

** Quantity of Mineral Filler will vary depending on type of soil.

Bituminous Surface Course – Section 512

"Bituminous Surface Course" – Square Yard (square meter)

"Fog Seal" – Gallon (liter) 0.6 Gal/yd^2 (2.5 L/m^2)

Calcium Chloride, Applied – Section 309

"Calcium Chloride Applied" – Ton (megagram) 3 lb/yd^2 (1.6 kg/m^2 or 0.0015 Mg/m^2)

Chip Seal – Special Provision

"Chip Seal Aggregate" – Cubic Yard (cubic meter) 25 lb/yd^2 (aggregate weight 1.4 tons = 1 yd^3) [11.0 kg/m^2 (aggregate weight 1.54 Mg = 1 m^3)]

"Chip Seal Emulsified Asphalt" – Gallon (liter) 0.32Gal/yd^2 (1.4 L/m^2)

Cold In-Place Recycling – Special Provision

"Cold In-Place Recycling" – Station or Square Yard (square meter)

"Repulverization & Aeration" - Station

"Emulsified Asphalt For Cold In-Place Recycling" – Gallon (liter) 3.5% weight of RAP

"Water For Cold In-Place Recycling" – MGallon (kiloliter) 4% weight of RAP & emulsified asph

Note: 1 Megagram = 1000 Liters

Cold Milling – Section 510

"Cold Milling, Class _____" – Station, Square Yard (square meter)

Cracking & Seating Concrete Pavement – Special Provision

"Cracking & Seating" – Square Yard (square meter)

Earth Shoulder Construction – Section 304

"Earth Shoulder Construction" – Station

"Water" – MGallon (kiloliter) 0.25 MGal/Sta (3.0 kL/Sta)

Note: Shoulders are measured separately

Fly Ash Stabilized Bituminous – Special Provision

"Fly Ash Stabilized Bituminous" – Station

"Fly Ash" – Ton (megagram) 10% weight of RAP

"Water for Fly Ash Stabilization" – Mgallon (kiloliter) 5% weight of RAP & Fly Ash

"Fog Seal" – Gallon (liter) 0.24 Gal/yd^2 (1.1Lm^2)

Note: If trimming is required. Estimate 2 applications.

Performance Graded Binder (**–**) Table

Asph. Conc. Type	PG Binder (**-**)	Gradation bands (0.5) multiply asph. conc. Tonnage by	Gradation bands (0.375) multiply asph. conc. Tonnage by	Gradation bands (0.19) multiply asph. conc. tonnage
GGCRM	(58-28)	8.5%	NA	NA
GGCRMLV	(58-28)	8.5%	NA	NA
** HRB	(64-34)	3.25%	NA	NA
LC	(70-28) Interstate (64-34) All others	NA	NA	7.6%
RLC	(64-28)	NA	NA	7.6%
** SPL	(64-34)	*5.0% /3.8%	NA	NA
** SPR	(64-34)	* 5.0% / 3.8%	NA	NA
SPS	(52-34)	* 5.0% / 3.8%	NA	NA
*** SP4 Special	(64-34)	* 5.0% / 4.8%	* 5.6% / 5.2%	NA
*** SP4	(64-34)	* 5.0% / 4.8%	* 5.6% / 5.2%	NA
SP5	(70-28)	* 5.0% / 4.8%	* 5.6% / 5.2%	NA

* For a virgin mix use 5% or 5.6%. If millings are on the project or the contractor has access to millings use 3.8%, 4.8% or 5.2%. Designers, for estimates use the higher percentage.

Thank You
NEBRASKA

OUTLINE

- Pavement, cont'd.
  - Asphalt (Flexible)
    - History of HMA
    - PG Binders
    - HMA Construction
  - Recycling
    - Partial Depth HMA
    - Full Depth HMA
    - PCC Recycling
- Pavement Design
  - Traffic
  - Rigid Design
  - Flexible Design
- Review Deliverables
- NDOR Pavement Design Manual
  - Quick References
- **Maintenance**
  - **Emulsions**
  - **HMA maintenance**
  - **PCC maintenance**

Maintenance

Emulsions

- Oil & Water

Emulsions

Emulsifiers – A surface-active agent (Surfactant) is used to charge water particles to attract and stabilize with asphalt.

Anionic Surfactants – Negative charged ions
Fatty Acids (wood derivatives) blended w/sodium hydroxide

Nonionic Surfactants – Neutral with no ionization
Harder to produce, no as common

Cationic Surfactants – Positive charges ions
Fatty Amines (amino acids, nitrogen-ammonia)
blended w/hydrochloric acid

Emulsions

Break completed

Emulsions

Set Time or Break Times

Slow Set– Designed for mixing stability and longer workability time. Can be used with material that have high amounts of fines.

Medium Set– Designed for mixing with graded material and does not break upon contact.

Rapid Set– Designed to break immediately on contact with material. Typically used with materials with small amounts of fines.

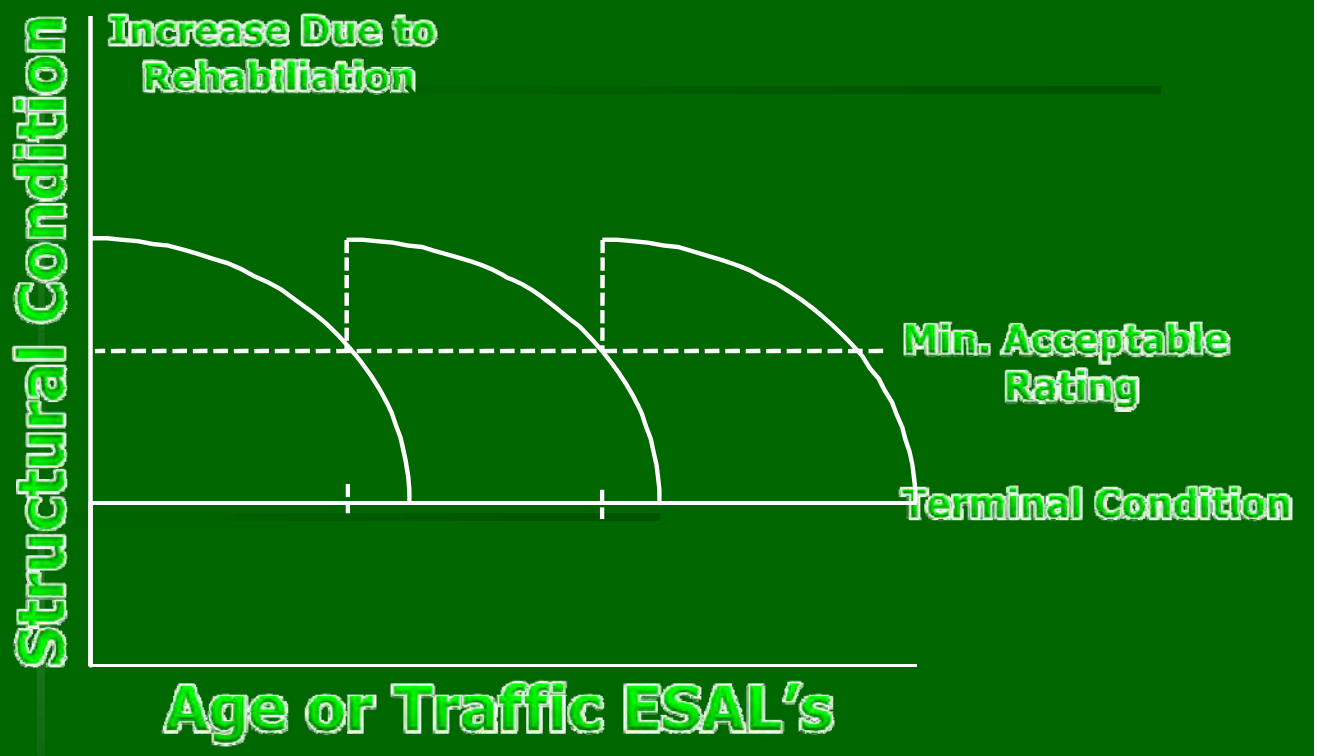
Other considerations:
Weather, Material, Rate.....

Emulsions

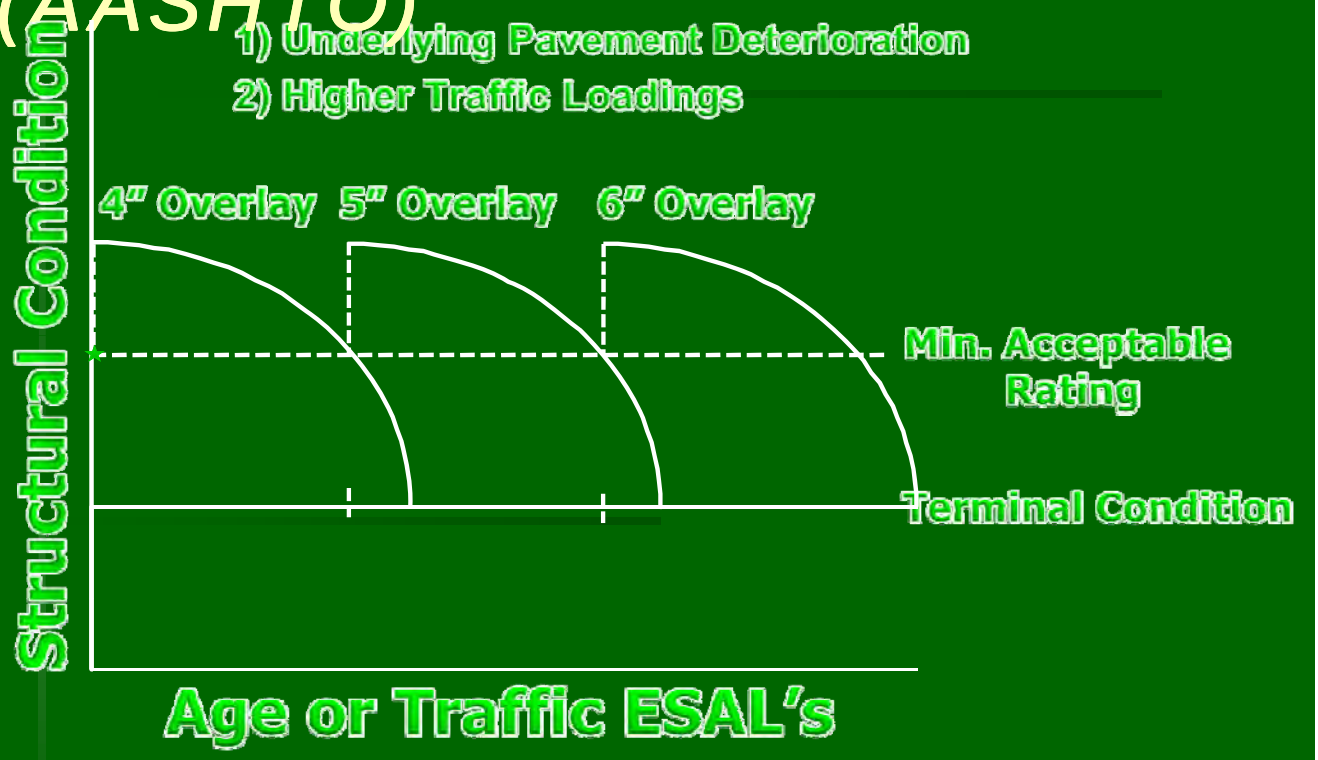
Typical emulsions used in Nebraska:

Rapid Set	**CRS-2P, CRS-2L**
Medium Set	**HFE-300**
Slow Set	**CSS-1, CSS-1H** **SS-1, SS-1H**

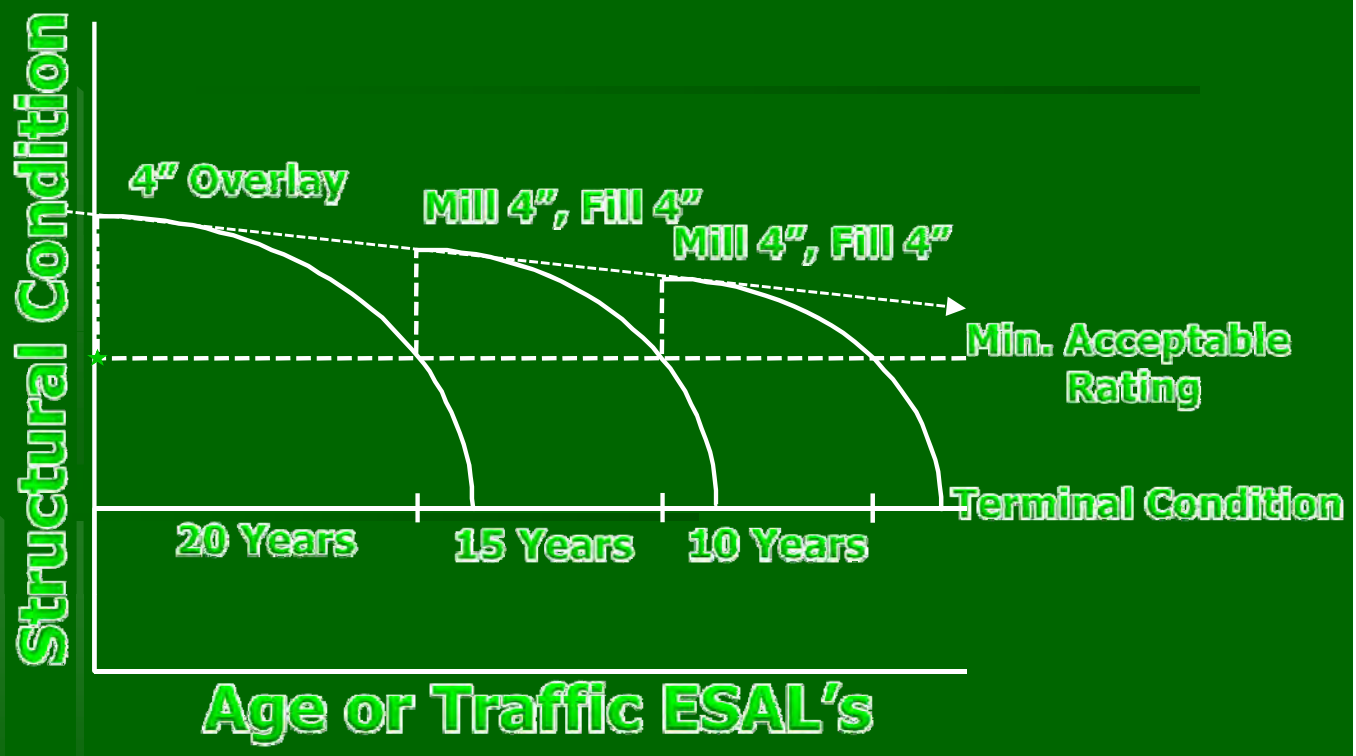
Remaining Life Analysis (AASHTO)



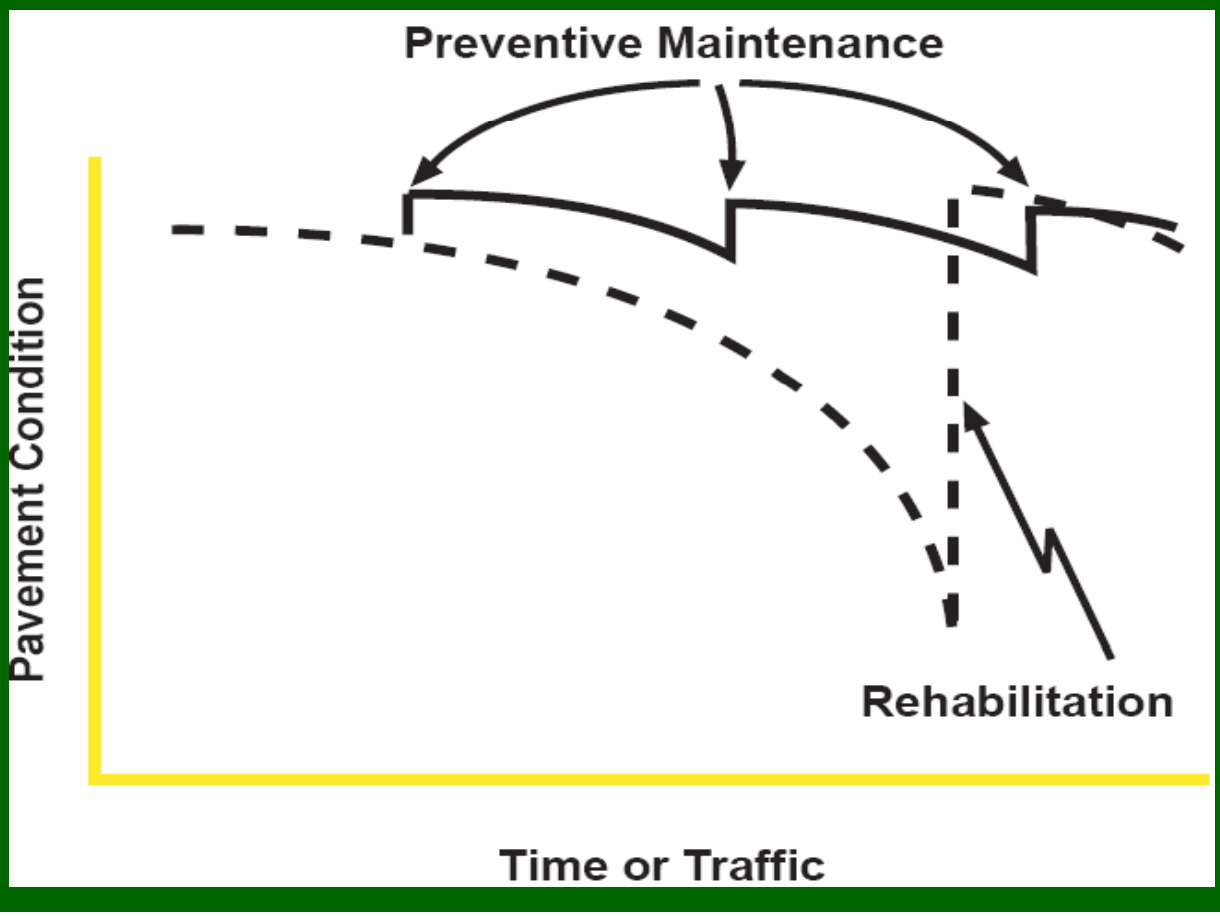
Remaining Life Analysis (AASHTO)



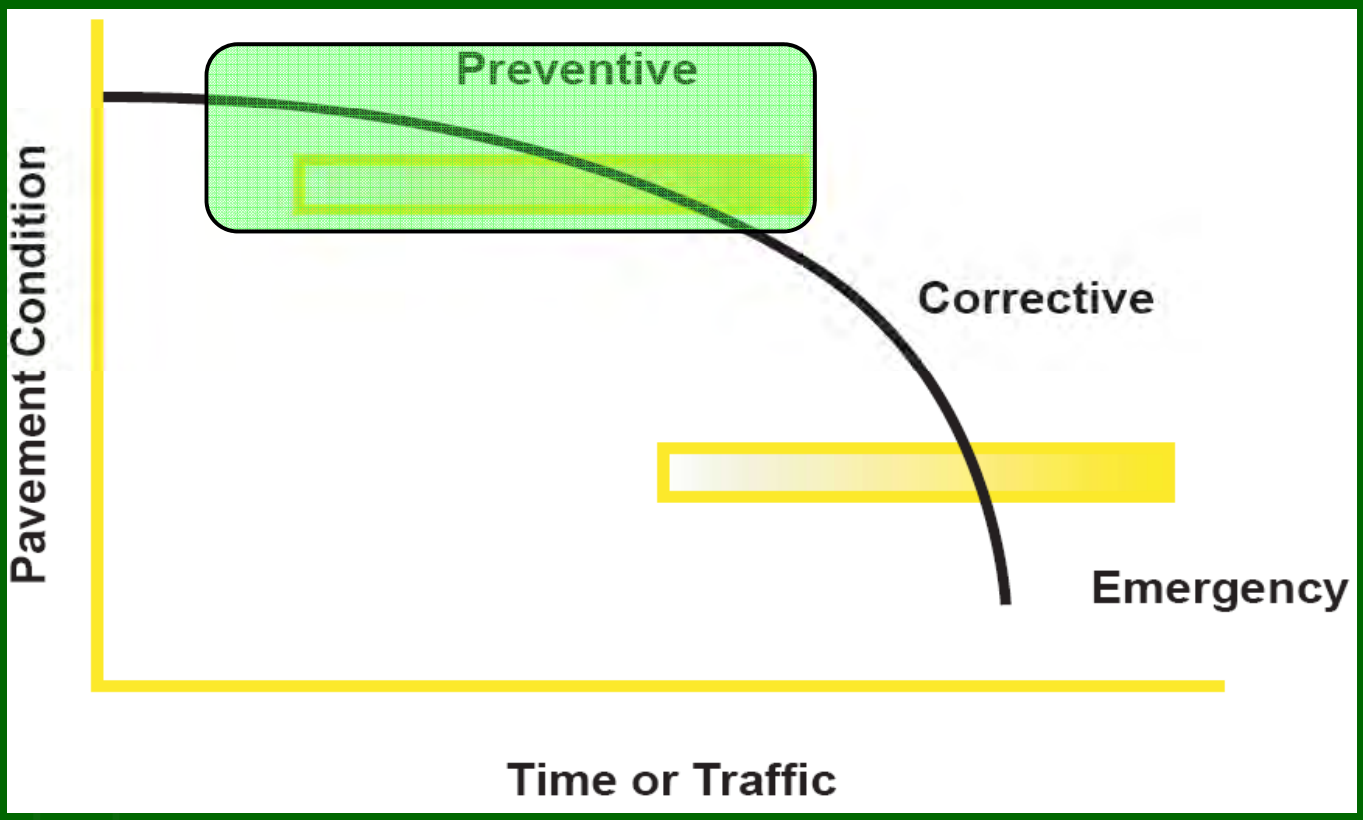
Remaining Life Analysis (AASHTO)



WHEN


Preventive Maintenance
Pavement Condition
Rehabilitation
Time or Traffic

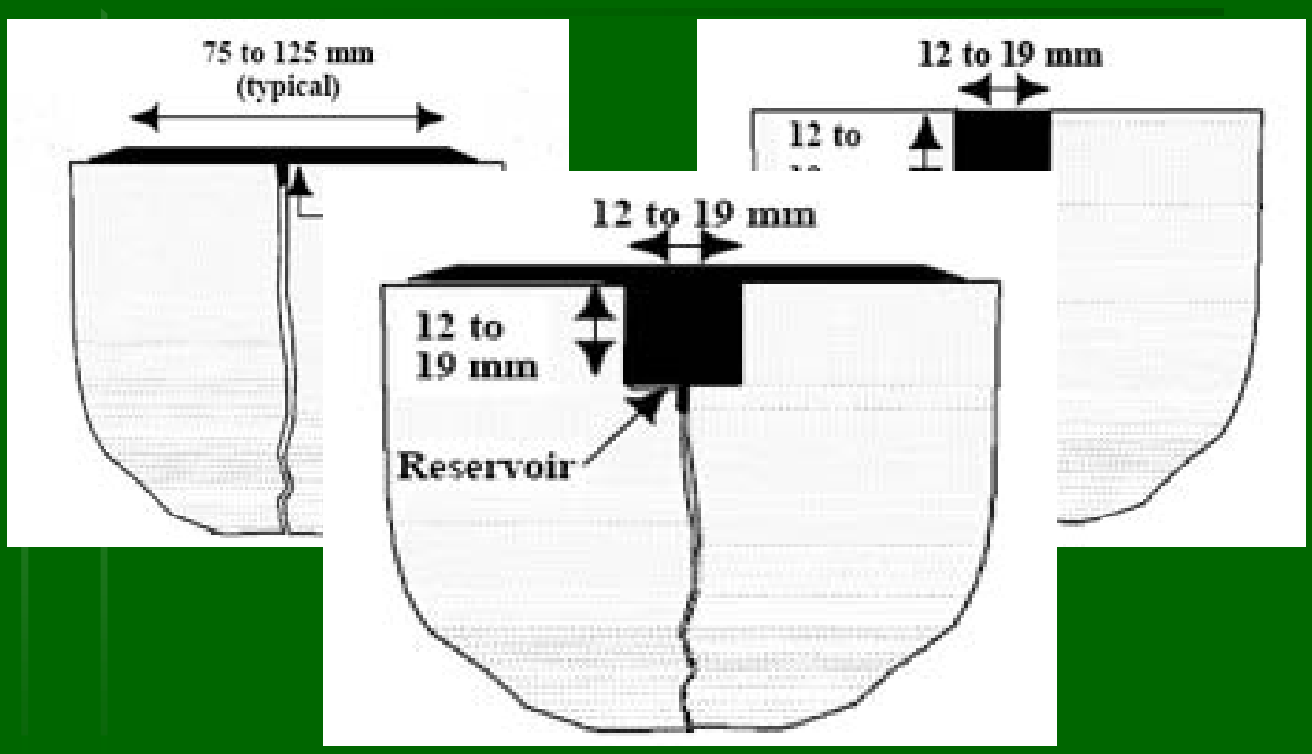
WHEN


Preventive
Corrective
Emergency
Pavement Condition
Time or Traffic

Crack Sealing

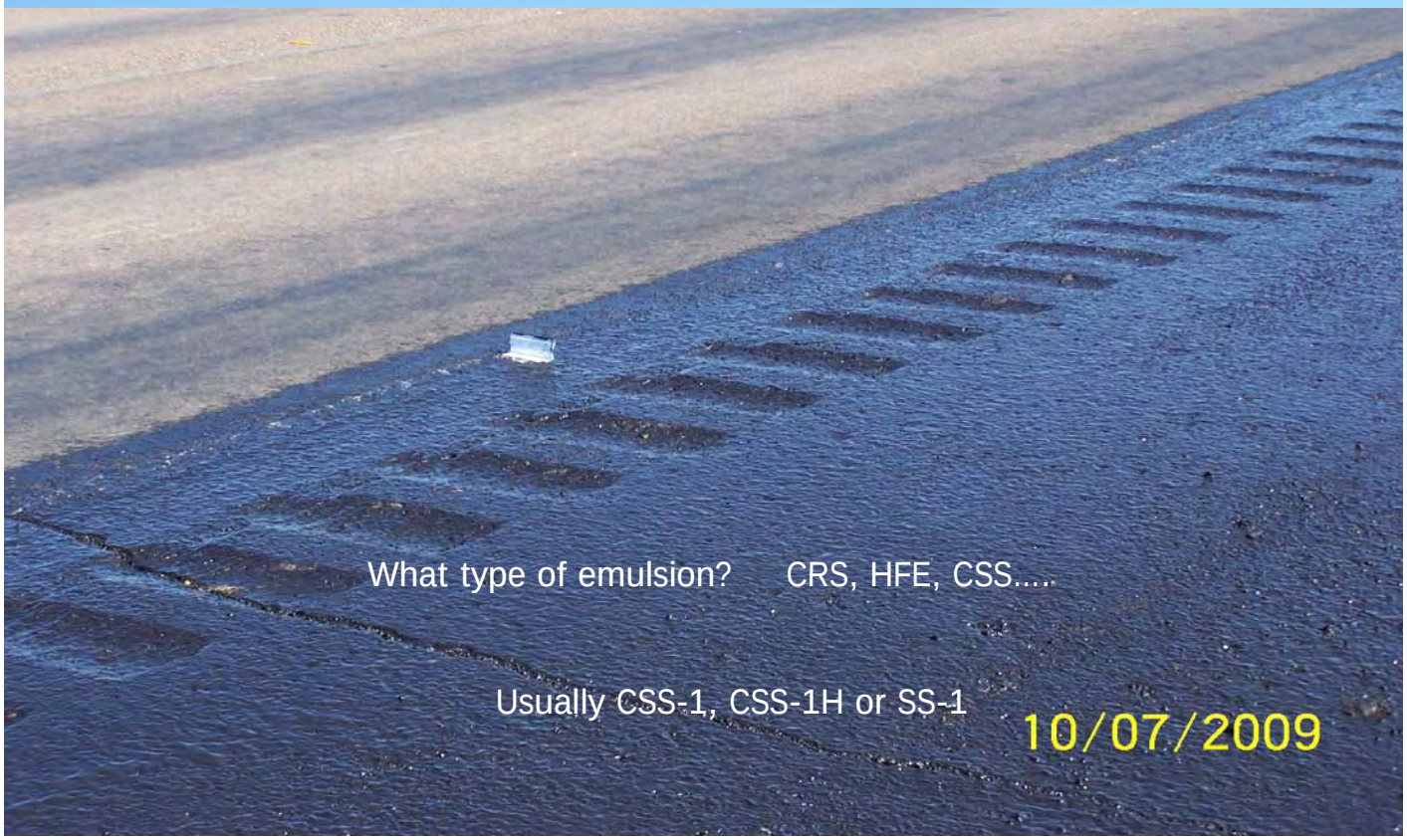
Crack Sealing

Crack Sealing

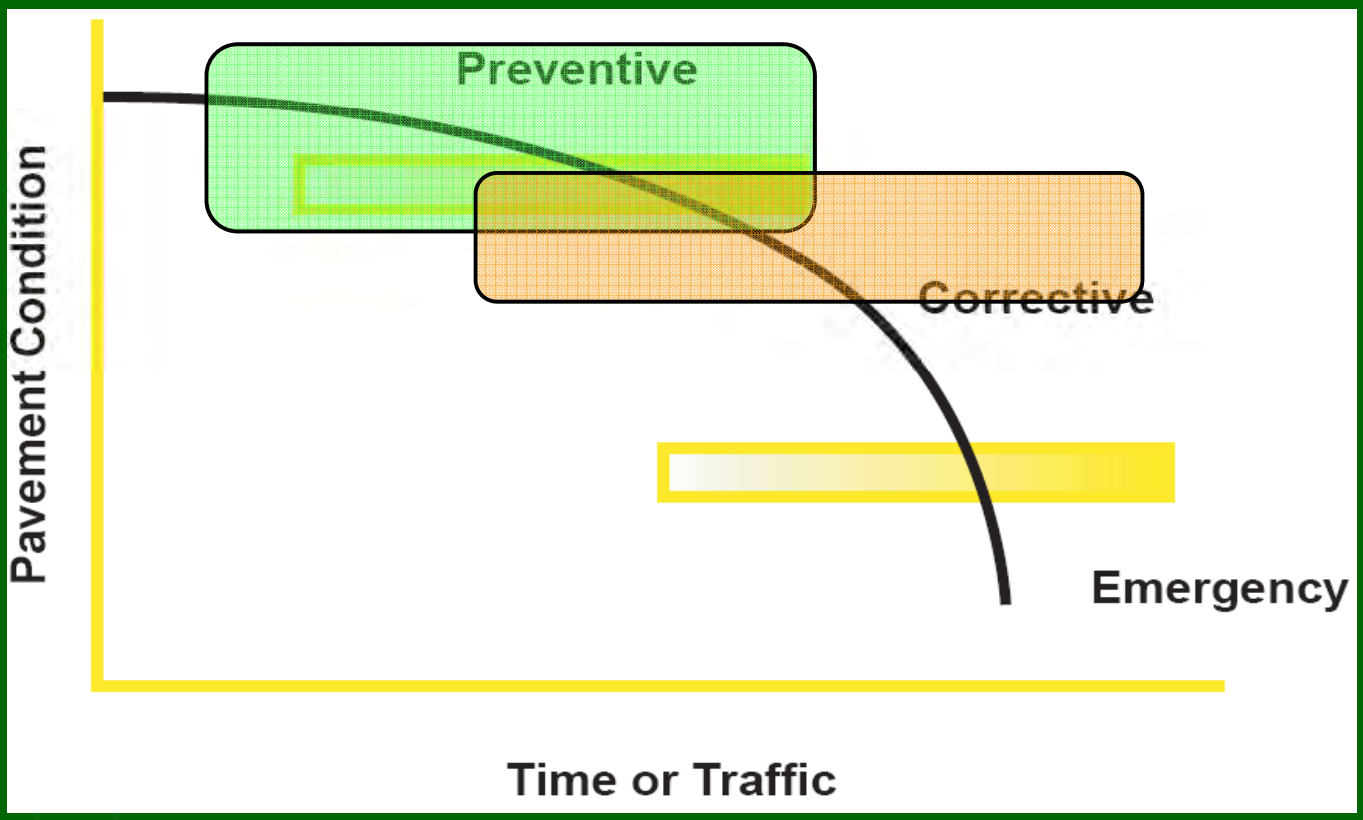


Surface Sealing

Fog Sealing


What type of emulsion? CRS, HFE, CSS....
Usually CSS-1, CSS-1H or SS-1
10/07/2009

WHEN


Preventive
Corrective
Emergency
Pavement Condition
Time or Traffic

Blade Patching

Note the blade angle

With all the pushing & squeezing you will start slicing out the oil balls in the mix which then coat the aggregate.

06/27/2006

Armor Coats & Chip Seals

09/17/2009

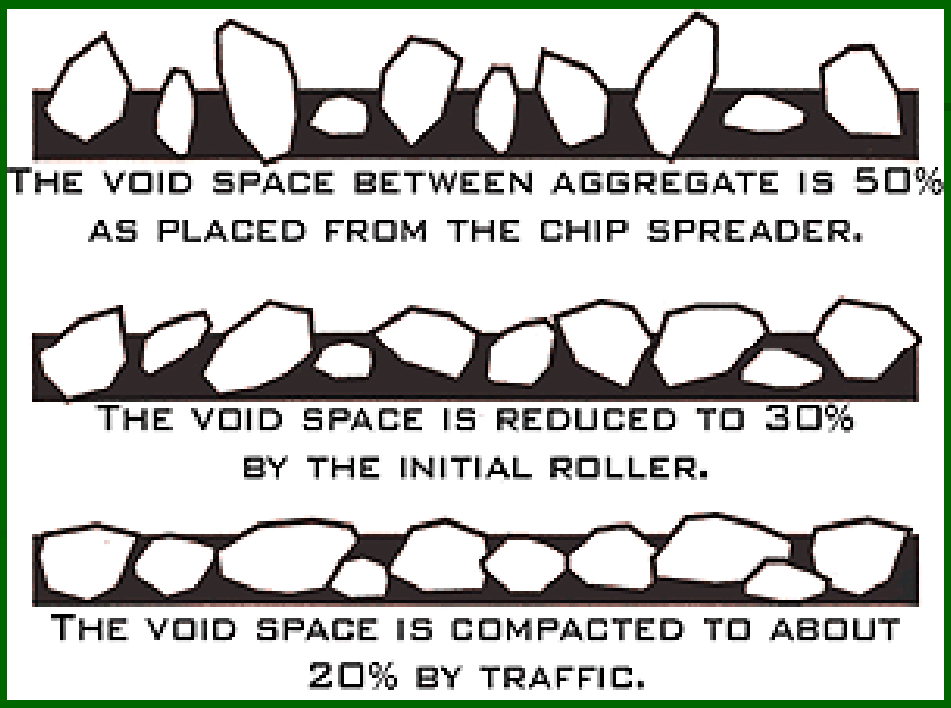
SPRHH
ROSCO
09/17/2009

ROSCO
ROSCO
SPRHH
09/17/2009

09/17/2009

CRS-2P
09/01/2009

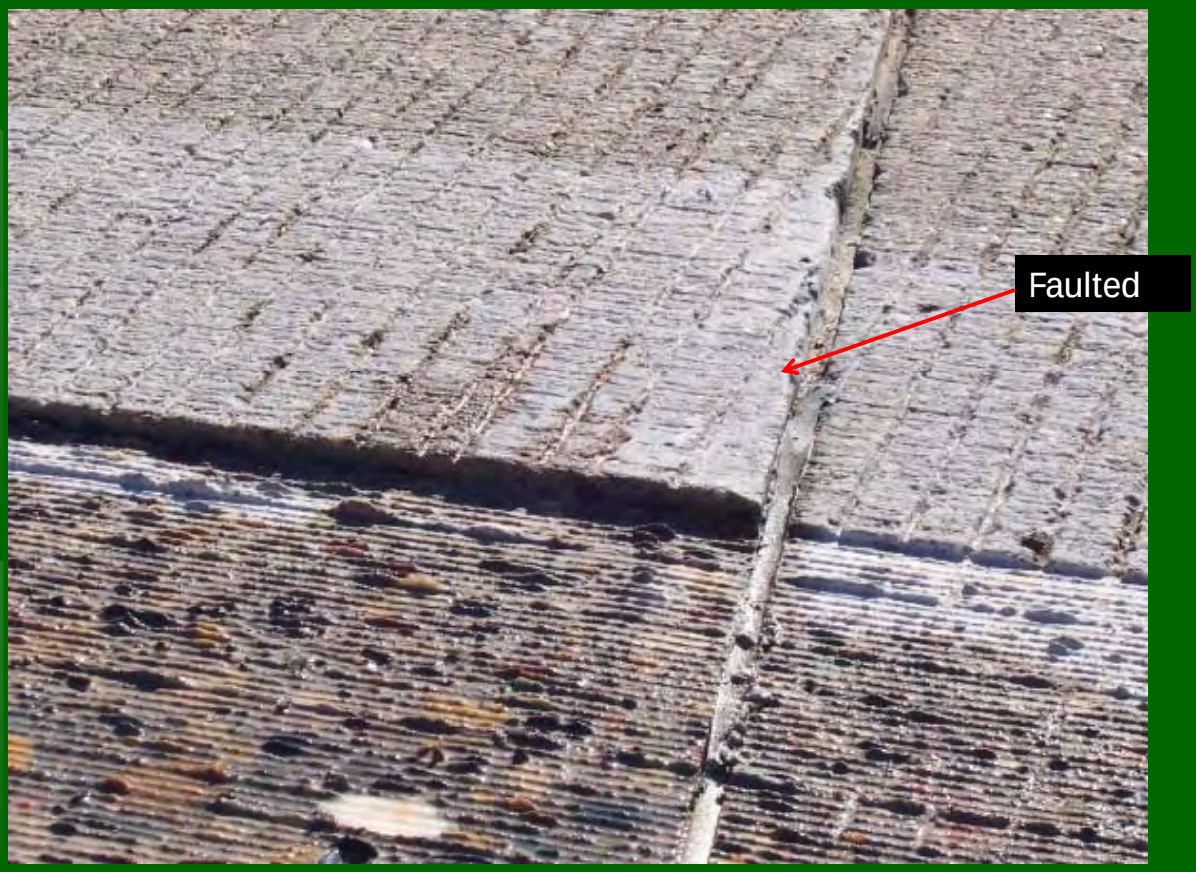
NDOR
09/01/2009


THE VOID SPACE BETWEEN AGGREGATE IS 50%
AS PLACED FROM THE CHIP SPREADER.
THE VOID SPACE IS REDUCED TO 30%
BY THE INITIAL ROLLER.
THE VOID SPACE IS COMPACTED TO ABOUT
20% BY TRAFFIC.

09/01/2009

08/26/2009

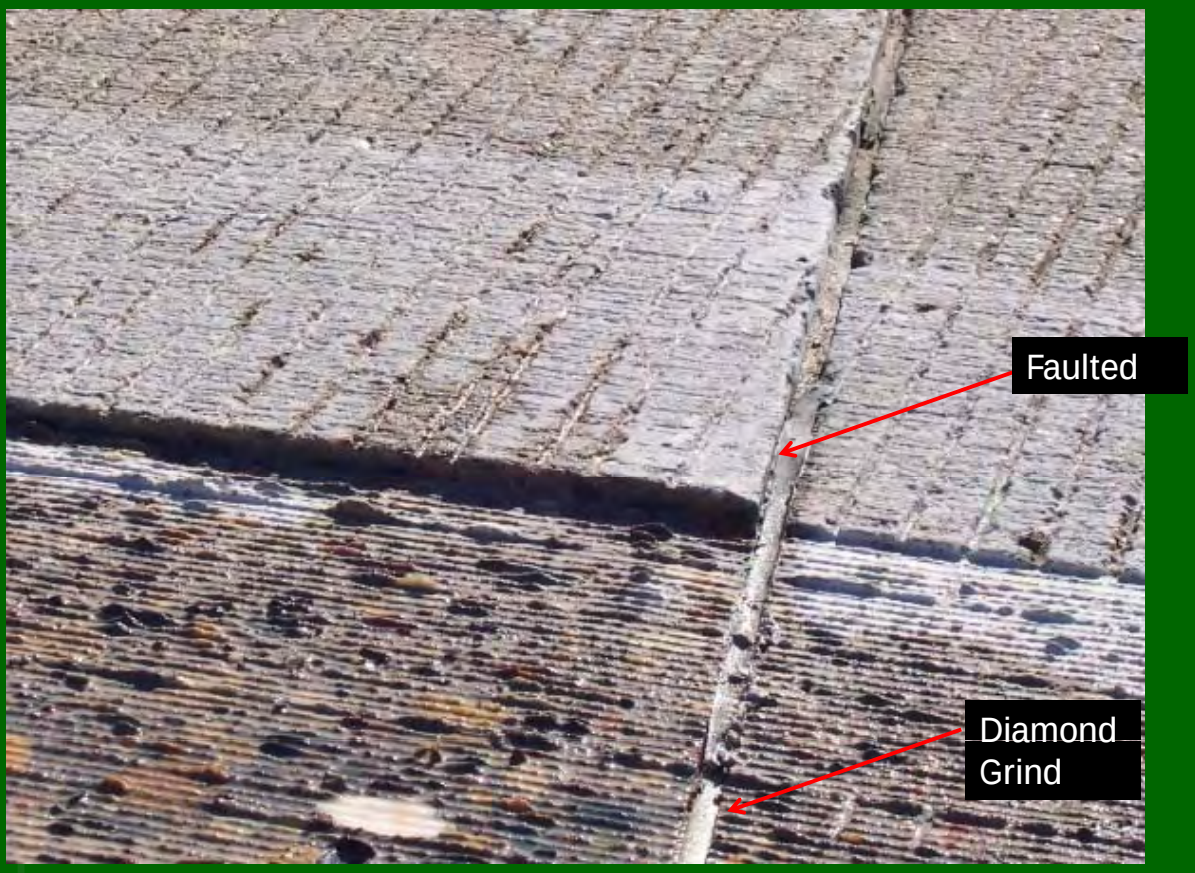
Concrete Surface Rehabilitation



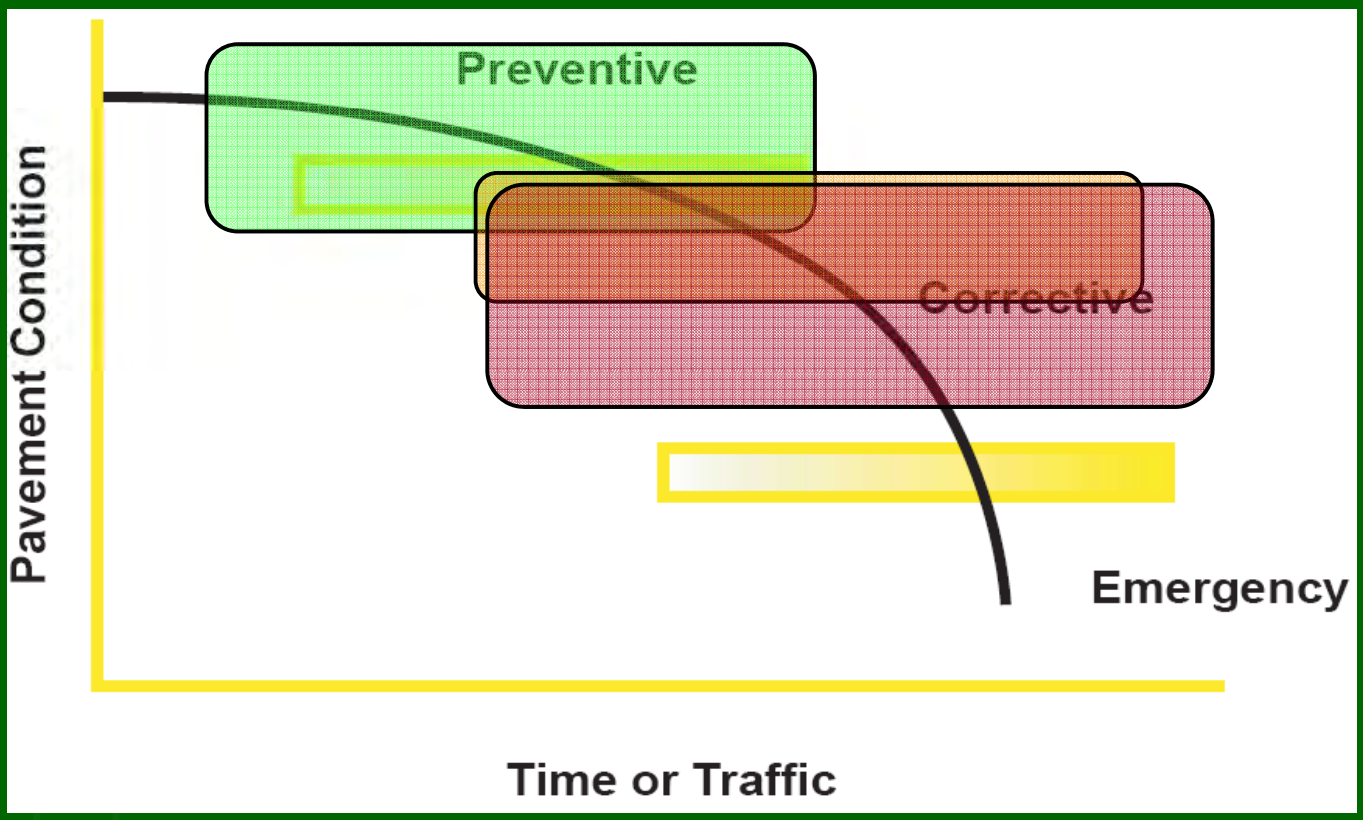
Dowel Bar Retrofit

Dowel Bar Retrofit

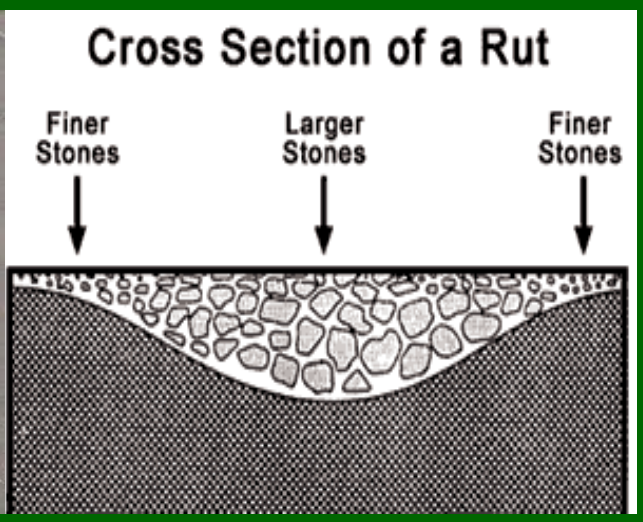
Dowel Bar Retrofit


Faulted
Diamond Grind

WHEN


Preventive
Corrective
Emergency
Pavement Condition
Time or Traffic

Micro-Surfacing



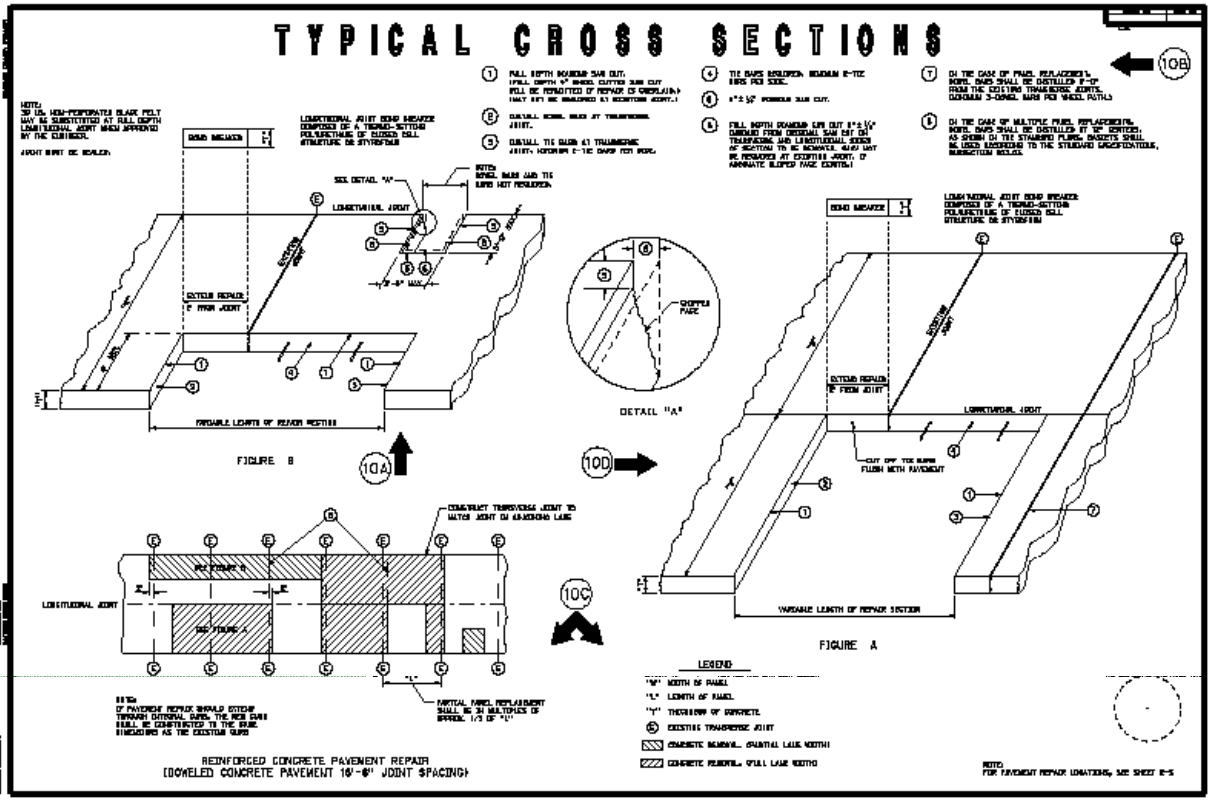
MONARCH

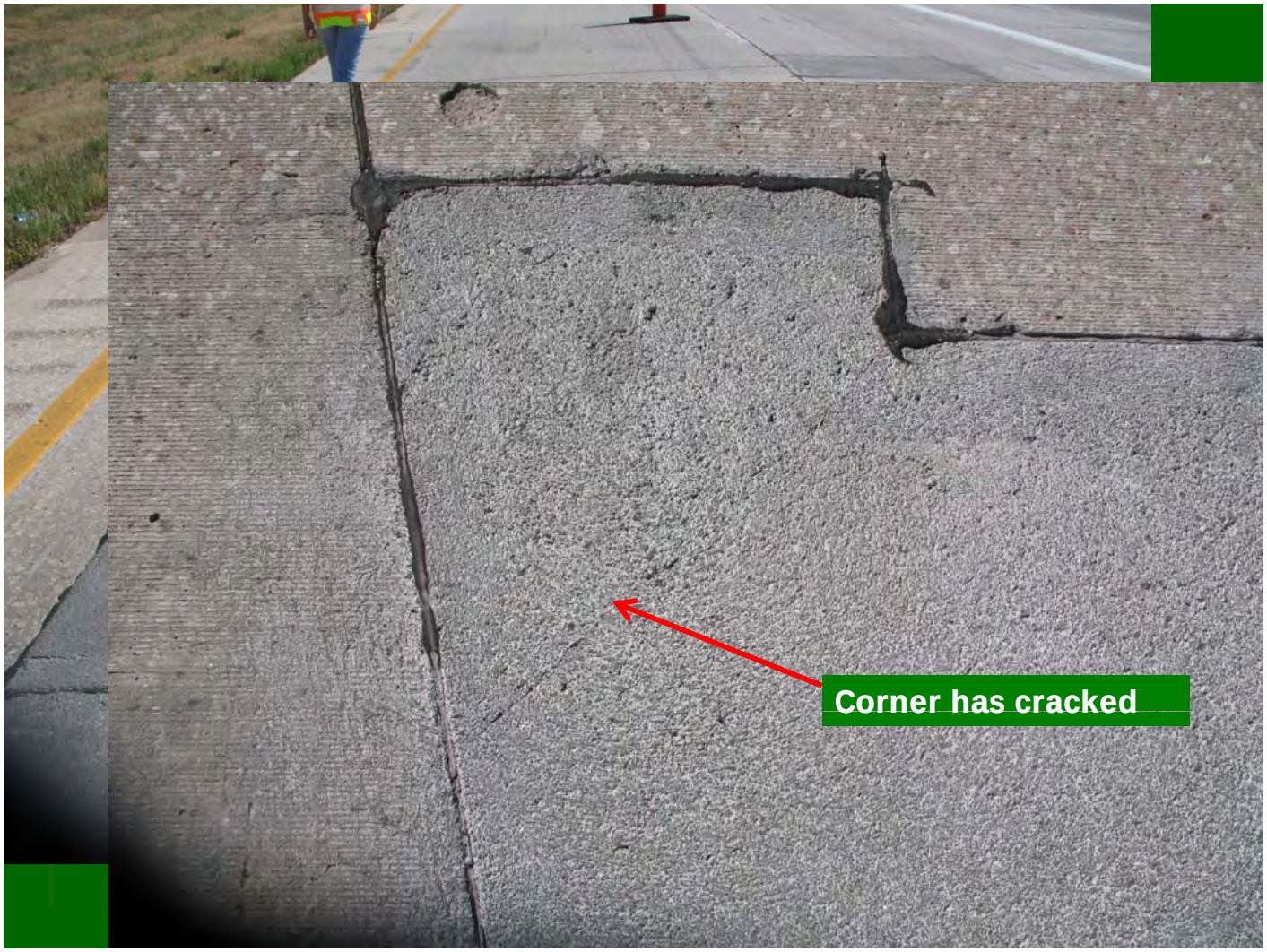
PASS
WITH
CARE
13 A
SPUR
1

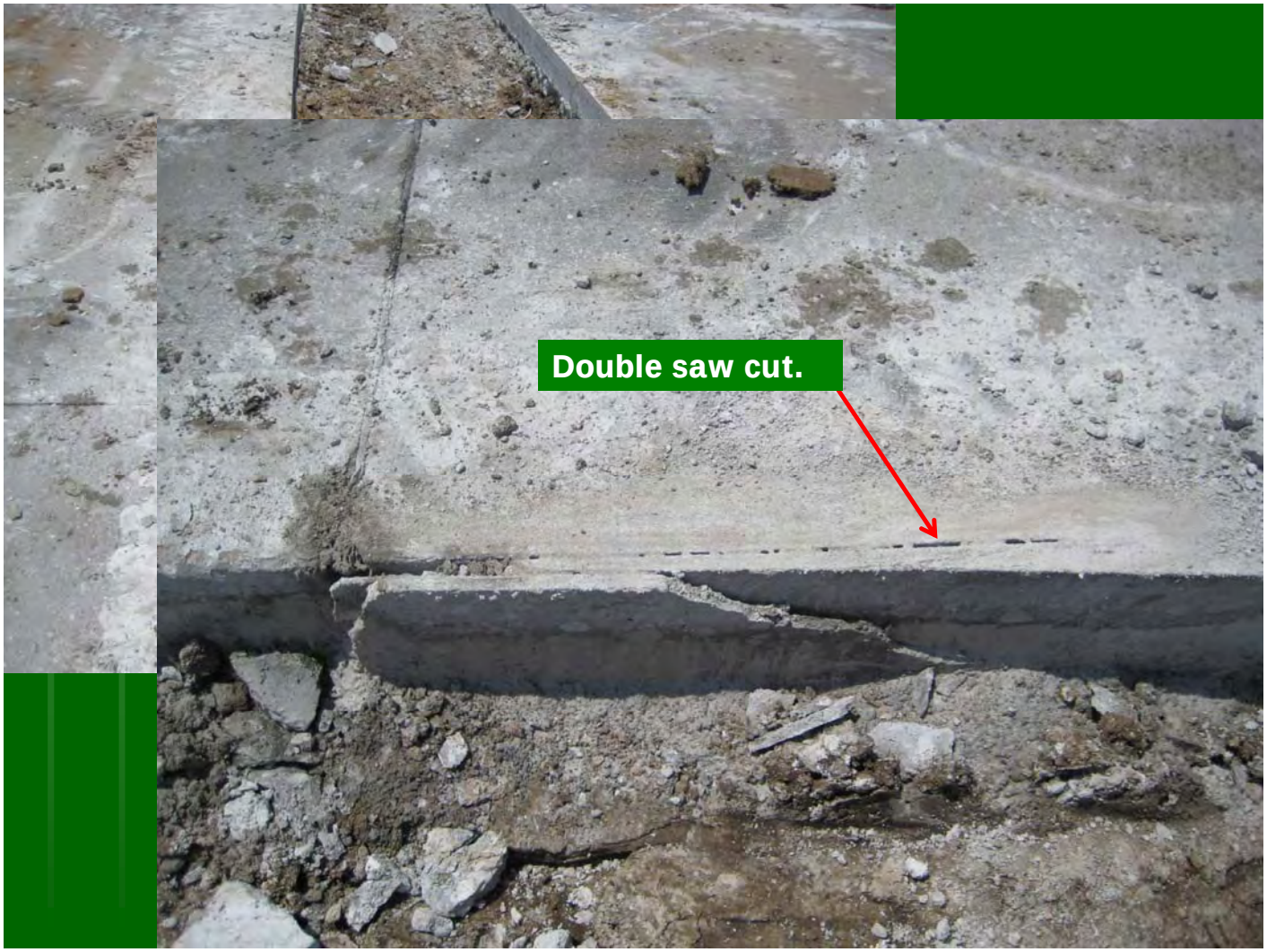
Failing Joint

Maintaining & Rehabing PCC

Co


TYPICAL CROSS SECTIONS
FIGURE B
FIGURE A
DETAIL "A"
LEGEND
REINFORCED CONCRETE PAVEMENT REPAIR
(DOWELED CONCRETE PAVEMENT 16'-6" JOINT SPACING)
10 of 10 3850 2 E 17


Corner has cracked

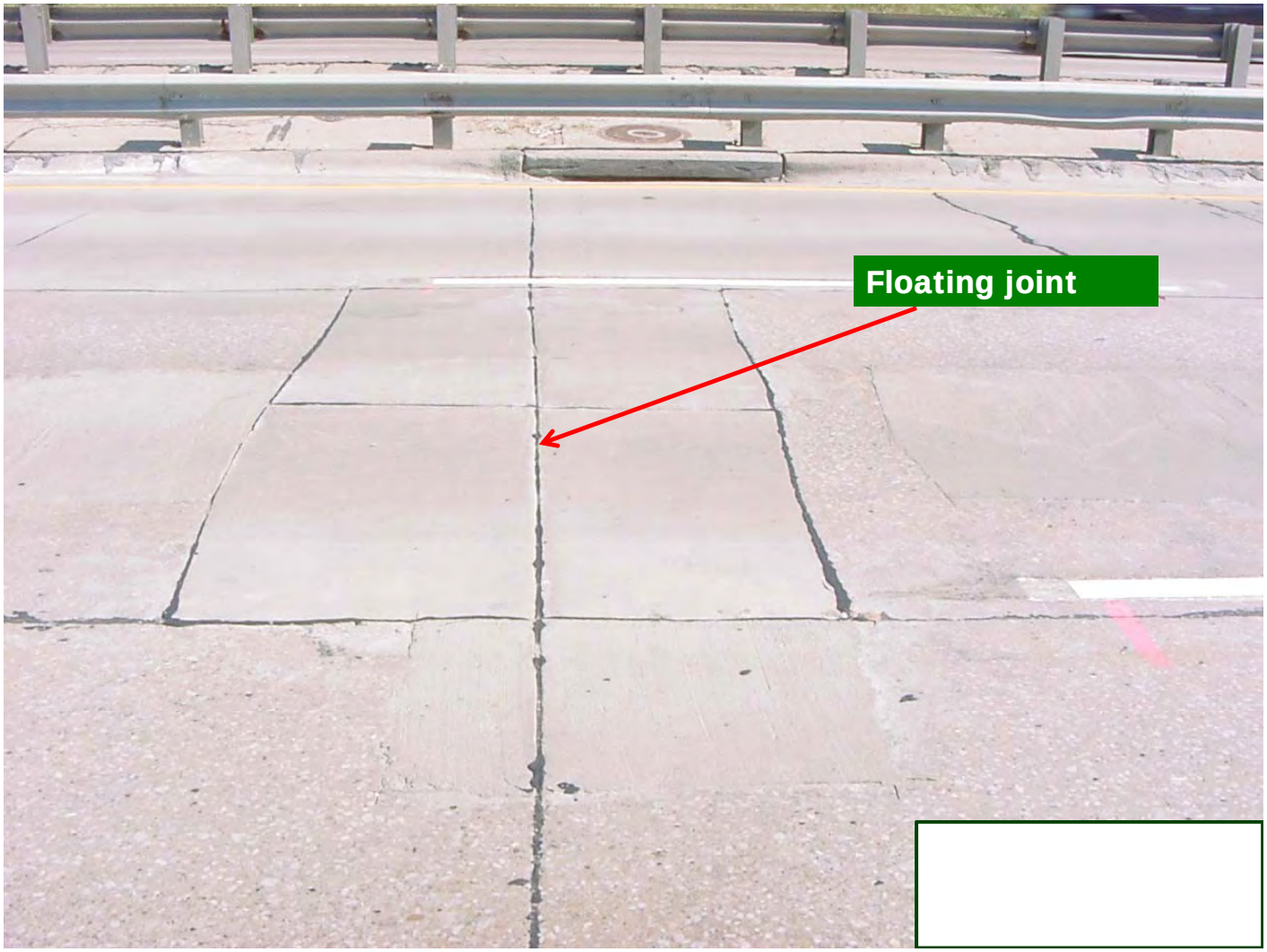

Double saw cut.

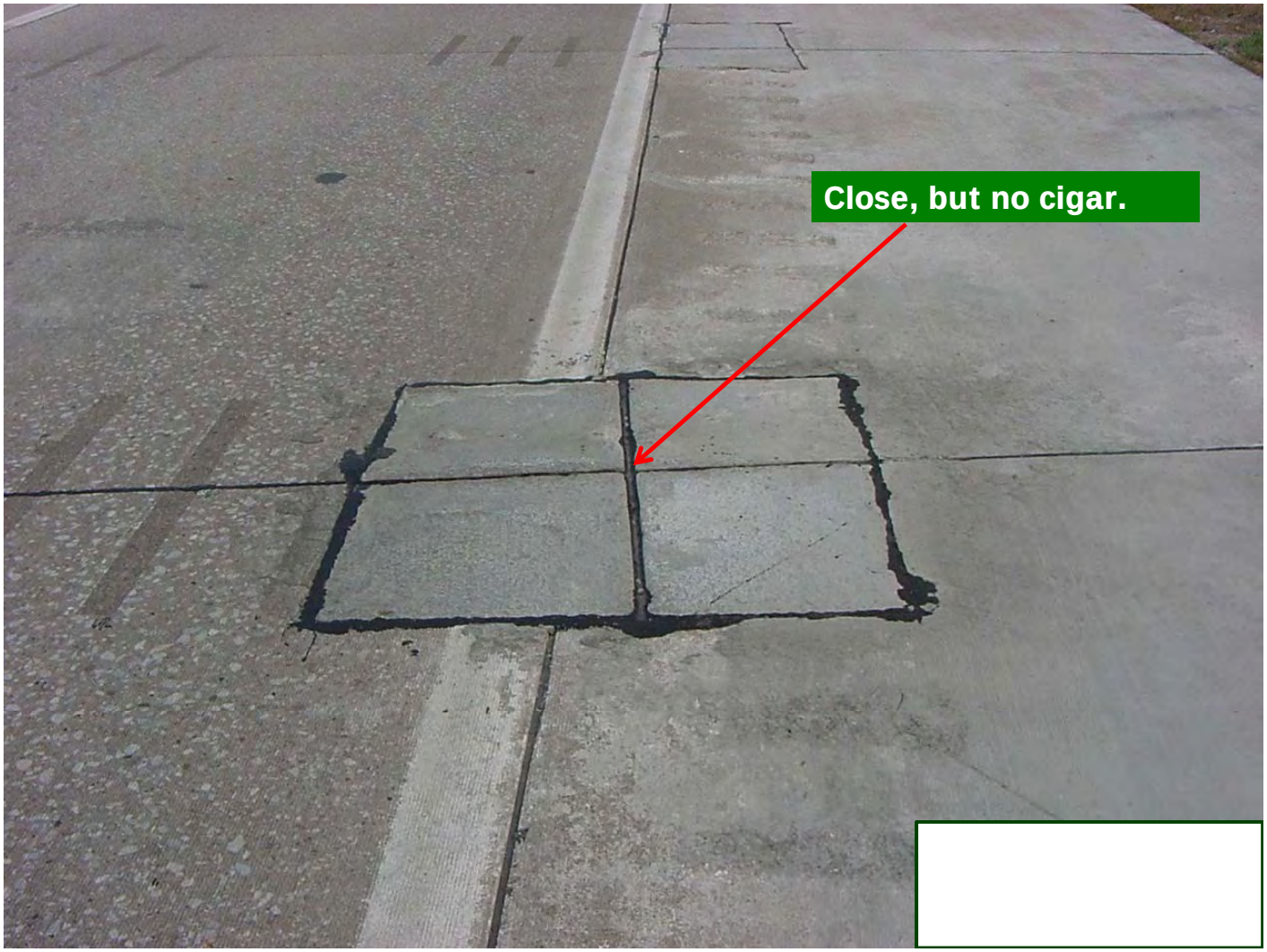
Repair should have been squared off and crack wouldn't of formed.

Repair should have been carried to adjacent joint

~5542644.JPG - Windows Picture and Fax Viewer
Poor consolidation against forms

Over cuts, misaligned joint and poor workmanship


Floating joint


Close, but no cigar.

Tied across the joint and a crack formed.

?