2013

NDOR Pavement Design Manual

Nebraska Department of Roads

Materials and Research Division

2013 NDOR Pavement Design Manual

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Note: NDOR utilizes the 1993 *AASHTO Guide for Design of Pavement Structures* and Part II Supplement as a basis for pavement design. The software version, DARWIN 3.1 is also used extensively. This manual is a compilation of NDOR design practices, procedures, materials data, etc. used on a daily basis in addition to the AASHTO manual.

Chapter 1: Pavement Design Presentation

Slides
http://www.transportation.nebraska.gov/mat-n-tests/Presentations/2011_Pavement_Design_Class/2011PDWrkshp.pdf

Video
http://campus.extension.org/user/view.php?id=11400&course=487

The user will need to enroll to watch the class.

Chapter 2: Pavement Design Overview

2.1 Pavement Determination Process

Date: Revised 2/22/13
Source: Varilek

Scoping Determination

Rehabilitation

- Pull project folder if it exists or create one. Verify a folder is not in circulation prior to creating a new folder.
- Print out the DR73 from Agility
- Create Pavement Histogram (See 2.2a)
    - Print pavement history, condition, etc. from Mainframe (2.2b & 2.2c)
        - See *Mainframe Printing Instructions* (2.2d)
    - Collect/copy applicable typicals from pavement design section and vault
    - Input mainframe and typical data into Histogram Spreadsheet
- Complete Worksheet/Checklist
    - Summarize info. from video log (Pathweb) and mainframe data (2.2e)
- Select appropriate strategy (4.1) and write Scoping Determination (2.2f)
    - Consider DE comments on DR73, pavement history, maintenance history, current condition, current/future truck traffic, current/future ethanol plants, cost, etc.
- Order FWD testing and Cores if necessary (all 3R Projects)
- Review Scoping Determination with Supervisor/Pavement Engineer
- Send Scoping Determination to District Engineer (DE) for comment (2.2g)
- Add DE approved Scoping Determination to Agility
  Add Histogram to Falcon
- File folder

Note: File mainframe data, histogram, typicals, report, FWD/Core request, Determination, email correspondence, distributions, etc. in project folder.

New Build

- Pull project folder if it exists, or create one. Verify a folder is not in circulation prior to creating a new folder.
- Print DR73 from Agility
- Run Darwin to determine pavement thickness(s)
    - Run rigid and/or flexible design modules as appropriate to project.
        - See Darwin Inputs (2.2h, 2.2i)
- Write Scoping determination.
- Review Scoping Determination with Supervisor/Pavement Design Engineer
- Send Scoping Determination to District Engineer (DE) for comment
- Add DE approved Scoping Determination to Agility

- File folder

Note: File Determination, email correspondence, distributions, etc. in project folder.

Activity 5258 & 5364 - Pavement Determination & Pavement Determination Review

- Review entire project folder
- Verify FWD/Coring has been accomplished or order if needed
    - Verify previous determination(s) compatible with FWD/Core data
- Write 5258 or 5364 based on previous determination(s) with any needed revisions
    - Revisions may result from core/FWD data, scope changes, changes/additions/deletions from designer, recent email discussions, etc.
- Review 5258 or 5364 with Supervisor/Pavement Design Engineer
- Distribute 5258 or 5364 to DE, Roadway, PSS, Survey, Pavement Design. DE approval not required unless significant change in scope has occurred (2.2k)
- Add 5258 or 5364 to Falcon
- Update status in Clarity
- File Folder

Note: File all email correspondence, distributions, etc. in project folder.

Activity 5406 – Final Pavement Determination

- Review entire project folder.
- Verify FWD/Coring has been accomplished
- Verify previous determination compatible with FWD/Core data
- Write 5406 based on previous determination with any needed revisions
    - Revisions may result from core/FWD data, scope changes, changes/additions/deletions from designer, email discussions, etc.
- Review with supervisor, obtain Pavement Design Engineer signature
- Route original to M&R Engineer then District Engineer for signature
- File original, signed 5406 in project folder
    - Distribute scanned copy to DE, Rdwy, PSS, Survey, Pavement Design (2.2l)

- Add 5406 to Falcon
- File Folder

Note: File Signed Determination, email correspondence, distributions, etc. in project folder.

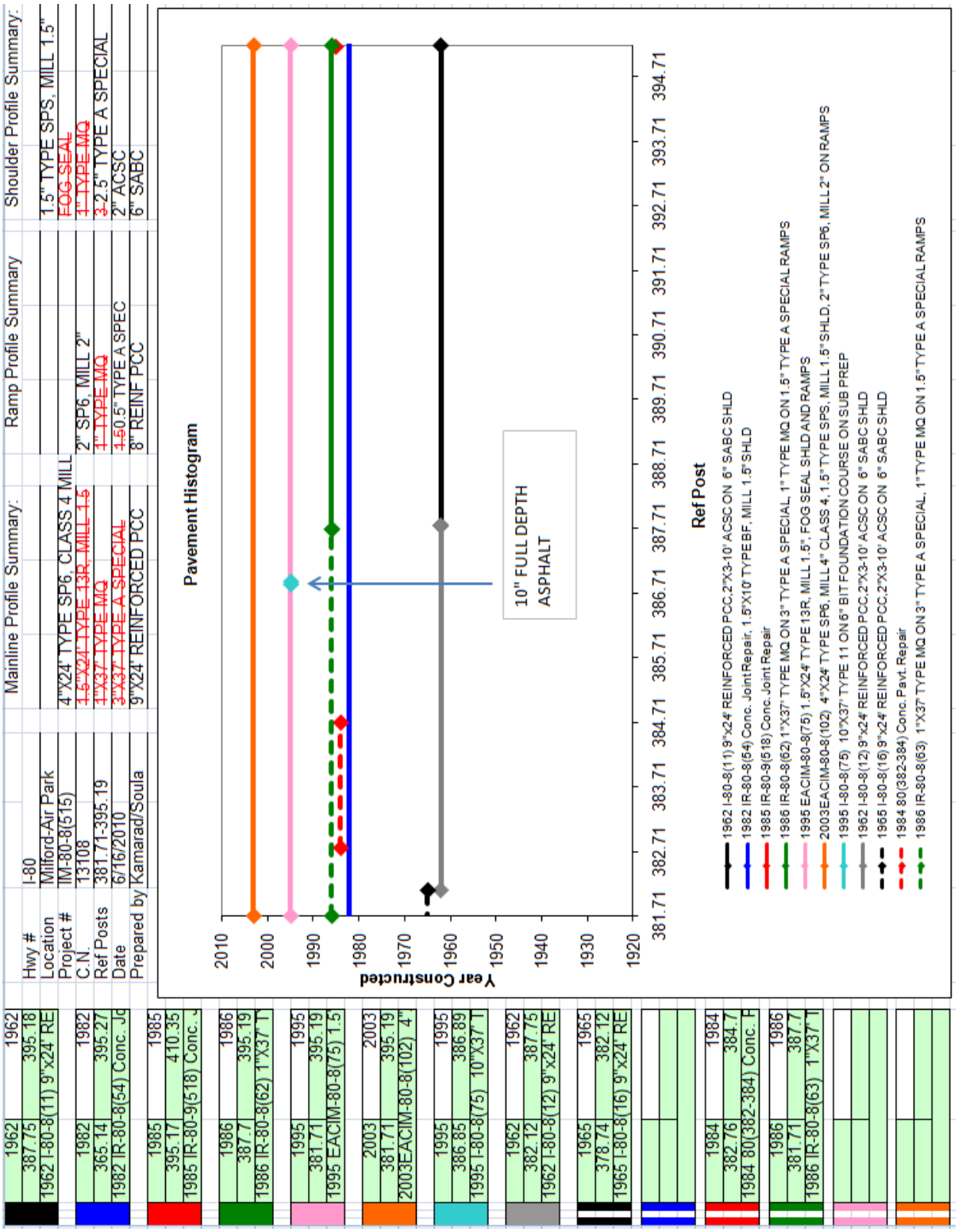
Activity 5655 – Final Pavement Determination Verification

- Perform final review of 5406
    - Review entire folder for unresolved issues
    - Verify Final Pavement Determination matches current state of practice
        - Current asphalt mixes specified, leveling courses used over PCC, gradation band compatible with lift thicknesses and consistent, etc.
    - Verify new pavement thickness meet minimum standards (NDOR policy)
- Review with Supervisor/Pavement Engineer if necessary
- Note date of review and any resolved issues on Final Pavement Determination
- Update status in Clarity

All documents will be saved in individual project folders on common drive (\\Dorimage1\mat\Pavement Design -) with standard naming conventions

2.2 Pavement Determination Process Examples

2.2a Pavement Histogram



2.2b Pavement History

```
PCMX302                    Nebraska Department of Roads                11/18/10
                        Project Compilation/History Data               09:07:39
                         History By County/Highway/Year

        County: __
      Hwy Num: 080___
         Year: ____
Beg Ref Post: 381.710
End Ref Post: 395.190

  C                                                                          F
S nC                                                  Beg      End      L     t
e td Hwy                                     Control Ref      Ref      D Projct N
l ye Num    Year Formatted Project Number    Number  Post     Post     C Length L
= == ===== ==== ========================== ======= ======= ======= = ====== =
 55 080    1961 I-80-9(48)DIV.3  Outside Range        395.190 396.830 B 01.581
Loc  LINCOLN WEST
Desc GR., CULVS., CONC. PAVT. 10"X24' DUAL LANE SEEDING

 55 080    1962 I-80-8(11)                            389.140 395.180 B 06.037 3
Loc  YORK-LINCOLN
Desc GR., CULV., BR., FENCE, CONC. PAVT. 9"X24' DUAL LANE,          (More)
     Seeding, G.R.
 55 080    1964 I-80-9(68)       Outside Range        395.190 400.660 B 00.000
Loc  LAFB INTER.-I80/I180
Desc ROADSIDE PLANTINGS

 55 080    1967 I-80-8(14)       N/A                  389.140 395.190 B 00.000 3
Loc  YORK-LINCOLN
Desc SIGNING

 55 080    1969 I-80-9(199)      Outside Range        395.190 400.660 B 00.000
Loc  LAFB INTER.-I80/I180
Desc ROADSIDE IMPROVEMENT


Command ===>                                   Prnt Adr: 2267 Reqd By: DR9091
MORE DATA AVAILABLE
PF1 =Help     PF2 =         PF3 =Exit     PF4 =         PF5 =Refresh PF6 =PrntScrn
PF7 =Bkwd     PF8 =Fwrd     PF9 =         PF10=         PF11=        PF12=PrevScrn
PF13=         PF14=         PF15=         PF16=         PF17=        PF18=
PF19=TopRgn   PF20=BotRgn   PF21=         PF22=         PF23=        PF24=
```

* Additional Pages omitted

2.2c Pavement Condition & Maintenance History

```
RDCX353                    Integrated Highway Inventory                    06/16/10
                      Nebraska Pavement Management System                  11:15:30
                                  Summary Query

     Hwy Num: 080                District:  1                      ADT:  16176
 Beg Ref Post: 381.710             County: SEWARD              Trk ADT:   4061
 End Ref Post: 395.190                                            D18K:   7716
 Lane Dir Cde: A                     Age:  7
    Lane Num: 02                  Length:  13.470          Nat Funct Cl:  1
    Sect Loc: MILFORD-LINCOLN AIRPARK                       St Funct Cl:  1
  Surface Percentages           Shoulder Percentages
                       ASC                        Rating   ASC    Rating
        BIT:                        Paved:                 100.00     9
   Composite:          100.00
        PCC:
      Other:
   Shoulders: INTERSTATE
-----------------------------------------------------------------------------
       Bituminous                 ASC  |          PCC
 Distress Elements                      |  Distress Elements
  IRI (mm/m)                     0.80   |   IRI (mm/m)
                                        |
 Cracking                               |  Cracking
                                        |   %Joint Seal
  Cracking Index                   11   |   %Bad Joints
  Trans. Cracking                  35   |   %Repairs
                                        |   %Bad Panels
 Rutting                         3.53   |   Faulting
  % over 13 mm                    0.2   |
 Friction Number                   41   |  Friction Number
 Texture                         .328   |  Texture
 Quality Attributes                     |  Quality Attributes
  PSI                              4.2  |   PSI
  NSI                            82.53  |   NSI
  Hist Low NSI                   82.53  |   Hist Low NSI
                                        |
 Optimum Rehab Year               2014  |  Optimum Rehab Year
 Critical Rehab Year              2018  |  Critical Rehab Year
-----------------------------------------------------------------------------
Command ===>                                  Prnt Addr: 2265 Reqd By: DR10035
QUERY FUNCTION COMPLETE
PF1 =Help   PF2 =       PF3 =Exit       PF4 =Prompt      PF5 =Refresh PF6 =PrntScrn
PF7 =Crew Card Trans  PF9 =Mnt Cost  PF10=Cond Hist  PF11=Project PF12=PrevScrn
```

RDCX355 Integrated Highway Inventory 06/16/10
Pavement Management System 11:15:45
5 Year Activity Cost Summary

Hwy Num: 080
Beg Ref Post: 381.710
End Ref Post: 395.190

Actv Cde	Activity Description	Summary Total 2005	2006	2007	2008	2009
2002	Road Profiling	4195.90	5569.12	1407.61	12759.65	
2003	Minor Milling	1288.95				
2004	Arm Coat Rdwy Srf					
2005	Fog Seal					
2007	Mudjacking					101275.30
2009	Maint/Muni Con Lnk					
2510	Joint & Crack Fill	864.48	1287.83	883.91	25.77	1150.91
2013	Joint Cutting					
2015	Subgrade Repair					
2025	Mach Ptch Rdwy Srf	12556.56	1810.35	16125.72	15595.40	4564.39
2026	Spot Patching	5556.46	6323.32	13418.78	29526.66	21837.90
2027	Concrete Patching	1949.28				
2030	Surf Shld Maint	1.75		2176.19	1066.86	
2031	Grading of Shld	238.18		1582.18		127.65
2032	Rebuild Unpvd Shld		1055.57	771.63	3224.26	5611.53
2035	Blading Unpvd Rds					
2036	Maj Rst Unpvd Rds					
Total:		26651.56	16046.19	36366.02	62198.60	134567.68

Command ===> Prnt Addr: 2265 Reqd By: DR10035
QUERY FUNCTION COMPLETE

PF1 =Help	PF2 =	PF3 =Exit	PF4 =	PF5 =Refresh	PF6 =PrntScrn
PF7 =	PF8 =	PF9 =	PF10= NxtRec	PF11=PrevRec	PF12=PrevScrn
PF13=	PF14=	PF15=	PF16=	PF17=	PF18=
PF19=	PF20=	PF21=	PF22=	PF23=	PF24=

RDCX354 Integrated Highway Inventory 06/16/10
Nebraska Pavement Management System 11:15:56
Pavement Condition History data

District: 1 Hwy Num: 080 Beg Ref Post: 381.710 End Ref Post: 395.190
Sect Loc: MILFORD-LINCOLN AIRPARK Lane Dir: A
Surf Typ: Lane Num: 02

NSI BIT		88	85	99	96	97	94	95	84	83
NSI PCC										
IRI		1.20	1.30	.77	.75	.83	.74	.75	.72	.80
PSI		4.2	4.2	4.4	4.3	4.3	4.4	4.3	4.2	4.2
Crkng Indx	BIT	7	10			1	3	2	10	11
Slab Distr	PCC									
#Tc	BIT	99	70		33	33	33	33	35	35
%Bad Jnts	PCC									
Faulting										
Rut Depth		3.8	3.3	1.9	4.1	2.9	1.5	3.0	2.2	3.5
% over 13mm		.2								.2
Friction Rtng		37	37	42	41		41			
Age					01	02	03	04	05	06
Year		2001	2002	2003	2004	2005	2006	2007	2008	2009

```
                 100|     |     | * | + | * |     |     |     |     |100
                  -|  +  |  +  |   | * |  -  |  *  |  *  |  +  |  +  |-
                  -|  *  |     |   |   |     |     |     |     |     |-
                  -|     |  *  |   |   |     |  -  |  -  |  *  |  *  |-
          N      80|  -  |  -  |   |   |     |     |     |  -  |  -  |80
                  -|     |     |   |   |     |     |     |     |     |-
          S       -|     |     |   |   |     |     |     |     |     |-
                  -|     |     |   |   |     |     |     |     |     |-
          I      60|     |     |   |   |     |     |     |     |     |60
                  -|     |     |   |   |     |     |     |     |     |-
                  -|     |     |   |   |     |     |     |     |     |-
                  -|     |     |   |   |     |     |     |     |     |-
                 40|     |     |   |   |     |     |     |     |     |40
                  -|     |     |   |   |     |     |     |     |     |-
                  -|     |     |   |   |     |     |     |     |     |-
                  -|     |     |   |   |     |     |     |     |     |-
     + = MAX     20|     |     |   |   |     |     |     |     |     |20
     - = MIN      -|     |     |   |   |     |     |     |     |     |-
     * = AVG      -|     |     |   |   |     |     |     |     |     |-
```

Command ===> Prnt Addr: 2265 Reqd By: DR10035
QUERY FUNCTION COMPLETE
PF1=Help PF3=Exit PF6=PrntScrn PF10=Nxtrec PF11=Prevrec PF12 = PrevScrn

***Additional Pages Omitted**

2.2d Mainframe Printing Instructions

Project History for Histogram

1) Select 8 *Integrated Highway Inventory System*
2) Select 15 *Project Compilation/History*
3) Select 2 *Query*
4) Select 2 *Project Compilation/History by County/Highway/Year Query*
   a) Input Highway Number, beginning and ending reference posts, hit Enter
   b) **Print** using "Print Screen" from "File" menu
      a. Scroll through additional screens using F8
      b. To retrieve "more" information on a particular project, place x before Hwy # and hit enter. Hit F12 to back out.
5) Use F12 to back out to *Integrated Highway Inventory System Main Menu*

Maintenance History for Folder

1) Select 18 *Roadway Condition*
2) Select 2 *Query*
3) Select 1 *Roadway Condition Summary Query*
4) Select appropriate district
5) Scroll with F8 until you find appropriate highway segment and select with "x". Hit Enter.
   a. If limits don't match exactly, query exact segment entering reference posts in last (blank) line
   b. Print
6) Hit Enter (w/cursor @ Command Prompt)
   a. *Nebraska Pavement Management System Summary Query* will appear.
   b. Print
7) Select F9 *Mnt Cost*
   a. Print
8) Select F12 to return to *Nebraska Pavement Management System Summary*
9) Select F10 *Cond Hist*
   a. Print
   b. Scroll using F10 and print any data from previous years

Project Summary

Hwy # _____ Project # _____
Location _____ Control # _____
Letting _____ R.P _____

DE Input (Scope) _____

Existing Structure
Total _____
Last project _____
Underlying _____

Truck Traffic _____

Distresses (Viewer/MF Data) _____

Maintenance History _____

Other Considerations _____

Proposed Strategy _____
_____
_____

Reasoning _____

Additional Reviews (Date/Changes) _____
_____
_____FWD/Core Review Notes
_____
_____
_____
_____

Important Tasks:
History on Falcon
Darwin Complete (New Build)
FWD/Cores ordered (3R)
Concrete Repair Estimate Requested (w/5364)
Design Verified with Darwin Back-Calcs (3R)
Bridge Work Added (5406)

Scoping Determination for DR-73

Project STP-121-3(105), N-32 North, CN 32208

Mainline – Mill 2” of existing asphalt by Cold Milling Class 3. Place 2” of Asphaltic Concrete Type SPR. There will be no grade raise.

Shoulders – NA

Drives: Mill 2”, Fill 2”. Verify at PIH.

Intersections: Mill 2”, Fill 2”. Verify at PIH.

Repair Estimate – 1200T AC Patching

Estimate(M&R assigned projects only) - $1.6 M (Including E&C)

This project consists of resurfacing N121 from R.P. 0.00 to 11.18 approximately 11.18 miles.

Designer

2/14/13

2.2g 5218 Distribution to District Engineer

From: Pavement Designer
Sent: Date
To: DE
Cc: Pavement Design Section
Subject: Scoping Determination, STP-121-3(105), N-32 North, CN 32208

DE,

The maintenance strategy shown below is intended to maintain the highway asset until the 3R project can be funded. TADT is 85. The structure from RP 0 to 4.99 is 4" AC Type B over 6" concrete and from RP 4.99 to 11.27 is 10.5"-12" AC over SABC. There is extensive thermal cracking the length of the project; at the worst locations Maintenance has patched the thermal cracks. Other distresses include alligator cracking, some longitudinal cracks and some shoving. Rutting in the first roadway segment is 11.21 mm. A M1.5/F1.5 would cost approximately $1.3 M and a M2/F2 would cost approximately $1.6 M. A M2/F2 would remove more of the rut susceptible AC Type B and possibly extend the roadway service life. Do you have a preference?

Since this is an interim project, do you want to skip surfacing the intersections and drives?

There are turnouts at a school house and cemetery; do you want those locations resurfaced?

Please review and comment.

Thanks,

Pavement Designer

Scoping Determination for DR-73

Project STP-121-3(105), N-32 North, CN 32208

Mainline – Mill 2" of existing asphalt by Cold Milling Class 3. Place 2" of Asphaltic Concrete Type SPR. There will be no grade raise.

Shoulders – NA

Drives: Mill 2", Fill 2". Verify at PIH.

Intersections: Mill 2", Fill 2". Verify at PIH.

Repair Estimate – 1200T AC Patching

Estimate - $1.6 M (Including E&C)

This project consists of resurfacing N121 from R.P. 0.00 to 11.18 approximately 11.18 miles.

Last Name of Pavement Designer

2/14/13

2.2h DARWIN Rigid Design Inputs

Date: Revised 2/22/13
Source: Pavement Design Section

The following inputs are values typically used by NDOR based on NDOR testing and design practices. 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 ---------- Proposed Design
- % of All Trucks in Design Lane ---------- 100 % (2-lanes) II-9
  80 % (Expressway and Interstate)
  60 % (6-lane, Range)
- % Trucks in Design Direction ---------- 50 % II-9
- % Heavy Trucks (of ADT) ---------- Current % of ADT
- Average Initial Truck Factor (ESALs/Truck) ----- See Average Initial Truck Factors table 2.2j
- Annual Truck Factor Growth Rate (%) ---------- 0 %
- Annual Truck Volume Growth Rate (%) ---------- ((Future TADT/Present TADT)$^{(1/yrs)}$ -1) x 100
- Growth Rate ---------- Compound
- Initial Serviceability ---------- 4.4 *II-10*
- Terminal Serviceability ---------- 3.0 (Interstate System)
  2.5 (All other Highway Systems)
- 28-Day Mean PCC Modulus of Rupture ---------- 668 psi
- 28-Day Mean Elastic Modulus of Slab ---------- 3,860,000 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. See Chapter 5 for M_R based on NGI	"
Optimum (Jun-Aug)	"	"
Dry (Sept-Nov)	"	"

*May use 30,000 psi year round for lime, fly ash, or cement stabilized soils.

- Base Type ---------- Foundation Course
- Base Thickness ---------- 4" (usually)
- Depth to Bedrock ---------- 20 ft *II-37*
- Projected Slab Thickness ---------- 10 in.
- Loss of Support---------- 1 (FC or Stab SG), 2 (SG Prep) *II-27*
- Reliability Level (%) ---------- 85 (Interstate System) *II-9*
  80 (Expressway System)
  75 (Highways w/Future ADT over 3000)
  70 (Highways w/Future ADT under 3000)
- Overall Standard Deviation ---------- 0.35 *II-10*
- Load Transfer Coefficient, J ---------- 3.0 (Doweled conc. w/tied conc. shlds.) *II-26*
  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 *II-26*

2.2i DARWIN Flexible Design Inputs

Date: Revised 2/22/13
Source: Pavement Design Section

> The following inputs are values typically used by NDOR based on NDOR testing and design practices. 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" HMA over PCC ---------- 15 yrs
  - HLSS, Fly Ash, & CIR w/ 3" HMA, Mill 4"/Fill 4"-- 15 yrs
- Two-way Daily Traffic (ADT) ---------- Current ADT
- Number of Lanes in Design Direction ---------- Proposed Design
- % of All Trucks in Design Lane ---------- 100 % (2-lanes) *II-9*
  80 % (Expressway and Interstate)
  60 % (6-lane)
- % Trucks in Design Direction ---------- 50 % (always) *II-9*
- % Heavy Trucks (of ADT) ---------- Current % of ADT
- Average Initial Truck Factor (ESALs/Truck) ------- See Average Initial Truck Factors table
- Annual Truck Factor Growth Rate (%) ---------- 0 %
- Annual Truck Volume Growth Rate (%) ---------- $((\text{Future TADT}/\text{Present TADT})^{(1/\text{yrs})} - 1) \times 100$
- Growth Rate ---------- Compound
- Initial Serviceability ---------- 4.4 *II-10*
- Terminal Serviceability ---------- 3.0 (Interstate System)
  2.5 (All other Highway Systems)
- Reliability Level ---------- 85 (Interstate System) *II-9*
  80 (Expressway System)
  75 (Highways w/Future ADT over 3000)
  70 (Highways w/Future ADT under 3000)
- Overall Standard Deviation ---------- 0.45 *II-10*

Effective Roadbed Soil Resilient Modulus Calculation:

Season:	*Roadbed Soil Resilient Modulus (M_R):
• Frozen (Dec – Feb)	20,000 psi
• Wet (Mar-May)	Soils Data. See Chapter 5 for M_R values based on NGI
• Optimum (Jun-Aug)	"
• Dry (Sept-Nov)	"
	*May use 30,000 psi year round for lime, fly ash, or cement stabilized soils.

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

Thickness Design (Specified)

Material Description	Struct Coeff.	Drain Coeff.	Thickness	One Direction Width
Asphalt	0.54 *(NCAT 09-03)*	1*(II-25)*	1st Guess	Proposed Design

2.2j Average Initial Truck Factors

Source: Rea (1998), Reviewed in 2013

Rigid Pavement

National Functional Classification			Truck Factors*
	01	Interstate/Freeway	1.8013
Rural	02	Principal Arterial	1.3392
	06	Minor Arterial	1.2810
	07	Major Collector	0.8295
	11	Interstate/Freeway	0.8715
Urban	12 & 14	Principal Arterial	0.9282
	16 & 17	Minor Arterial & Major Collector	0.6657

*Truck Factors are recommended values based on National Functional Classification & adjusted for NE traffic.

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

Flexible Pavement

National Functional Classification			Truck Factors*
	01	Interstate/Freeway	1.1390
Rural	02	Principal Arterial	0.8823
	06	Minor Arterial	0.8680
	07	Major Collector	0.5611
	11	Interstate	0.5816
Urban	12 & 14	Principal Arterial	0.6859
	16 & 17	Minor Arterial & Major Collector	0.4817

*Truck Factors are recommended values based on National Functional Classification & adjusted for NE traffic.

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

2.2k 5364 Pavement Determination Review

From: Designer
Sent: Date
To: DE; Roadway Design Division Head; Roadway Design Section Head; Roadway Design Unit Head, Roadway Designer, and Project Scheduling Analyst
Cc: Pavement Design Unit Personnel
Subject: Project IM-80-1(181), Brownson to West Sidney, CN 51458

Below is the Pavement Determination Review for the subject project. Changes since the previous determination dated 4/4/11 include a tapered concrete thickness for the new concrete shoulders, changed to Asphaltic Concrete, Type SPR for the ramp resurfacings, and adjusted R.P's. Please review and send me any comments. Thanks,
Designer

Task 5364 -Pavement Determination Review

Project IM-80-1(181), Brownson to West Sidney, CN 51458

Mainline and Inside Shoulder – Remove 15" of existing pavement structure (asphalt, concrete, and cement treated foundation course). Build 12" Doweled Concrete Pavement on Foundation Course 4" on Stabilized Subgrade, Type Fly Ash. There will be no grade raise.

Outside Shoulders – Remove 15" of existing pavement structure. Build 12" Concrete Pavement at the ML edge, tapering to 9" at the outside edge on Foundation Course 4" on Stabilized Subgrade, Type Fly Ash.

Drainage – Install granular subdrains.

Maintenance Turn-Arounds: Build Surfacing 6" on Subgrade Preparation.

Cross-overs – Build 10" Concrete Pavement on Subgrade Preparation.

Temporary Pavement/Slip Ramps - Build Temporary Surfacing 10" on Stabilized Subgrade, Type Fly Ash.

Interchange Exit 48

Ramp Rebuild (Through Curve)

> *Mainline* – Remove existing pavement. Build 12" Doweled Concrete Pavement on Foundation Course 4" on Stabilized Subgrade, Type Fly Ash. There will be no grade raise.
>
> *Shoulders* – Remove existing pavement. Build 12" Concrete Pavement at the ML edge, tapering to 9" at the outside edge on Foundation Course 4" on Stabilized Subgrade, Type Fly Ash.
>
> *Drainage* – Install granular subdrains.

Ramps (From Curve On)

> *Mainline and Shoulders* – Repair underlying concrete. Mill approximately 4" of existing asphaltic concrete, by Cold Milling, Class 4. Mill 4" of existing asphaltic concrete shoulders, by Cold Milling, Class 3. Place 4" of Asphaltic Concrete, Type SPR over mainline and shoulders.

Overhead L17C (between ramps)

Mainline and Shoulders - Make concrete repairs as needed. Mill 2" of existing asphalt, by Cold Milling, Class 3. Place 2" of Asphaltic Concrete, Type SPR.

Rest Areas (Note: Rest area work is tentative, pending study of Sydney Rest Area)

Ramp Rebuild (Up to Gore)

Mainline – Remove existing pavement. Build 12" Doweled Concrete Pavement on Foundation Course 4" on Stabilized Subgrade, Type Fly Ash. There will be no grade raise.

Shoulder - Remove existing pavement. Build 12" Concrete Pavement at the ML edge, tapering to 9" at the outside edge on Foundation Course 4" on Stabilized Subgrade, Type Fly Ash.

Drainage – Install granular subdrains.

Ramps (From Gore On)

Mainline and Shoulder – Make concrete repairs as needed. Mill 4" of existing asphaltic concrete, by Cold Milling, Class 4. Mill 4" of existing asphaltic concrete shoulders, by Cold Milling, Class 3. Place 4" of Asphaltic Concrete, Type SPR over mainline and shoulders.

Concrete Truck Parking Area

Make concrete repairs as needed. Mill 1" of existing concrete, by Concrete Surface Milling. Place 3" of Asphaltic Concrete, Type SPR. *Note: The existing millings base used for truck parking will not be overlaid.*

Passenger Car Parking Area

Make concrete repairs as needed. Mill 1" of existing concrete, by Concrete Surface Milling. Place 3" of Asphaltic Concrete, Type SPR.

Note: Cement treated foundation course to be wasted (approx.. 3" deep x roadway width + 3' outside both sides of roadway). Longitudinal joints will separate the following: Inside shoulder and passing lane (16' width), driving lane (12' width), outside shoulder (12' width).

Notes for Special Provisions – The 4" of SPR on the Ramps will be placed in two 2" lifts. Allow 47B or BX-3000 for use on Concrete Shoulders, Surfacing 10" and 6" and Temporary Surfacing 10". Temporary Surfacing 10" may also be Asphaltic Concrete, Type SPR or SPH.

Bridges – S080 04882, S080 05035L/R, S080 05420L/R, S080 05466L/R

Drives and Intersections – NA

Repairs – Include $100K for PCC repairs

This project consists of rebuilding Interstate 80 from R.P. 46.81 to 55.01 approximately 8.20 miles.

Designer

2.2l 5406 Memo and Distribution

From: Pavement Designer
Sent: Date
To: Roadway Design Division Head, Roadway Design Section Head, Roadway Design Unit Head, Roadway Designer, Project Scheduling Analyst

Cc: Pavement Design Personnel; Roadway Design Survey Coordinator; M&R Division Head; District Engineer
Subject: Project HSIP-77-3(129), US-77 5th St to 10th St in Fremont, CN 22434

Attached is the signed Pavement Determination Approval Memo for the subject project. It is also available on Falcon under.

C.N.

Materials

Pavement Design

Pavement Recommendation

Pavement Designer

Materials and Research

Pavement Design

Phone

2.3 NDOR Abbreviations & Definitions

Date: Updated 2013
Source: Varilek

Abbreviations

A.C. – Armor Coat

A.C.S.C.- Asphaltic Concrete Surface Course

B.S.B.C. – Bituminous Sand Base Course OR Bituminous Stabilized Base Course

B.M. - Bituminous Material

B.M.S.C. – Bituminous Material Surface Course

BR. - Bridge

CONC. - Concrete Pavement

CRCP – Continuously Reinforced Concrete Pavement

GR. - Grading

G.R. – Guard Rail

JRCP – Jointed Reinforced Concrete Pavement

JPCP – Jointed Plain Concrete Pavement

P.C. – Prime Coat

S.A.B.C.- Soil Aggregate Base Course

S.S.B.C. Stabilized Sand Base course OR Stabilized Soil Base Course

T.S.B. – Tar Stabilized Base

9”-7”-9” Conc. - Parabolically Crowned Concrete with 7” thickness at center and 9” thickness at edge

Definitions

Stabilized Subgrade – Lime, Fly Ash, Cement, Cement Kiln Dust, etc. added to upper 8” of cohesive soil

Subgrade Stabilization – Soil Binder added to upper 6” of granular soil

Subgrade Preparation – Topsoil removed and top 6” of soil compacted

2.4 Design Documentation Checklist

Date: 2/22/13
Source: Varilek

Maintenance Project Definition and Examples

- Mill/Fill ≤2" OR Overlay ≤2" (pending RDWY review)
  - (Mill/Fill ≥ 1 ½" requires ADA compliance per operating instructions 60-10)
- In-Place Recycle w/minimal cap & grade raise
  - HIR 2" + Armor Coat, **OR** Mill 1", HIR 2" + 1 ½" AC (average SN of 4" recycle = 1" AC)
  - FDR + Double Armor Coat

3R Project Definition and Examples

- Mill/Fill >2" OR Overlay >2"
  - Virgin and/or Recycled mixes
- In-Place Recycle w/standard 2.5-3" overlay
- Repair by Replacement
  - Allowable in some cases
  - Subgrade Prep only, no stabilization or other base work allowed

New and Reconstruction Definition

- Projects exceeding maintenance and 3R scope

Design Documentation Checklist

- **Federal Funds Included?** (3 digits in project #)
  - Yes – Proceed below
  - No – Skip to State Funds only
- Maintenance Project?
  - Yes – No additional work
  - No – Proceed below
- 3R?
  - Yes; FDR, HLSS, Mill/Fill
    - Order Cores and FWD to confirm depths and strength
    - Coring Crew verifies design with DARWIN Back-Calculations.
      - Adjust design if necessary.
  - No – Proceed below
- New and Reconstruction?
  - Obtain soils data
  - Run Darwin pavement thickness design
  - Determine appropriate thickness based on Darwin, minimum design policy, and engineering judgment

See also 3.5 Maintenance and 3R Definitions for FHWA Funded Projects.

State Funds Only? (4 digits in Project #)

- Maintenance Project?
  - Yes – No additional work
  - No – Proceed below
- 3R?
  - Yes; FDR, HLSS, Mill/Fill
    - Order Cores and FWD to confirm depths and strength
    - Coring Crew verifies design with DARWIN Back-Calculations.
      - Adjust design if necessary.
  - No, Proceed below.
- New and Reconstruction?
  - Obtain soils data
  - Run Darwin design software for pavement thickness design
  - Determine appropriate thickness based on Darwin, minimum design policy, and engineering judgment

Notes: Major design changes to projects assigned to M&R will require an updated estimate for John Miller's section. This documentation is in addition to standard design practice; report, pavement history, maintenance history, etc.

2.5 Local Public Agency (LPA) Pavement Design Guidance

Date: Jan 2013
Source: Varilek

The NDOR is required by the Code of Federal Regulations (CFR) Title 23 to review all pavement designs for federally funded projects administered by the state. The NDOR requires different levels of documentation for different types of pavement projects. Below are the required documentation requirements for:

Maintenance projects (2" or less of HMA), pavement repairs, bike paths, minor intersection modifications (matching or exceeding existing pavement depths), preventative maintenance projects (microsurfacing, armor coats, etc.)

- Pg 1 only of Pavement Determination Data Sheet

New and Reconstruction (Resurfacing with >2" of HMA, new build HMA or PCC)

- Pg 1 & 2 or 1 & 3 of Pavement Determination Data Sheet as applicable
- Appropriate tables, figures and nomographs
- All Design assumptions and calculations

Useful References:

- AASHTO Guide For Design of Pavement Structures 1993 (Referenced as **AASHTO** below)
  May be purchased at: https://bookstore.transportation.org/
- Nebraska Department of Roads Pavement Design Manual (Referenced as **NDOR PDM** below)
  http://www.dor.state.ne.us/mat-n-tests/
- 2011 Pavement Design Workshop Presentation (Power Point)
  http://www.dor.state.ne.us/mat-n-tests/divisionPresentations.htm
- 2011 Pavement Design Workshop Presentation (Video)
  http://campus.extension.org/user/view.php?id=11400&course=487
- Summary of AASHTO 93 Pavement Design Process (See Below)
  - NDOR uses and recommends the AASHTO design method. Other nationally accepted design methods may be acceptable.

Common Errors:

- Utilizing a 24.3 Growth Factor from Pavement Design Workshop example for all design scenarios
  - GF = 24.3 is only applicable for a 20 year performance period with 2% Growth Rate
- Assuming traffic projection time period (yrs) must be the same as performance period (n).
  - The performance period (n) is independent of the traffic projection (yrs) and can represent any design life the designer chooses. Typical values include 20 years for full depth HMA and 35 yrs for full depth PCC.
- Not using direction or lane factors in ESAL calculation typically resulting in 2X the appropriate ESALs. See equation below.

Summary of AASHTO 93 Pavement Design Process

Input values are based on specific project details and in accordance with the *1993 AASHTO Guide for Design of Pavement Structures.*

Calculating Equivalent Single Axle Load (ESAL):

1. Calculate Traffic Growth Rate: **GR = ((Future ADT/Present ADT)$^{(1/yrs)}$ -1)*100 =**
2. Calculate Traffic Growth Factor: **GF = ((1+g)^{n}-1)/g =** **g = GR/100**
   a. GF equation may be used in lieu of interpolation of *Table D.20 pg D-24 AASHTO*
   b. n = Analysis Period also known as Performance Period or Design Life. This variable (n) is independent of the time period associated with the traffic projection (yrs).
3. Calculate ESALs: **ESALs = Present ADT x 365 days/yr x HT x GF x TF x D_D x D_L**
   a. HT = Heavy Trucks (%/100)
   b. GF = Traffic Growth Factor calculated above
   c. TF = Truck Factor
      i. Use single Truck Factor and ESAL calculation based on National Functional Classification, section 2.2 j NDOR PDM **OR**
      ii. Multiple Truck Factors if detailed traffic distribution is known or assumed *pg D-25 AASHTO*
   d. D_D = Directional Distribution Factor (%/100) *pg II-9 AASHTO*
   e. D_L = Lane Distribution Factor (%/100) pg *II-9 AASHTO*

Flexible Pavement Design (New Build)

1. Calculate ESALs as shown above
2. Calculate Effective Roadbed Soil Resilient Modulus (M_R) *pg II-14 Fig. 2.3 AASHTO*
   a. Opt, wet, dry M_R values for NE soils available section 5.3 NDOR PDM
   b. Frozen and chemically stabilized M_R values available section 2.2h NDOR PDM
   c. Note: nomograph can be replaced by $u_f = 1.18 \times 10^8 \times M_R^{-2.32}$ *pg II-14 AASHTO*
3. Estimate Design Structural Number (SN) *pg II-32 Fig. 3.1 AASHTO*
4. Identify desired materials and required depths to meet SN through iterative process. There are numerous potential solutions to any given SN *pg II-35 AASHTO* $\mathbf{SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3 + \ldots}$
   a. a_1, a_2, a_3 = layer coefficients of surface, base and subbase
      i. typical coefficients available section 3.9 NDOR PDM
   b. D_1, D_2, D_3 = depths of surface, base and subbase
   c. m_2, m_3 = drainage coefficients of base and subbase
      i. coefficients available *pg II-25 Table 2.4 AASHTO*

*Flexible Pavement Design Example available in *Appendix H AASHTO*

Rehabilitation of Flexible Pavement – Condition Survey Method:

(Used for HMA overlay, mill and overlay, recycle and overlay, etc.)

1. Calculate required Structural Number; Steps 1-3, Flexible Pavement Design (New Build)
2. Identify desired material(s) and required depth(s) to meet SN through iterative process *pg II-35 AASHTO*
   $\mathbf{SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3 + \ldots}$

a. Process similar to Step 4, Flexible Pavement Design (New Build). Primary difference is rehabilitation typically only involves HMA surface, leaving existing HMA, base, subbase, etc. below.
    i. Age and condition of existing underlying materials must be taken into consideration when assigning layer coefficients.
    ii. Typical coefficients available section 3.9 NDOR PDM
b. A shorter performance period may be appropriate depending on scope of rehabilitation

Rigid Pavement Design (New Build):

1. Calculate ESALs as shown above
2. Calculate Effective Modulus of Subgrade Reaction (k) *pg II-38 Table 3.2 AASHTO*
    a. Estimate Roadbed Resilient Modulus (M_R) for each season
        i. Opt, Wet, Dry M_R values for NE soils available section 5.3 NDOR PDM
        ii. Frozen and chemically stabilized M_R values available section 2.2h & 2.2i NDOR PDM
    b. Estimate Subbase Elastic Modulus (E_{SB}) **ONLY IF** design includes foundation course for each season
    c. Calculate Composite Modulus of Subgrade Reaction (k) *pg II-39 Figure 3.3 AASHTO* for designs with foundation course **OR** k = M_R/19.4 for slab on grade *pg II-44 AASHTO* for each season
    d. Modify k-value for effect of rigid foundation if bedrock within 10' *pg II-40 Fig 3.4 AASHTO* for each season if necessary. This step typically not applicable in NE.
    e. Calculate Relative Damage to pavement *pg II-41 Fig 3.5 AASHTO* for each season based on Composite k value calculated in step c (unless step d was used).
    f. Calculate Average Relative Damage by completing *pg II-38, Table 3.2 AASHTO*
    g. Back calculate composite k value using Average Relative Damage *pg II-41 Fig 3.5 AASHTO*
    h. Correct k value for loss of support *pg II-42 Fig 3.6 AASHTO*
3. Estimate required pavement thickness *pg II-45 Fig 3.7 AASHTO*
    a. This is the minimum required thickness based on project inputs. Local minimum design policies, engineering judgment, constructability issues, etc. may dictate additional depth.

*Rigid Pavement Design Example available in *Appendix I AASHTO*

Rehabilitation of PCC – PCC Condition Survey Method:

(Used for HMA overlay of PCC)

1. Calculate required slab depth for future traffic (D_f).; Steps 1-3, Rigid Pavement Design (New Build)
2. Calculate the effective depth of existing PCC based on condition $\mathbf{D_{eff} = F_{jc} \times F_{fat} \times F_{dur} \times D_{ex}}$ *pg III-121 AASHTO*
    a. D_{eff} = Effective slab depth (in)
    b. F_{jc} = Joints and Cracks adjustment factor
    c. F_{fat} = Fatigue Damage adjustment factor
    d. F_{dur} = Durability adjustment factor
    e. D_{ex} = Existing slab depth (in)
        i. Recommended factors *pg III-123 AASHTO*
3. Calculate A factor $\mathbf{A = 2.2233 + 0.0099(D_f - D_{eff})^2 - 0.1534(D_f - D_{eff})}$ *pg III-115 AASHTO*
    a. D_f = Slab depth for future traffic (in)
4. Calculate depth of overlay required (D_{ovl}). $\mathbf{D_{ovl} = A(D_f - D_{eff})}$ *pg III-115 AASHTO*

2.6 Local Public Agency (LPA) Pavement Determination Data Sheet

Pavement Determination Data Sheet

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

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		

Soils	
Classification	
Optimum Modulus	
Wet Modulus	
Dry Modulus	
Frozen Modulus	

Traffic	
Current ADT	
___yr Forecast ADT	
% Heavy Trucks	
Predicted ESAL's	

Design Method Used:	AASHTO

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

Flexible Design Inputs

Structure Number based on ESAL's		
Performance Period (Yrs)		*Use this method for New Build design or for establishing required structure number for comparison to Rehabilitation design.*
Number of Lanes in Design Direction		
% of Trucks in Design Lane		
% of Trucks in Design Direction		
Average Initial Truck Factor (ESALS/Truck)		
Traffic Growth Rate (GR)		
Traffic Growth Factor (GF)		
Initial Serviceability		
Terminal Serviceability		
Reliability Level		
Overall Standard Deviation		*Use these inputs & the Flexible Pavement Nomograph (Figure 3.1, pg.II-*
Structure Number Required		

HMA Condition Survey Method (Rehabilitation)

Surface Course		
Type		*Use this method for Rehabilitation of existing asphalt roadways or for Bituminous Recycling Strategies*
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 ($SN_1 + SN_2 + SN_3 + \ldots$)	

Add or Subtract Layers as

Comments:

Rigid Design Inputs

Thickness based on ESAL's

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

Performance Period (Yrs)		Base Type	
Number of Lanes in Design Direction		Base Thickness	
% of Trucks in Design Lane		Depth to Bedrock	
% of Trucks in Design Direction		Projected Slab Thickness	
Average Initial Truck Factor (ESALS/Truck)		Loss of Support	
Traffic Growth Rate (GR)		Reliability Level	
Traffic Growth Factor (GF)		Overall Standard Deviation	
		Load Transfer Coefficient	
Initial Serviceability		Drainage Coefficient	
Terminal Serviceability			
28-Day Mean PCC Modulus of 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

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

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

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

Definitions:

D_{ovl} = HMA overlay thickness (inches)
D_r = PCC required thickness (inches) based on ESAL's
D_{eff} = Condition Survey or factor of existing PCC as thickness (inches)
D_{ex} = Existing PCC Depth
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_{ex}=	
D_{eff}=	

A=	

D_{ovl}=	

Comments:

NDOR
Nebraska
Department of Roads

Design

Preliminary Pavement Design

Instructions for Use: Sections of this form are to be completed by the LPD PC before forwarding to NDOR M&R Pavement Design Section to check the Pavement Design related items on the 30% Plan Set. The NDOR LPD PC will submit a copy of the 30% PIH Plan set and the Pavement Determination to NDOR M&R to conduct this review.

Local Public Agency *(LPA)*:	LPA Responsible Charge:	
State Project No.:	Project Name and Location:	
State Control No.:	Date of Review:	This Form was Completed By:

This section to be completed by the LPD PC:

Item #	Task Description or Questions	Completed			If No, Define Corrective Action	Details or Information Used to Verify Content	Additional Comments
		Yes	No	N/A			
1.	Have the 30% PIH plans been submitted and are they ready for review?	☐	☐	☐			A pavement design analysis is not required for maintenance projects.
2.	Has the Pavement Determination Data Sheet *(PDDS)* been submitted?	☐	☐	☐			Sheet 1 required for maintenance projects *(<2" HMA)*. Sheets 1 & 2 or 1 & 3 required for resurfacing and new build projects. Appropriate nomographs required for new build.
3.	Will a Permit to Occupy State ROW be required and has that been noted on the submittal memo?	☐	☐	☐			Only if applicable.
4.	Has the LPA notified the PC of any known relaxation of design standards?	☐	☐	☐			

Remaining sections to be completed by Materials and Research.

Remaining Pavement Design

Item #	Task Description or Questions	Completed			If No, Define Corrective Action	Details or Information Used to Verify Content	Additional Comments
		Yes	No	N/A			
5.	Has a copy of the pavement design analysis been received?	☐	☐	☐			A pavement design analysis is not required for maintenance projects.
6.	Was the pavement design developed using a nationally recognized method? *(AASHTO, Asphalt Institute Method, Portland Cement Association)*	☐	☐	☐			
7.	Are all of the necessary inputs for the pavement design included? (ADT, %HT, expected life, layer coefficients…)	☐	☐	☐		Design Analysis Input and Output	
8.	Does the pavement strategy seem reasonable for the project scope? *(Check for constructability issues, material availability, etc.)*	☐	☐	☐		Existing Pavement Information, existing pavement determination, material testing information.	
9.	Have all the pavement mix types been pre-approved?	☐	☐	☐		City of Omaha & Lincoln have had their asphalt mixes pre-approved. All other asphalt or concrete must be a current NDOR mix.	

Plans

Item #	Task Description or Questions	Completed			If No, Define Corrective Action	Details or Information Used to Verify Content	Additional Comments
		Yes	No	N/A			
10.	Do the project plans have typical sections or details that address all of the necessary pavement work?	☐	☐	☐			
11.	Have all the pavement related items been properly labeled in the typical section or detail? *(Depth of strategy, shouldering, preparation, inlays).*	☐	☐	☐			

Item #	Task Description or Questions	Completed			If No, Define Corrective Action	Details or Information Used to Verify Content	Additional Comments
		Yes	No	N/A			
12.	Is the existing pavement depth shown or described on the plans? (Needed for all removal, rehabilitation, repair or recycling sections of the project)	☐	☐	☐			

NDOR
Nebraska
Department of Roads

Design

Final Pavement Design, Final Quantities, and Special Provisions

Instructions for Use: This form is to be completed by NDOR M&R Pavement Design Section to check the Pavement Design, Final Quantities and Special Provisions in the Final Plan Set package prior to submitting them to NDOR PS&E. The NDOR LPD PC will submit a copy of the Final Plan set, final quantities, special Provisions and the Pavement Determination to NDOR M&R to conduct this review.

Local Public Agency *(LPA)*:	LPA Responsible Charge:	
State Project No.:	Project Name and Location:	
State Control No.:	Date of Review:	This form was completed by:

Pavement Design

Item #	Task Description or Questions	Completed			If No, Define Corrective Action	Details or Information Used to Verify Content	Additional Comments
		Yes	No	N/A			
1.	Were the Pavement Design related comments, provided during the preliminary design review, incorporated into the current set of plans?	☐	☐	☐			
2.	Has a copy of the pavement design analysis been received?	☐	☐	☐			A pavement design analysis is not required for maintenance projects
3.	Was the pavement design developed using a nationally recognized method? (AASHTO, Asphalt Institute Method, Portland Cement Association….)	☐	☐	☐		Refer to the Preliminary Pavement Design Checklist	
4.	Are all the necessary inputs for the pavement design included? (ADT, %HT, expected life, layer coefficients…)	☐	☐	☐		Design Analysis Input and Output	

Item #	Task Description or Questions	Completed			If No, Define Corrective Action	Details or Information Used to Verify Content	Additional Comments
		Yes	No	N/A			
5.	Does the pavement strategy seem reasonable for the project scope? (check for constructability issues, material availability, etc)	☐	☐	☐		Existing Pavement Information, existing pavement determination, material testing information.	
6.	Have all the pavement mix types been pre-approved?	☐	☐	☐		City of Omaha & Lincoln have had their asphalt mixes pre-approved. All other asphalt or concrete must be a current NDOR mix.	

Plans, Quantities and Special Provisions

Item #	Task Description or Questions	Completed			If No, Define Corrective Action	Details or Information Used to Verify Content	Additional Comments
		Yes	No	N/A			
1.	Do the project plans have typical sections or details that address all of the necessary pavement work?	☐	☐	☐			
2.	Have all the pavement related items been properly labeled in the typical section or detail? (Depth of strategy, shouldering, preparation inlays...)	☐	☐	☐			
3.	Has the existing pavement depth been shown or described? (Needed for all removal, rehabilitation, repair or recycling sections of the project)	☐	☐	☐			
4.	Has a pay item summary sheet been received for each pavement related pay item?	☐	☐	☐			
5.	Do the summary sheets and plans accurately match one another?	☐	☐	☐			

Item #	Task Description or Questions	Completed			If No, Define Corrective Action	Details or Information Used to Verify Content	Additional Comments
		Yes	No	N/A			
6.	Have all the final pavement quantities been verified and placed on a Final Summary Sheet by M&R?	☐	☐	☐			
7.	Have all special provisions been attached for items not covered by the NDOR Standard Specification for Highway Construction book.	☐	☐	☐		M&R and Construction Division will review and pre-approve ALL special provisions submitted.	
8.	Has the proper soil compaction table been included in the plan set?	☐	☐	☐		NDOR Pavement Design Section will coordinate this review with the Geotechnical Section	

Chapter 3: Pavement Design Policies and Guidance

3.1 Asphalt Mix, Binder, Gradation & Minimum Thickness Policy

Date: 2/26/13
Source: Pavement Design

Use	Mix Type
Mainline: 0 – 750 Heavy Trucks per day	SPR, SPR(fine)
Mainline: >750 Heavy Trucks per day	SPH
Shoulder	SPS

Performance Graded Binders

Mainline SPH	PG 64-34
Mainline SPR, SPR(fine)	PG 64-34
Leveling Course, Type LC	PG 64-34
Shoulder SPS	PG 52-34
Temporary Interstate/Expressway SPR	PG 70-16 *(Or better)*
Temporary Non Interstate/Expressway SPR	PG 64-22 *(Or better)*

A Performance Graded Binder means that tests are performed to measure the physical properties of the binder. The first number represents the 7 day maximum pavement design temperature in degrees Celsius (°C). The second number is the lowest single day design temperature in degrees Celsius (°C). For example, a binder graded as PG 70-28: Resists deformation up to 70°C (158°F) and Thermal Cracking to -28°C(-18°F)

Gradation

$^{3}/_{16}$" (0.19) gradation band for thicknesses less than 1", Type LC only
$^{3}/_{8}$" (0.375) gradation band for thicknesses 1" or greater, SPH or SPR(fine)
½" (0.5) gradation band for thicknesses 1 $^{1}/_{2}$" or greater, SPH or SPR

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

3.2 Relinquishment Policy

Date: 1/15/02
Source: Operating Instruction 60-13

Nebraska Department of Roads
Operating Instruction 60-13
February 15, 2002

RELINQUISHMENT OF ROADS FROM THE HIGHWAY SYSTEM

*** 1. **Purpose:** To provide policy for the relinquishment of roads, by preparation, distribution, and disposition of relinquishment agreements between the Nebraska Department of Roads and an outside party. The office of primary responsibility for this DOR-OI is the Materials & Research Division. This DOR-OI supersedes DOR-OI 60-13 dated January 30, 2002.

*** 2. **General:**

When a segment of highway is relocated, the functional classification of the old highway will be changed. The Department will offer to relinquish to the political or governmental subdivision(s) or public corporation(s), any portion of the old state highway that has been relocated. If an offer to relinquish a highway segment is not accepted by the local jurisdiction(s), the State may abandon it as provided by law (See Section 8 "Abandonment of Roadway"). The Department will relinquish the highway to the local agency after following the approved policy for relinquishment of highways.

Before relinquishment, the Department may improve the surface of existing highways if the roadway has a Nebraska Serviceability Index (NSI) or Present Serviceability Index (PSI) less than or equal to:

	NSI	PSI
Bituminous Pavements	70	2.5
Composite (overlay) Pavements	60	2.5
Portland Cement Concrete Pavements	50	2.5

Other than surface rehabilitation, improvements to the roadway will not be made. At the time of relinquishment, the Nebraska Department of Roads (NDOR) will assess the adequacy of structures and determine if any reparation or corrective action is required. It is the intent of the State to relinquish only those structures which are structurally and functionally adequate for the purpose for which they will be used.

In any relinquishment or closure proceeding where the Department of Roads owns fee simple title to the underlying land, ownership should be reserved by the Department of Roads. However, the land may be sold according to Nebraska Statute Sec. 39-1325. If sold, the contract must guarantee that utility companies have a perpetual right to utilize the former state right of way.

3.3 Portland Cement Concrete Design Policy

Date: 2/11/2000
Source: Jamshidi

February 11, 2000

PORTLAND CEMENT CONCRETE
PAVEMENT DESIGN POLICY

1. The "AASHTO Guide for Design of Pavement Structures, 1986-1993" shall be used as a guide for the pavement type selection and design process.

2. Rigid Pavement Design – All rigid pavement will be plain jointed Portland cement concrete including dowel bars at all transverse joints as follows:

   a. Rural Areas – In rural areas epoxy coated dowel bars at 12 in. (300 mm) centers will be placed at at all transverse joints.

   b. Urban Areas – In urban areas each section will be analyzed to determine the need for dowel bars. If dowel bars are required they will be of the same design as in rural areas.

3. Minimum Pavement Thickness – The minimum pavement thickness of Portland cement concrete pavement on the State Highway System shall be as follows:

   Interstate System, I-76 Junction East.....12 in. (305 mm)
   Interstate System, I-76 Junction West, and Expressway System.....10 in. (255 mm)
   All Other Highways.....9 in. (230 mm)

4. Final Pavement Thickness – The pavement thickness to be constructed, subject to the minimum pavement thickness defined above, will be the required pavement thickness using the AASHTO Guide for Design of Pavement Structures rounded up to the nearest 1in. (25 mm).

5. Transverse Joint Spacing – Transverse joints will be at 16'-6" (5.0m) centers placed perpendicular to the centerline of the roadway.

6. Tied Concrete Shoulders – Rigid pavement projects will be reviewed on a case by case basis to determine if anticipated traffic volumes from turning movements or the anticipated future use of the shoulder for a driving surface, justifies the addition of full width Portland cement concrete shoulders. For Interstate and Expressway System the minimum design shall be as follows:

   a. Interstate (4 lane), and Expressway System & DR-2 non-expressway – The inside and 3' of the outside shoulder shall be full depth concrete poured monolithically with the mainline. The remainder of the outside shoulder shall be determined in the pavement design process.

   b. Interstate (6 lane) – The shoulders, including the median surfacing design, will be reviewed on a case by case basis.

Recommended:

Moe Jamshidi
Materials and Tests Engineer

Approved:

Wayne Teten
Deputy Director - Operations

Monty W. Fredrickson
Deputy Director – Engineering

John L. Craig
Director – State Engineer

3.4 In-Place Recycling Policy

Date: 12/9/03
Source: Rea

NDOR
Nebraska
Department of Roads

Memorandum

Date: December 9, 2003

To: Monty Fredrickson – Deputy Director Engineering John Jacobsen – Deputy Director Operations 12-15-03

From: Robert C. Rea – Pavement Design Engineer

Thru: Moe Jamshidi – Materials and Research Engineer

Subject: In-Place Recycling Projects

DEPARTMENT OF ROADS
DEC 11 2003
DIRECTOR-STATE ENGINEER

After reviewing many of the comments from the District Engineers on the subject, I submit the following: Many of our roadways are requiring recycling strategies to address the distresses in the existing pavement layers prior to the overlay to optimize its performance. The processing of the existing layers provides "growth" of the roadway, essentially creating additional material. In an attempt to minimize the grade raise of the final roadway section, a trench widening strategy has been used to provide a location for this excess material. Generally, the additional width is 2 feet on each side for a total surfaced width of 28'. There have been several benefits from the combination of these strategies.

1) Trench widening provides shouldering material that is windrowed at the edge of the roadway for prompt shouldering operations, reducing exposure time of drop offs during paving operations.
2) Eliminates/reduces the need to haul in borrow material for shoulder construction.
3) The trenching operation is easily expedited and the amount of 'opened' trench is limited to two days of production, which also greatly reduces exposure time of the drop off at the edge of the pavement.
4) Grade raise is minimized, therefore reducing some of the steepening of the foreslopes.
5) Maintaining vegetation and shoulder material on 24' widths is a recurring cost and time-consuming burden on the maintenance forces.
6) Shoulder drop offs should be reduced, providing less potential hazards of the roadway section.
7) A wider paved section provides more surfacing to better accommodate wide loads and agricultural equipment, and it also provides greater driver comfort.
8) Snow plowing and 'winging' operations are safer and easier by giving the equipment more surface to work off of.

These benefits come with some associated costs: the trenching operation and the bituminous surfacing. The trenching operation is offset by the cost to trim and haul off the recycled material, the reduction of material required to perform the shouldering operation, and the reduced amount of barrels required to delineate the drop off at the edge of the pavement.

Therefore the initial cost to construct this section is the cost to place the bituminous surfacing, which amounts to approximately $10,000 per centerline mile for 2.5 inches of asphalt. Additionally, there will be some costs from future strategies when applying surface treatments or overlaying a wider pavement section.

If we look at Nebraska's roadway system, there are approximately 2000 miles that do not meet the criteria for the 28-foot top system. In general, these roadway sections will be resurfaced every 20 years, which amounts to approximately 100 miles per year. Therefore, an annual expenditure of $1,000,000 would be required to widen these facilities as described. At first glance, it would appear that a million dollar annual expenditure is a substantial initial cost, however, when compared to the savings in reduced maintenance activities, a safer driving section, and better accommodation of our agricultural vehicles, the additional cost is well justified. In light of these benefits and value, both projected and perceived, I recommend that we take full advantage of the widened in-place recycle strategies on all of these roadway sections, whenever possible.

Concurrence _____ Deputy Director Engineering — 12/12/03 Date

Concurrence _____ Deputy Director Operations — 12/15/03 Date

3.5 Maintenance and 3R Definitions for FHWA Funded Projects

Date: 7/23/10
Source: Knott

July 23, 2010

Meeting to discuss Definition of Maintenance in Relation to Overlays & Inlays

Attendees: Monty Fredrickson, Randy Peters, Khalil Jaber, Jeff Schroeder, Mick Syslo, Moe Jamshidi, Jim Knott

The attendees discussed the application of design standards to pavement overlays and inlays. The Federal Highway Administration (FHWA) has determined that for all projects on the Nation Highway System (NHS) regardless of funding and for all federally funded projects that a pavement preservation project designed to maintenance standards shall not have greater than 2" or its equivalent of pavement thickness (overlay or inlay) placed with the project.

This determination is based upon their evaluation that this strategy will have approximately an average five year useful life. FHWA and NDOR have as one of our goals, an overall reduction of highway fatalities. One of the NDOR and FHWA's critical emphasis areas is minimizing the incidence and severity of run off the road crashes. Improving the roadway geometry to the 3R standards and up-grading the safety appurtenances to crash worthy assemblies for long life projects is one of the strategies we use to achieve this goal. It is FHWA's desire that safety appurtenances and roadway geometry be updated in a timely manner.

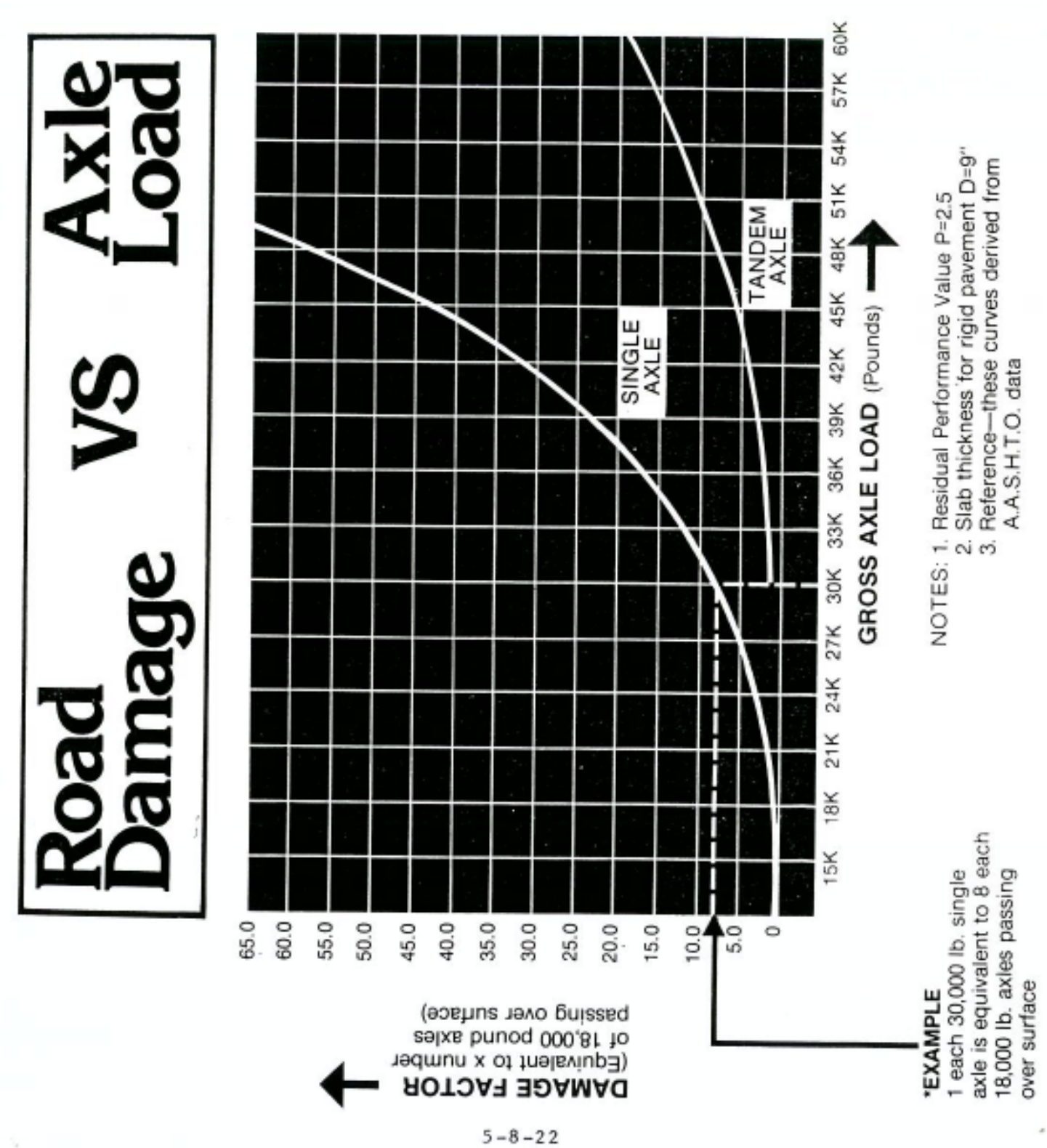
Due the many different strategies available for pavement preservation, use of the five year threshold would have been unwieldy; consequently FHWA chose the 2" thickness as a threshold. Because the NDOR and the LPAs use pavement modifications processes such as recycling and reclamation to stabilize or improvement the pavement prior to overlay the phrase "or its equivalent" was added to modify the threshold. The meaning of this phrase becomes clear when we understand that Materials and Research has determined that a roadway gains approximately 1" of new structure for every 4" of a reclamation or recycle strategy, e.g. a pavement determination of 2" of reclamation followed by a 1½" overlay is equivalent to a 2" thickness. Therefore, a pavement rehabilitation strategy requiring the reclamation of 2" and resurfacing with 1.5" would be equivalent to a 2" resurfacing.

The 2" thickness is the guiding principle regardless of whether the surface is milled prior to being resurfaced.

Those present agreed that the principle of "2" thickness of resurfacing or its equivalent" shall guide the choice of design standard for the NDOR. Pavement rehabilitation strategies that require in excess of 2" thickness or its equivalent will be designed to Resurfacing, Restoration and Rehabilitation (3R) standards.

3.6 Road Damage vs. Axle Loading Comparison

Date: ?
Source: AASHTO

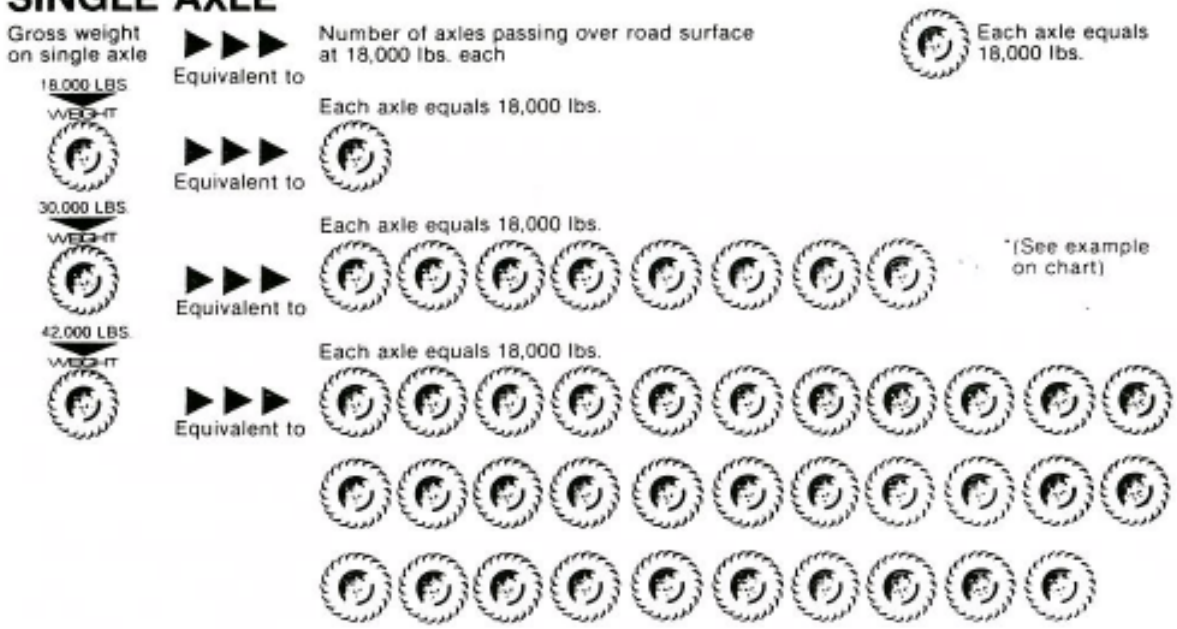


Road Damage vs Axle Load

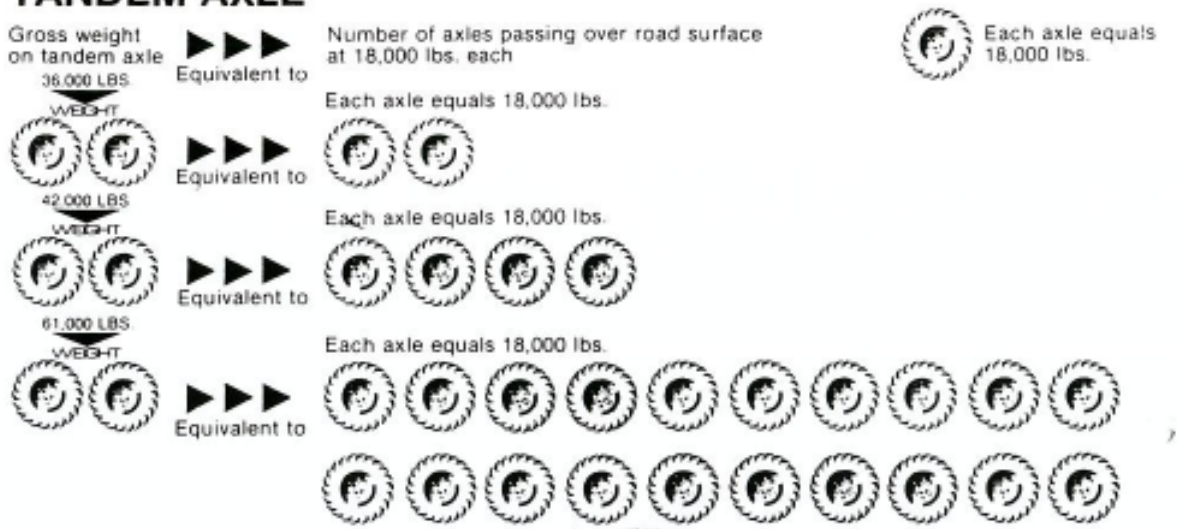
ROAD DESIGN AND DAMAGE CRITERIA ARE BASED ON AXLE LOAD

Data from American Association State Highway Transportation Officials Studies (A.A.S.H.T.O.)
U.S. Government Data - Washington, D.C., U.S.A.

SINGLE AXLE



TANDEM AXLE



5-8-23

3.7 Vehicle Classifications

Date: 2001
Source: http://pavementinteractive.org/index.php?title=Trucks_and_Buses

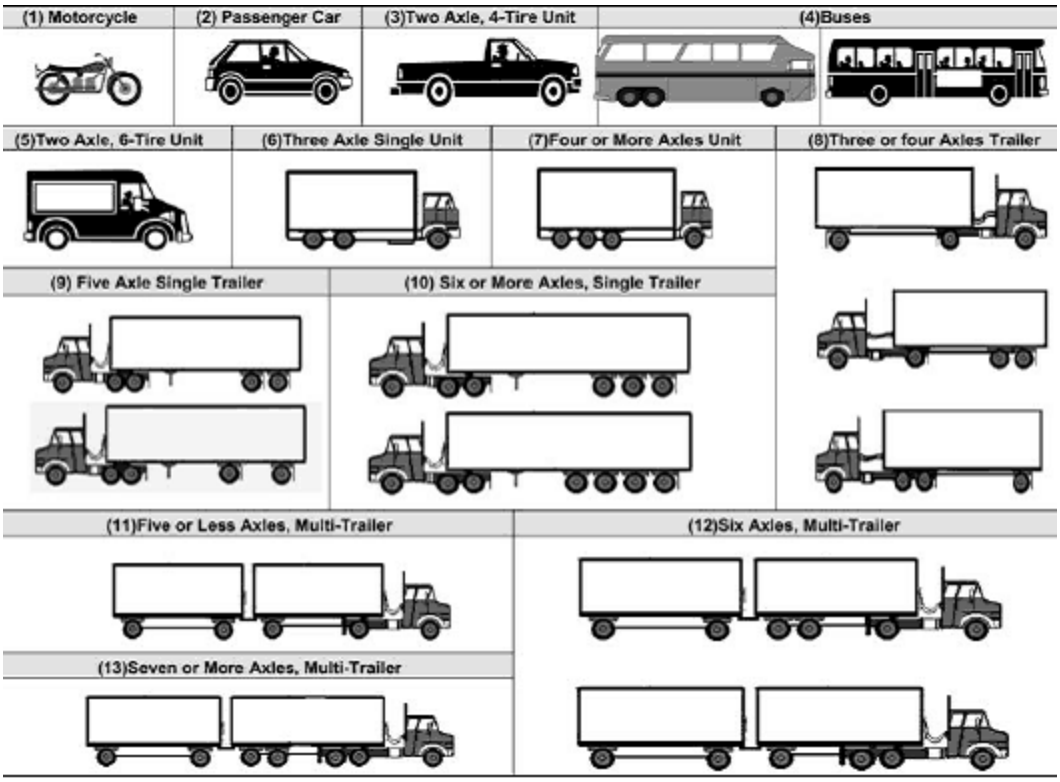
The FHWA classifies vehicles in terms of their configuration rather than weight. This type of classification system is more conducive to traffic applications but can be adapted for pavement loading applications. It can also be easily confused with the vehicle manufacturer's truck classification system. The FHWA *Traffic Monitoring Guide* (TMG) recommends classifying vehicles into 13 different categories. Figures 4 through 9 show some FHWA vehicle class examples.

Table 2. FHWA Vehicle Classification (from FHWA, 2001)[1]

Class	Type	Description	Typical ESALs per Vehicle[2]
1	Motorcycles	All two- or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handle bars rather than wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheel motorcycles. This vehicle type may be reported at the option of the State.	negligible
2	Passenger Cars	All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.	negligible
3	Other Two-Axle, Four-Tire Single Unit Vehicles	All two-axle, four tire, vehicles, other than passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, and carryalls. Other two-axle, four-tire single unit vehicles pulling recreational or other light trailers are included in this classification.	negligible
4	Buses	All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. All two-axle, four-tire single unit vehicles. Modified buses should be considered to be a truck and be appropriately classified.	0.57
5	Two-Axle, Six-	All vehicles on a single frame including trucks, camping and recreational vehicles,	0.26

	Tire, Single Unit Trucks	motor homes, etc., having two axles and dual rear wheels.	
6	Three-Axle Single Unit Trucks	All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having three axles.	0.42
7	Four or More Axle Single Unit Trucks	All trucks on a single frame with four or more axles.	0.42
8	Four or Less Axle Single Trailer Trucks	All vehicles with four or less axles consisting of two units, one of which is a tractor or straight truck power unit.	0.30
9	Five-Axle Single Trailer Trucks	All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.	1.20
10	Six or More Axle Single Trailer Trucks	All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.	0.93
11	Five or Less Axle Multi-Trailer Trucks	All vehicles with five or less axles consisting of three or more units, one of which is a tractor or straight truck power unit.	0.82
12	Six-Axle Multi-Trailer Trucks	All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.	1.06
13	Seven or More Axle Multi-Trailer Trucks	All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.	1.39

FHWA Vehicle Classifications



VEHICLE CLASSIFICATION VERSUS VEHICLE TYPE

Source: http://www.fhwa.dot.gov/pavement/wim/pubs/if10018/tb02.cfm

As used in this manual, vehicle classification refers to the identification of vehicles according to FHWA's 13 Class Scheme as described in the Traffic Monitoring Guide (http://www.fhwa.dot.gov/ohim/tmguide/). However, individual classes within this scheme include vehicles with different axle configurations and operating characteristics that need to be uniquely identified by a WIM system's classification algorithm. Additionally, the ability to perform analyses on vehicles with similar axle configurations and operating characteristics, regardless of FHWA classification, can be of great benefit in performing data analyses. Vehicle type is used to refer to vehicles with similar axle configurations and operating characteristics. A few examples of vehicle types follow.

Class 7 includes all trucks on a single-frame with four or more axles. For trucks with "variable load suspensions" or "lift axles" (as shown in Figure 8), only the axles in contact with the pavement are counted to determine classification.

Figure 8. Photo. Class 7, single-unit truck with four of its five axles in contact with pavement.

Class 8 includes several common three- and four-axle single-trailer configurations. Figure 9 displays a two-axle tractor with a single axle semi-trailer and Figure 10 displays a three-axle tractor with a single axle semi-trailer. For this method of defining a truck combination type, the first value is the number of axles on the power unit (tractor or straight truck), the "S" signifies a semi-trailer, and the following value is the number of axles on the trailer.

Figure 9. Photo. Class 8, Type 2S1.

Figure 10. Photo. Class 8, Type 3S1.

Class 9 includes five-axle single-trailer trucks. Figure 11 displays the three-axle tractor and two-axle semi-trailer, which is by far the most predominant Class 9 type. Figure 12 displays the same type but with a "spread" tandem on the trailer. If this axle spread exceeds eight feet it is not a true tandem axle and is considered to be two individual axles. Figure 13 displays a three-axle straight truck pulling a two-axle full trailer. As such, there is no "S" preceding the value defining the trailer's number of axles.

Figure 11. Photo. Class 9, Type 3S2.

Figure 12. Photo. Class 9, Type 3S2 with "spread" rear tandem.

Figure 13. Photo. Class 9, Type 3S2.

Class 10 includes six-axle single trailer trucks. Figure 14 displays the most common configuration, the Type 3S3 which has a semi-trailer with a tridem axle.

Figure 14. Photo. Class 10, Type 3S3.

Class 11 includes five-axle multi-trailer trucks. Figure 15 displays the most common configuration, the Type 2S12. The first value defines the number of axles on the power unit, the "S1" defines the single axle semi-trailer, and the last value defines the second trailer as a two-axle full trailer.

Figure 15. Photo. Class 11, Type 2S12.

Class 12 includes six-axle multi-trailer trucks. Figure 16 displays the most common configuration, the Type 3S12.

Figure 16. Photo. Class 12, Type 3S12.

Class 13 includes multi-trailer trucks with seven or more axles for which there are a large number of possible axle configurations. Although there are exceptions, most agencies do not find it necessary to uniquely define these by type since they account for a very low percentage of the truck traffic stream.

3.8 Layer Coefficients for Design

Date: 12/18/12
Source: Pavement Design Section

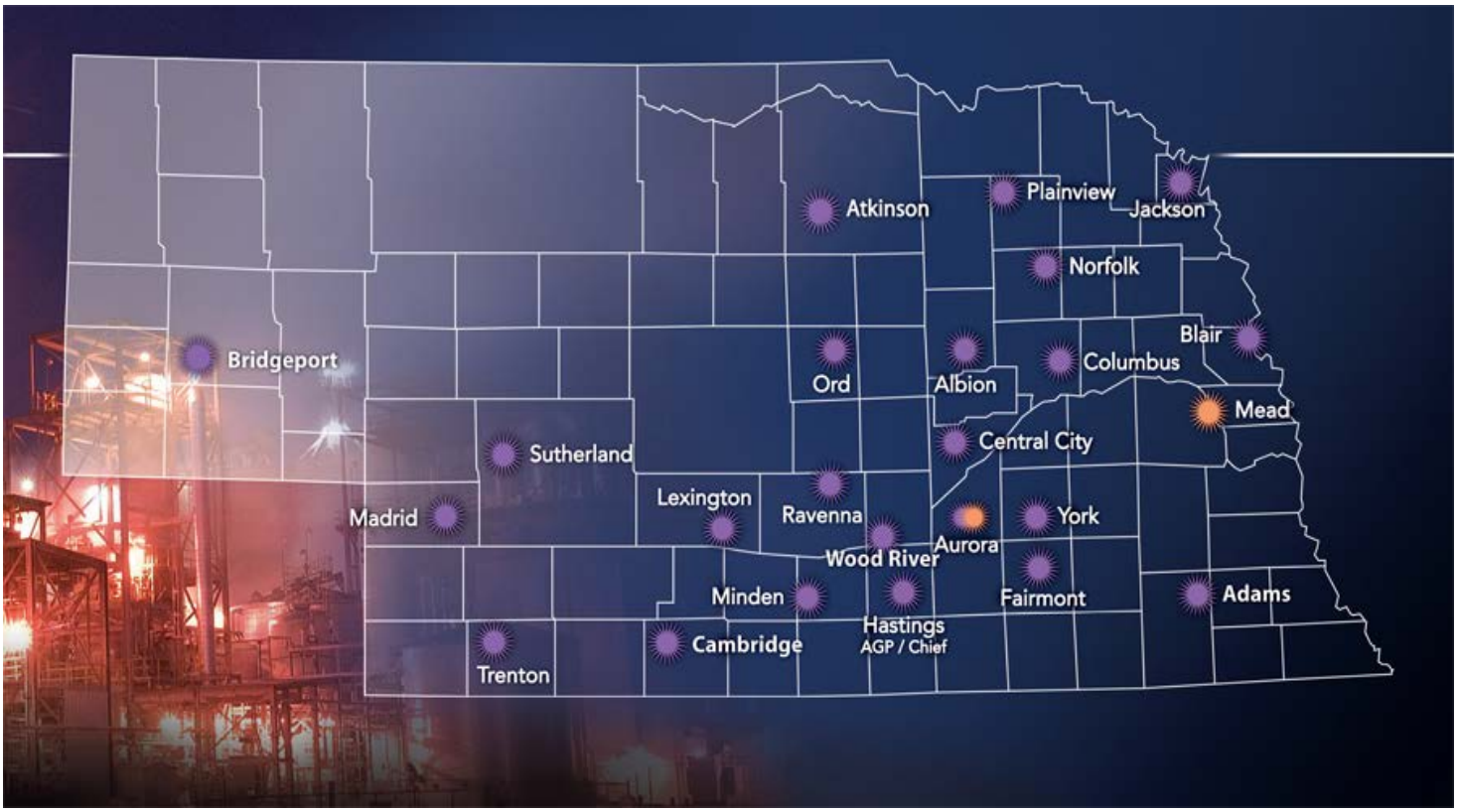
New Asphalt	0.54
Existing Asphalt	0.24-0.35
Existing Bituminous Sand	0.2
Bituminous Millings	0.2
Cold-In-Place Recycle	0.25
Full Depth Reclamation w/PC or Fly Ash	0.25
Full Depth Reclamation w/water only	0.14
Hydrated Lime Slurry Stabilization	0.25
Foundation Course	0.2
Soil Aggregate Base Course	0.14
Lime or Fly Ash Stabilized Subgrade	0.22

PCC does not have a layer coefficient. However, a value of 0.5-0.75 has been used by some researchers for comparison purposes only.

3.9 NE Ethanol Plant Locations

Updated September 14, 2012

Map of Nebraska Ethanol Plants



Nebraska Ethanol Plants

E-Energy Adams *Adams* • 13238 East Aspen Road • Adams, NE 68301 • Carl Sitzmann • Opened: 2007 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 55 MGY • Grind: 20 MBY • Permanent Employees: 41	*Valero Renewable Fuels* *Albion* • 2615 260th Street, Suite 100 • Albion, NE 68620 • Andy Roberts • Opened: 2007 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 110 MGY • Grind: 41 MBY • Permanent Employees: 55
NEDAK *Atkinson* • PO Box 391 • Atkinson, NE 68713 • Jerome Fagerland • www.nedakethanol.com • Opened: 2008 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 44 MGY • Grind: 17 MBY • Permanent Employees: 38	*Aventine Renewable Energy* *Aurora* • 1205 South "O" Road • Aurora, NE 68818 • Brian Pasbrig • Opened: 1995 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 50 MGY • Grind: 18 MBY • Permanent Employees: 43

Cargill, Inc. *Blair* • 650 Industrial Park PO Box 300 • Blair, NE 68008 • Brain Silvey • Opened: 1995 • Mill Process: Wet • Feedstock: Corn • Production Capacity: 198 MGY • Grind: 73 MBY • Permanent Employees: 40	*Bridgeport Ethanol* *Bridgeport* • 9216 Road 90 PO Box 884 • Bridgeport, NE 69336 • Ted Free • Opened: 2008 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 54 MGY • Grind: 20 MBY • Permanent Employees: 28
Nebraska Corn Processing *Cambridge* • 107 Potter St. • Cambridge, NE 69022 • Eric Meeuwsen • Opened: 2008 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 44 MGY • Grind: 16 MBY • Permanent Employees: 36	*Green Plains Renewable Energy* *Central City* • 214 20th Street • Central City, NE 68826 • Dwayne Braun • Opened: 2004 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 100 MGY • Grind: 36 MBY • Permanent Employees: 47

ADM *Columbus* • 3000 East 8th Street • Columbus, NE 68601 • Steve DeWald • www.adm.com • Opened: 1992 • Mill Process: Wet • Feedstock: Corn • Production Capacity: 500 MGY • Grind: 143 MBY • Permanent Employees: 285	*Advanced BioEnergy* *Fairmont* • 1214 County Road G • Fairmont, NE 68354 • Grant Johanson • www.advancedbioenergy.com • Opened: 2007 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 115 MGY • Grind: 43 MBY • Permanent Employees: 45
Chief Ethanol Fuels *Hastings* • PO Box 488 • Hastings, NE 68902 • Duane Kristensen • www.chiefind.com • Opened: 1985 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 68 MGY • Grind: 25 MBY • Permanent Employees: 60	*Ag Processing (AGP)* *Hastings* • PO Box 2118 • Hastings, NE 68902 • Dave McCormich • • Opened: 1995 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 55 MGY • Grind: 20 MBY • Permanent Employees: 45
Siouxland Ethanol *Jackson* • 110 East Elk • Jackson, NE 68743 • Chuck Hofland • www.siouxlandethanol.com • Opened: 2007 • Mill Process: Dry	*Cornhusker Energy* *Lexington* • 111 East Industry Drive • Lexington, NE 68850 • Tydd Rohrbough • www.cornhuskerenergy.com • Opened: 2006 • Mill Process: Dry

• Feedstock: Corn • Production Capacity: 50 MGY • Grind: 22 MBY • Permanent Employees: 36	• Feedstock: Corn • Production Capacity: 50 MGY • Grind: 19 MBY • Permanent Employees: 50
KAAPA Ethanol *Minden* • PO Box 238 • Minden, NE 68959 • Chuck Woodside • Opened: 2003 • Mill Process: Dr • Feedstock: Corn • Production Capacity: 60 MGY • Grind: 22 MBY • Permanent Employees: 43	*Louis Dreyfus Commodities* *Norfolk* • 3002 N Victory Road • Norfolk, NE 68701 • Allen Sievertsen • ldnorfolk.com • Opened: 2007 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 53 MGY • Grind: 20 MBY • Permanent Employees: 40
Standard Ethanol-Madrid *North Platte* • 1900 E State Farm Road • North Platte, NE 69103 • Bob Lundeen • www.standard-ethanol.com • Opened: 2007 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 55 MGY • Grind: 20 MBY • Permanent Employees: 36	*Green Plains Renewable Energy* *Ord* • 48167 Val-E Road • Ord, NE 68862 • Les Glinsmann • www.gpreinc.com • Opened: 2007 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 50 MGY • Grind: 19 MBY • Permanent Employees: 35
Husker Ag, LLC *Plainview* • 54048 Hwy 30 BOX 10 • Plainview, NE 68769 • Seth Harder • Opened: 2003	*Abengoa Bioenergy* *Ravenna* • 35955 Navaho Rd PO Box 85 • Ravenna, NE 68869 • Adam Hass • Opened: 2007

• Mill Process: Dry • Feedstock: Corn • Production Capacity: 76 MGY • Grind: 27 MBY • Permanent Employees: 47	• Mill Process: Dry • Feedstock: Corn • Production Capacity: 80 MGY • Grind: 30 MBY • Permanent Employees: 62
Midwest Renewable Energy *Sutherland* • 27532 West Highway 30 *Sutherland, NE 69165* • Troy Gavin • Opened: 1999 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 25 MGY • Grind: 10 MBY • Permanent Employees: 30	*Trenton Agri Products* *Trenton* • 36638 US Hwy 34 • Trenton, NE 69044 • Ralph Scott • Opened: 2004 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 45 MGY • Grind: 17 MBY • Permanent Employees: 34
Pioneer Trail BioFuel Energy Corp *Wood River* • 7874 S. 140th Road PO Box 515 • Wood River, NE 68883 • Doug Anderson • Opened: 2008 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 115 MGY • Grind: 43 MBY • Permanent Employees: 50	*Abengoa Bioenergy* *York* • 1414 Road O • York, NE 68467 • Mitch Stuhr • www.abengoabioenergy.com • Opened: 1994 • Mill Process: Dry • Feedstock: Corn • Production Capacity: 55 MGY • Grind: 20 MBY • Permanent Employees: 55

3.10 Pavement Condition Definitions

Source: State of Nebraska, Pavement Management Systems, March 2012

International Roughness Index (IRI)
Definition: Measure of pavement roughness expressed in millimeters per meter.

Description	mm/m	in/mile
Very Smooth	0 – 0.85	0 – 53.86
Smooth	0.86 – 2.48	54.49 – 157.13
Moderately Rough	2.49 – 3.33	157.77 - 210.99
Rough	3.34 – 4.21	211.62 – 266.75
Very Rough	4.22+	267.38+

Rutting
Definition: Average depth of displacement between wheel path and adjacent asphalt pavement.

Ave. Rut Depths less than or equal to 3 mm Very Good
>3 mm and <6 mm ..... Good
≥6 mm and <8 mm ..... Fair
≥8 mm ..... Poor
9+ should be addressed by resurfacing

Nebraska Serviceability Index (NSI)
Definition: Formulae based pavement rating which incorporates the following distresses:
Asphaltic Concrete: Cracking (longitudinal, transverse, wheel path, etc), failures, potholes, raveling, weathering, bleeding, and rutting.
Portland Cement Concrete: Joint condition (repairs, spalls, sealant, fault depth, etc.) and panel condition (repairs, spalls, cracking, fault depth, etc.)

Description	Range
Very Good	90+
Good	70 - 89
Fair	50 - 69
Poor	30 - 49
Very Poor	0 – 29

Faulting
Definition: Displacement between two adjacent concrete slabs, measured at the common joint.

Description	mm
High	6+

Chapter 4: Strategies

4.1 NDOR Pavement Strategy Summary

Date: Revised 11/12/10, Updated 2013
Source: Syslo/Varilek

Flexible Pavements

Resurfacing

Mill and Asphalt Overlay or Overlay

- Mill/Fill depths determined by project specifics
    - Existing lift types and thicknesses as well as overall depth of structure
    - Core condition to include stripping, breaks, bond to PCC, etc.
    - FWD data including pavement and subgrade modulus through back calculations
    - Design Standard (Maintenance vs. 3R) and design life
    - Budget
- Includes SuperPave mixes, Crumb Rubber mixes (dense graded and gap graded), and other specialty mixes (Ultra-Thin Bonded Wearing Course, Fibermat, etc.)

Hot In Place Recycling

- Can be used alone to rejuvenate surface or in conjunction with additional mill and overlay
- Wearing surface typically applied to HIR. Typically HMA but can be armor coat on low volume roadways.
- Consists of very long train of trucks with alternating mill heads and propane burners
- Mix design by private lab, approved by M&R
- No QA/QC during field production, process controlled by method specification

Hydrated Lime Slurry Stabilization

- Used when cracking/stripping and depressed thermal cracks are present, sometimes even with moderate rutting as the lime does a good job of stiffening the binder/mix matrix
- FWD tests and cores must be taken to verify subgrades capability of supporting extremely heavy paving train, and thickness depth verification of project history
- Best candidates 5”+ inches of hot mix over SABC
- Process no closer than within 1” of SABC, leaving this to protect the SABC and leave a sealed surface to place HLSS upon
- Equipment capable of processing 3”-5”. 4” typical for NE.
- Place a minimum 2 ½” overlay
- Place overlay after 7 days cure time but overlay to within 28 days
- Generally 1.5% CSS-1 emulsion and 1.5% Lime Slurry
- Fog seal only to prevent moisture infiltration from imminent storm or to mitigate raveling
- Mix design by private lab, approved by M&R
- No QA/QC during field production, process controlled by method specification

Cold-In Place Recycling (w/emulsion)

- Used sparingly on existing asphaltic or bituminous sand pavements
- Will likely be replaced with CIR w/ Foamed Asphalt
- Recently revised to a controlled depth strategy (vs. original full depth) to eliminate incorporation of virgin granular subgrade requiring additional emulsion
- Restores old, dry, cracked bit sand or asphalt pavements
- Uses High Float Emulsion (HFE-300)
    - Cutter helps mix and rejuvenate existing material
- HFE is typically applied at 2.5 to 3%
- Designed with Marshall Stability and Retained Stability
- Mix design is done by a private lab and approved by M&R
- No QA/QC during field production, process controlled by method specification

Cold-in Place Recycling (Foamed Asphalt)

- Used to create a stable base when significant stripping, pavement distress, and/or significant patching is present. This process will likely replace CIR w/HFE.
- Minimum 2.5" overlay required.
- Uses a PG binder. During the recycling process the binder is maintained at a minimum 300ºF and water is injected causing a foaming action that expands. The expanded binder tacks the RAP together.
- The recycling train equipment includes a scalping shaker, a crusher for reducing the oversized material from the shaker, a pug mill and a strike-off screed. This is followed by a padfoot roller, motor grader, pneumatic and steel rollers. Depending on the depth of the recycle a material transfer vehicle and paver may be used and padfoot/motor grader omitted.
- Designed with Marshall Stability and Retained Stability
- Mix Design is done by a private lab and approved by M&R. Used when the existing asphalt does not provide adequate support for a mill and overlay strategy.

Fly Ash Slurry Injection

- This process intends to address bituminous thermal cracks and is done in conjunction with a mill and overlay.
- The process involves drilling injection holes near the thermal crack and Fly Ash slurry is injected through the drilled hole to fill the void beneath the thermal crack.
- Injection is limited to ½" of pavement lift.
- The minimum 7-day unconfined compressive strength of the fly ash slurry is 400 psi.
- The fly ash mix design is submitted to M&R for approval.

Fly Ash or Cement Stabilized Bituminous

- Used when extreme cracking/stripping and depressed thermal cracks are present. May also resolve rutting problems. Primarily used when the pavement is basically gone, and when hydrated lime slurry stabilization cannot be performed due to the pavements lack of ability to support a paving train operation. Also used when poor subgrade conditions exist.
- Generally process full depth including approximately 1-3" of underlying subgrade soil, the equipment is generally capable of going 16 inches in depth.
- Place no less than 1" leveling course and 2" wearing course. 4" overlay preferred.

- Place overlay after 1 day of cure time but within 28 days, generally 10% fly ash with 4% water.
- 7 day moist cured strength, 24 hours room temperature drying prior to compressive tests. Target minimum 90 psi.
- Fog seal to protect and cure until overlaid.
- Mix design by NDOR.
- No QA/QC during field production, process controlled by method specification

Full Depth Pulverization (w/water only)

- Similar to Fly Ash or Cement Stabilized Bituminous but no bonding agent present
- Significantly lower strength
- Rarely used and only on low volume roadways
- Very susceptible to moisture, must be overlaid within 7 days.
- Mix design by NDOR.
- No QA/QC during field production, process controlled by method specification

Concrete Overlay

- Placement of concrete over bituminous pavement
- Minimum 5" depth, 6-8" depth more common
- Often preceded by significant milling to minimize grade raise and shouldering
- Best candidates are thick AC pavements with available detour

Maintenance
Microsurfacing (Slurry Seal) - Corrects rutting on high traffic areas that need to be repaired quickly
Chip Seal - ¼"- ½" of oil and stone (limestone)
Armor Coat - ¼"- ½" of oil and stone (sand and gravel)
Fog Seal – Application of oil to seal surface
Crack Seal – Application of sealant to prevent water infiltration through existing cracks

<u>Rigid Pavements</u>

Resurfacing
Concrete Overlay

- Placement of concrete over existing concrete
- Thin overlays (2"-4") have had mixed results nationally and are rarely used in NE.
    - Concrete must be in relatively good shape and new joints must match existing
- Thick overlays (5"+) more common. AC bond breaker needed for pavements (existing and new) to act independently. Joints are not matched.

Asphalt Overlay

- Most common resurfacing of concrete pavement. 50yr concrete pavement design includes 4" AC overlay at yr 35.
- Typically 3"-4" overlay required
- 1" leveling course typical to prevent bumps at concrete joints

FiberMat™

- FiberMat™-is a Stress Absorbing Membrane Interlayer.
- Chopped fiber glass strands are sandwiched between two layers of binder and then overlaid with asphalt.
- The SAMI is intended to reduce reflective cracking in bituminous pavements or reflective cracks and joints in PCC pavements.

Crack and Seat (w/overlay)

- Existing concrete pavement is broken into approximate 3' panels (transverse direction) by truck mounted guillotine hammer. Small panels then seated into existing subgrade by overweight single axle cart before a 3-4" overlay is applied.
- Multiple hairline fractures reduce reflective cracking of original joints through overlay and amount of concrete repair work needed
- Traffic is maintained throughout process

Rubbilization (w/overlay)

- Concrete is reduced to a crushed concrete base by a resonant hammer
- Significant (5"+) overlay required to carry traffic
- Traffic must be detoured following rubbilization
- Best candidates are concrete pavement deteriorated past the point of rehabilitation by Crack and Seat or Overlay such as pavements with advanced ASR.

Maintenance
Diamond Grind and Joint/Crack Seal – Fine grinding of PCC to remove faulting followed by sealing.

Dowel Bar Retrofits – Placement of dowels in existing plain PCC for load transfer to eliminate future faulting. Slots are cut into pavement at transverse joints, dowel bars placed, and slots filled with epoxy. Works well in good pavements, accelerates deterioration in bad (ASR) pavements.

2011 TxDot Pavement Design Guide

Subgrades

Subgrade Preparation

- Upper 6" of subgrade prepared for paving
- Topsoil is removed and subgrade scarified, mixed, shaped and compacted at proper moisture per plans and specifications (compaction requirements).

Subgrade Stabilization

- Upper 6” of subgrade stabilized to support paving equipment
- Clay binder added to granular soils
- Mix design by M&R based on Soil Lab testing
- Clay binder added until following values achieved (approximately 12CY per Sta):
    - 15% passing #200 (subgrade + binder) AC Laydown
    - 18% passing #200 (subgrade + binder) PCC Slip forming
- Foundation course (bituminous millings or crushed concrete) pushed out ahead of paver often used as alternative to subgrade stabilization

Lime Stabilized Subgrade

- Upper 8” of subgrade stabilized for paving
- Typically used for soils with PI’s over 20
- Used to significantly reduce PI and frost heave potential and to increase strength
- Expect approximate10 fold increase in strength, typically around 300 psi
- Hydrated or pebble quick lime used
- Mix design by M&R based on Chemistry and Soil Lab testing
- Lime typically applied at 4 to 6% as determined by Eades and Grim test
- Moisture (soil + lime) determined by mix design, typically 3-4% over optimum (soil)
- No Field QA/QC. Modified soil can be tested to investigate lime application rate.

Fly Ash Stabilized Subgrade

- Upper 8” of subgrade stabilized for paving
- Use Class “C” ash
- Applied at a rate of 10 to 15%, typically 1% under optimum moisture
- Used on soils with PI’s under 20, but not granular
- Used to increase strength and/or dry saturated soils with slight PI reduction
- Lab testing requires 7 day moist cured strength and 24 hours room temperature drying prior to compressive tests. Target 100-350 psi depending on soil and fly ash
- Mix design by M&R based on Soils and Chemistry Lab testing
- No Field QA/QC. Modified soil difficult to test for application rate or coring for compressive strength.

Cement Kiln Dust (CKD) Stabilized Subgrade

- Upper 8” of subgrade stabilized for paving
- Applied at a rate of 6 to 9%, 2 to 3% over optimum moisture
- Used on all types of soils, including granular (though often not necessary)
- Used to reduce PI and increase strength
- Availability of CKD often limited
- Lab tests require 7 day moist cured strength and 24 hours room temperature drying prior to compressive tests. Similar effects on high PI soils as lime and low PI soils as fly ash, works well in granular
- Mix design by M&R based on Soils and Chemistry Lab testing
- No Field QA/QC. Modified soil difficult to test for application rate or coring for compressive strength.

4.2 Evolving Rehabilitation Strategies for Asphalt Pavement

Date: 7/23/08
Source: Jensen, Rea, Syslo

Evolving Rehabilitation Strategies for Asphalt Pavement

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Strategies for rehabilitation of flexible pavements have traditionally included mill and overlay or reconstruction. Three new strategies for flexible pavement rehabilitation currently being utilized by the Nebraska Department of Roads include partial depth in-place recycling, full depth in-place recycling and full-depth reclamation. Cost differences between the new and the traditional strategies were evaluated and conditions under which the new strategies are appropriate for use are discussed in this paper. A comparison based upon cost of rehabilitating a section of pavement using the two conventional and three new strategies found that the three recycling strategies provide flexible pavement which costs more than mill and overlay but less than complete reconstruction.

Keywords: Pavement rehabilitation, recycling, reclamation.

1. Introduction

When flexible pavement has deteriorated to the point where rehabilitation or reconstruction is necessary, pavement engineers have traditionally used either the mill and overlay strategy or complete reconstruction. Today numerous other alternatives are available, each of which is characterized by a different level of cost and performance.

Newer evolving strategies include several variations of partial or full depth milling and full depth stabilization/reclamation. This paper explores the Nebraska Department of Roads (NDOR) experiences with several alternatives to mill and overlay or complete reconstruction and analyzes these alternatives with regards to initial cost.

State transportation agencies are being required to maintain a larger inventory of pavement with little or no increase in budget, causing engineers to seek solutions that deliver a sustained level of performance coupled with cost-effectiveness. The procedures discussed in this paper provide effective alternatives to the constraints imposed by many of the more traditional strategies.

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2. Conventional Approaches

The conventional, least expensive approach to correcting flexible pavement distress has been mill and overlay. This process typically involves milling 25-100 mm from the existing pavement to remove surface distress (i.e. rutting, cracking, raveling, etc.). A tack coat is applied to the milled surface and a layer (or two) of new asphalt is added as a leveling/wearing course. Nebraska has many sections of highway where the mill and overlay strategy has been employed for forty or more years, resulting in flexible pavements with a total thickness of 300 mm or more. Items and costs associated with the mill and overlay strategy are shown in Table 1. Cost is estimated using the average unit prices for the August 2005 bid lettings.

Table 1. Cost/km of mill and overlay.

Item	Unit	Price ($/Unit)	Quantity	Total Cost
Asphaltic Concrete, Type SP4	Mg	25.50	1,300	$33,150.00
Performance Graded Binder (64-28)	Mg	290.00	70.2	$20,358.00
Tack Coat	L	0.35	3350	$1,172.50
Hydrated Lime for Asphalt Mixtures	Mg	308.70	13	$4,013.10
Milling	Sta M	400.00	10	$4,000.00
			Cost for 1 Km =	$62,693.60

The mill and overlay strategy is very cost effective, which has been the primary reason for its widespread and long-term use. The costs shown in Table 1 reflect the cost of placing a 75 mm layer of 7.3 m wide asphalt over a distance of one kilometer. The principal reason for not using the mill and overlay strategy to solve flexible pavement problems under all conditions is that surface distresses often reflect stability problems originating in lower pavement layers or in the subgrade. Under these conditions, distresses in the lower layers will soon propagate upward through a new overlay to the surface. Milled and overlaid asphalt pavements with problems in the subgrade or lower pavement will generally remain in good condition for two to five years before significant deterioration in performance can be measured at the surface.

The second conventional approach, commonly used where long-term performance is more important than cost, is total reconstruction of the asphalt pavement. When using this strategy, existing pavement is removed by milling, subgrade layers are prepared to a depth of approximately 150 mm, asphalt millings are placed and stabilized as a base material and a new asphalt layer is compacted on top. Items and costs associated with the reconstruction strategy are shown in Table 2. Cost is estimated using the average unit prices for the August 2005 bid lettings.

Table 2. Cost/km of reconstruction.

Reconstruction

Item	Unit	Price ($/Unit)	Quantity	Total Cost
Asphaltic Concrete, Type SP4	Mg	25.50	2,440	$62,220.00
Performance Graded Binder	Mg	290.00	131.76	$38,210.40
Tack Coat	L	0.35	1,680	$588.00
Hydrated Lime for Asphalt Mixtures	Mg	308.70	24.4	$7,532.28
Water	Kl	2.60	102	$265.20
Bituminous Foundation Course	m^2	1.95	7,300	$14,235.00
Milling of Existing Asphalt	m^2	2.25	7,300	$16,425.00
Subgrade Preparation	m^2	1.20	7,300	$8,760.00

Cost for 1 Km = $148,235.88

The principal advantage of reconstruction is that all distresses in the lower layers of the existing pavement are removed during the reconstruction process. Reconstruction results in pavement that, if properly designed, will provide high quality performance for ten or more years before significant distress becomes apparent. Table 2 itemizes the cost of placing a 137 mm layer of 7.3 m wide asphalt over 100 mm of asphalt millings base and 150 mm of prepared subgrade for a distance of one kilometer.

As can be seen from Table 2, removal of problems in the lower layers of pavement and/or subgrade is not inexpensive. The cost of complete reconstruction per kilometer is more than twice the cost of mill and overlay. However, pavement life expected from reconstruction more than doubles that expected from mill and overlay, resulting in lower annual cost. Pavement engineers at the Nebraska Department of Roads have been engaged for several years in developing repair and rehabilitation strategies that can provide longer pavement life than the mill and overlay strategy without incurring the cost associated with complete reconstruction.

3. Evolving Strategies

Three evolving strategies currently being utilized on highways in Nebraska include partial depth milling with in-place recycling, full-depth milling with in-place recycling and full depth reclamation. Which strategy is more appropriate for a specific pavement depends upon a number of factors, including the condition and thickness of the existing pavement and the stability of the subgrade.

The first strategy currently being utilized by the NDOR is partial depth milling with in-place recycling of the flexible pavement. This option can be used only for highways with subgrades and/or lower asphalt layers that possess sufficient bearing capacity to resist the stress imposed by the recycling train as it passes overhead. A recycling train commonly consists of a milling unit, a screening unit and a pug mill. The recycling train mills existing asphalt and leaves behind a windrow of material that is subsequently picked up and placed by a paving machine. Pneumatic and steel wheel rollers follow the paving machine. Detailed descriptions of this pavement recycling process are available from a number of sources (Epps 1990; Wood et al. 1988).

Unstable subgrades pose a major problem for partial depth milling operations, as the recycling train is supported only by the flexible pavement remaining (after an upper layer has been milled off) and the subgrade. Subgrade stability problems caused a cold in-place recycling project to be abandoned at Pleasant Creek State Park in Iowa in 1997 (Jahren et al., 1999). The method used to define the minimum soil bearing capacity necessary to support a recycling train becomes very important. Cross and Ramaya (1995) used a dynamic cone penetrometer to determine the bearing capacity of subgrade soils for cold in-place recycling (CIR) in Kansas. Jahren et al. (1999) recommend a modified procedure using the same instrumentation based upon studies of Iowa soils.

The Nebraska Department of Roads uses a falling-weight deflectometer (FWD) to measure subgrade capacity and thus assess whether or not a subgrade can support a recycling train. FWD testing is conducted using a towed Kuab 2m-FWD. Data is recorded electronically and processed using the software provided with the instrument. Differences (in deflection) of 600 μm or less between the D_o and D_2 sensor have been found to indicate that the soil has sufficient capacity to support a paving train.

A diagram showing the pavement structure before and after partial depth, in-place recycling of flexible pavement is shown in Figure 1. Depending upon the vertical grade alignment, placing new leveling and wearing courses can increase overall pavement depth by 62-100 mm or more if no material is removed.

Existing **Rehabilitated**

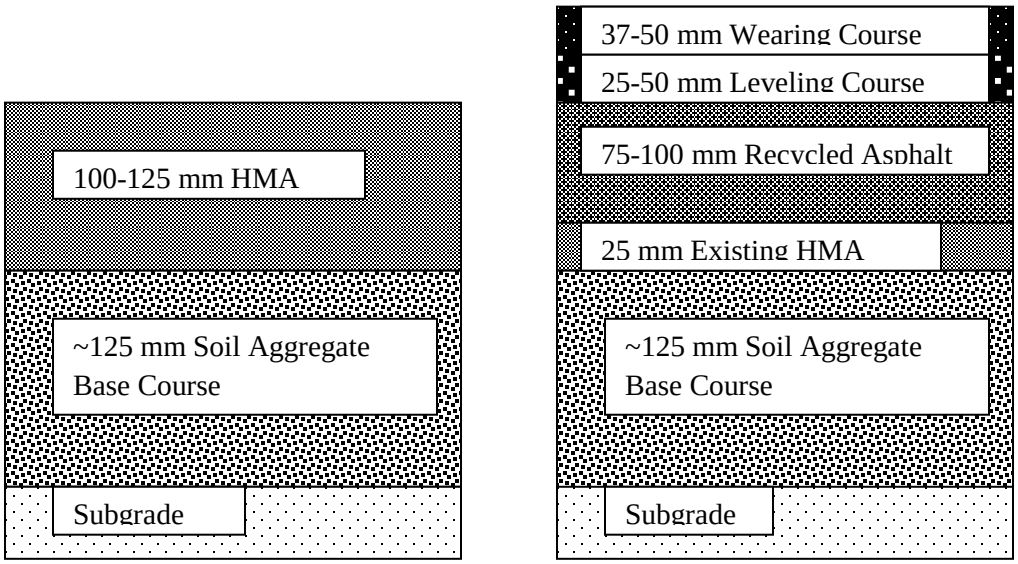


Figure 1. Typical partial depth in-place recycling pavement section.

Partial depth milling with in-place recycling can be completed with minimum delays since most of the material required is already located on site. Asphalt is milled and windrowed by a milling unit, picked up from the roadway surface by a screening unit, screened, crushed if necessary, mixed with lime and/or emulsion, and deposited back on the milled asphalt surface. A paving machine then distributes the millings for subsequent compaction by a roller. The milled asphalt is often compacted to form a new surface less than an hour after first being disturbed. A section of roadway being rehabilitated during the day can often be re-opened to traffic that evening. Traffic moves across the recycled asphalt until a wearing/surface course is added seven to twenty-eight days later.

A second strategy currently used by the NDOR is full depth, in-place recycling. Full depth recycling is used primarily where the lower layers of pavement have significant distresses and/or the pavement and subgrade below have insufficient strength to support the recycling train. These conditions are defined by differences of more than 600 μm between the D_o and D_2 sensors on the FWD.

Reclaimers/soil stabilizers are specialized machines specifically designed for deep (150-300 mm) mixing of soil and/or aggregate. Most have the ability to incorporate solid or liquid binding agents during the mixing process. Reclaimers can be utilized to mechanically stabilize deteriorated asphalt pavement by pulverizing and mixing pavement with an asphalt emulsion or sometimes with a thin layer of soil and binder. Reclaimers are normally equipped with floatation tires or tracks to decrease surface pressure.

When working on full depth in-place recycling projects, Nebraska contractors are required to pulverize and mix all but a thin (~25 mm) layer of asphalt at the base of the pavement structure. This thin layer of asphalt is left in place as a working platform to protect the subgrade during construction. The upper surface of the recycled asphalt is normally bladed with a motor grader or other equipment capable of slope control before being compacted by pneumatic and then by steel wheel rollers. A diagram showing the pavement structure before and after full depth, in-place recycling is shown in Figure 2.

As with partial depth in-place recycling, placing new leveling and wearing courses can increase overall pavement depth by 62-100 mm or more if no material is removed.

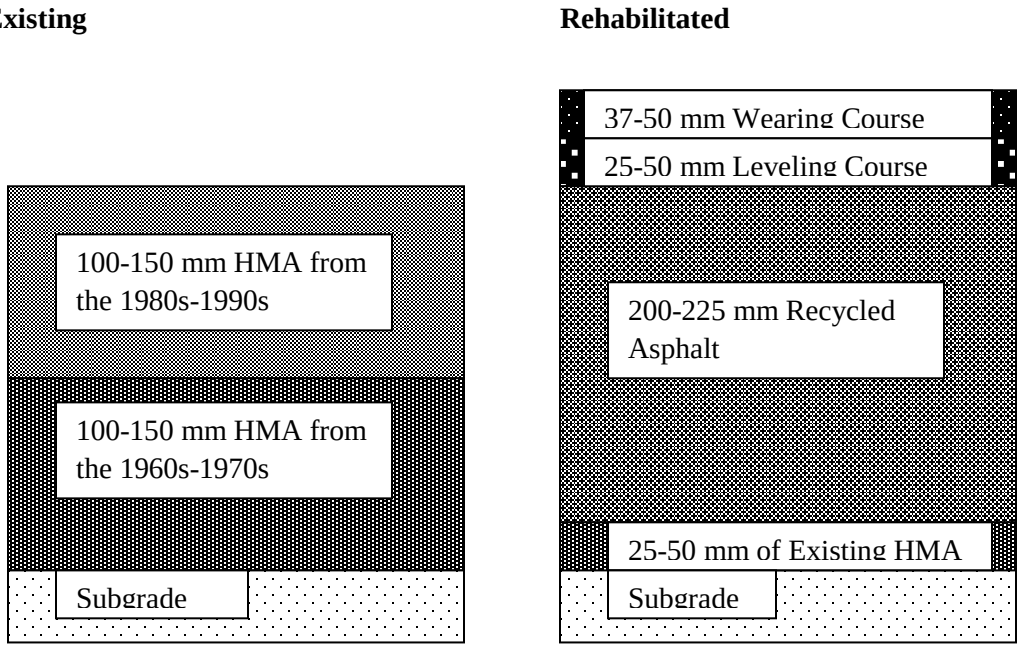


Figure 2. Typical full depth in-place recycling pavement section.

One alternative used with full depth, in-place recycling is partial depth milling (usually to a depth of 100-150 mm) followed by full depth recycling. During this process, asphalt is milled and then windrowed onto the milled surface where it is spread by a blade. Additives may be sprayed onto the milled material or added later during the pulverization/mixing process. Milled material is pulverized and mixed with the asphalt beneath using a reclaimer. Compaction is completed in a manner identical to that used for full depth, in-place recycling.

An exception to the use of full or partial depth recycling is recommended in situations where thermal cracking penetrates through the full depth of the flexible pavement layers. In this situation, subgrade material has often been weakened or even locally removed by water traveling downward through the crack. The subgrade as a platform, however, may still exhibit sufficient strength (when tested by falling weight deflectometer) to support a recycling train, so partial depth or full depth in-place recycling is often contemplated. Use of partial depth or even full depth recycling does not eliminate the zone of weakness in the vicinity of where the thermal crack exits the pavement base, which results in a reflection crack that will propagate upward to the pavement surface through the new asphalt. When full depth thermal cracking is the problem, full depth reclamation offers the only permanent solution short of pavement reconstruction.

The final strategy now being utilized is full depth reclamation. This process is used only when the subgrade and/or lower pavement offers significantly less than adequate capacity to support a recycling train or when the existing asphalt

pavement has deteriorated to the point that recycling is no longer feasible. When using full depth reclamation, the objective is to thoroughly pulverize and mix all existing asphalt layers and to incorporate 25-150 mm of the underlying subgrade into this mix. Fly ash is commonly incorporated by spreading it on top of the pavement ahead of a reclaimer. Mixing cohesive soil and 8-12% fly ash with the pulverized asphalt provides a mixture that, when compacted into a subgrade and covered by pavement, will be of sufficient strength to support heavy traffic loads. A diagram showing the pavement structure before and after full depth reclamation is shown in Figure 3.

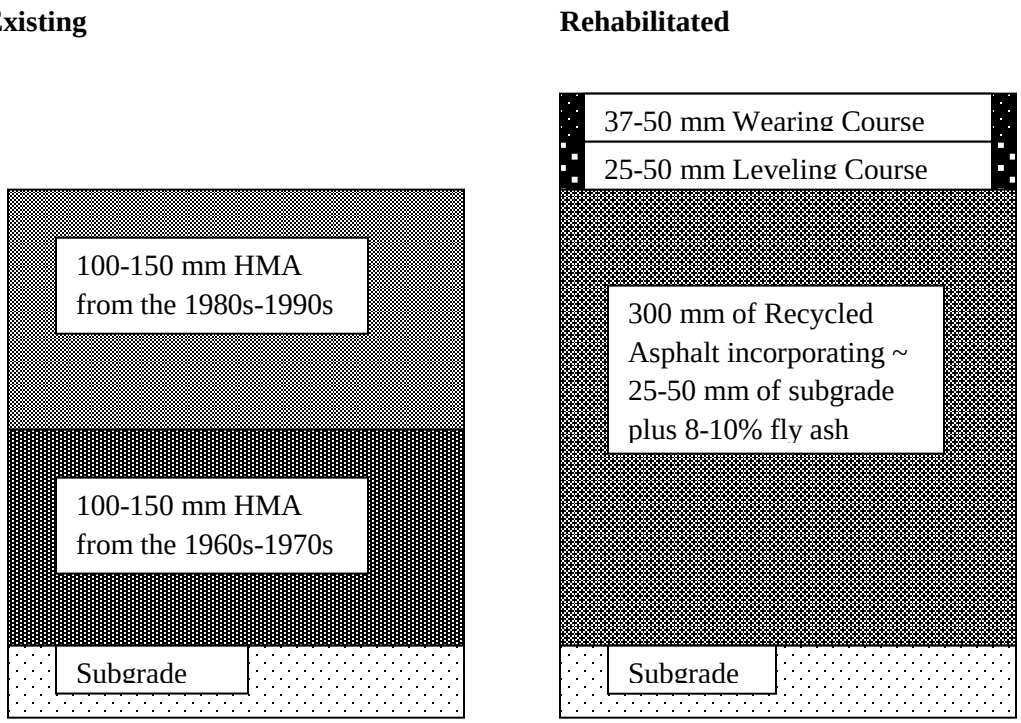


Figure 3. Typical full depth reclamation pavement section.

As with the recycling strategies described earlier, placing new leveling and wearing courses can increase overall pavement depth by 62-100 mm or more if no material is removed. Increase in pavement depth results from the 'fluff' that occurs whenever existing pavement is milled and/or pulverized and a stabilizing agent is added. The NDOR has noted that, for asphalt pavements in Nebraska, fluff typically averages about 20%. If the fluff is needed within the new pavement structure and an increase in finished pavement elevation is acceptable, fluff is simply incorporated into the finished pavement.

If fluff is not needed within the pavement structure or if an increase in grade is not acceptable, the NDOR specifies that fluff be used to widen the pavement section. There are currently two approved methods for widening pavement sections. The first method is used with partial depth strategies and involves milling a 600 mm wide by 150 mm deep trench adjacent to the outside edge of existing pavement. The NDOR specifies the trench must be milled with its outside edge vertically aligned to insure a uniform depth of asphalt at that location. The entire width of existing asphalt is milled to the appropriate depth, processed and replaced using an asphalt distributor set to a 4.27 m width for each lane (NDOR CIR Paver Layered 2006). The second method involves using a grader, with its moldboard canted to 600 mm effective width,

to create a trench adjacent to the existing pavement (NDOR CIR Blade Layered 2006). This method is used primarily for full-depth reclamation due to the depth of material being processed and the fact that full depth reclamation is often completed without the use of milling equipment.

The NDOR requires contractors to meet strict specifications regarding time and sealing constraints for asphalt pavements processed using different recycling methods. Time and sealing constraints for various processes are outlined in Table 3. One final consideration is weather. The NDOR's specifications require that the air temperature remain at or above 15° C while pavement is being recycled and that work is halted when precipitation occurs.

Table 3. Time and sealing constraints for various pavement recycling strategies.

STRATEGY	OVERLAY WITHIN	COMMENTS
Partial Depth, Using Lime and Emulsion	Twenty-eight calendar days	Contractor must wait seven days for lime to cure before overlaying. Sealing can be completed within these seven days.
Full Depth In-Place, Using Emulsion	Twenty-eight calendar days	Aeration is required after initial processing to obtain uniform moisture content.
Full Depth Reclamation, Using Fly-Ash	Twenty-eight calendar days	Sealing is required for curing of the fly-ash and reducing surface raveling.
Full Depth Reclamation, Using water and aggregate	Seven calendar days	Use on low volume roadways only. Process is susceptible to moisture damage since no stabilizing agent is used; sealing is critical.

Information in Table 3 was obtained from various sources including:

NDOR Specifications for "Cold in-place recycling-Internal liquidated damages" 2006.

NDOR Specifications for "Fly ash stabilized bituminous" 2006.

NDOR Specifications for "Fly ash stabilized bituminous-Internal liquidated damages" 2006.

NDOR Specifications for "Full depth pulverization" 2006.

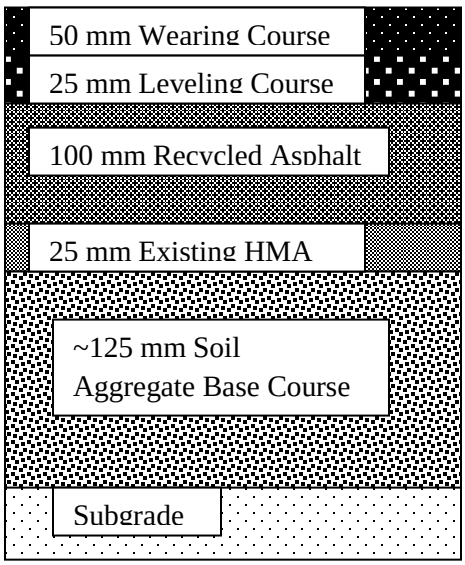
NDOR Specifications for "Full depth pulverization-Internal liquidated damages" 2006.

NDOR Specifications for “Hydrated lime slurry stabilization” 2006.

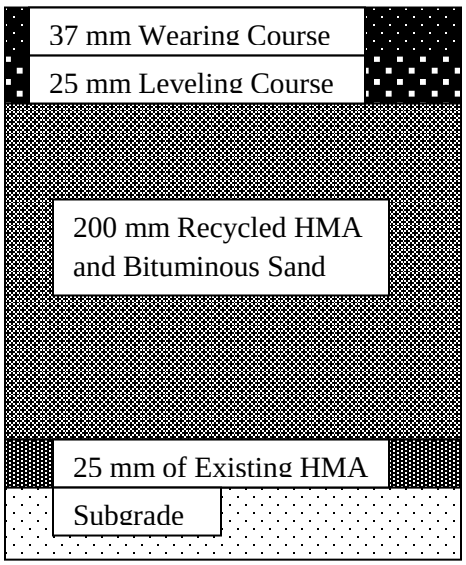
NDOR Specifications for “Hydrated lime slurry stabilization-Internal liquidated damages” 2006.

4. Analysis and Results

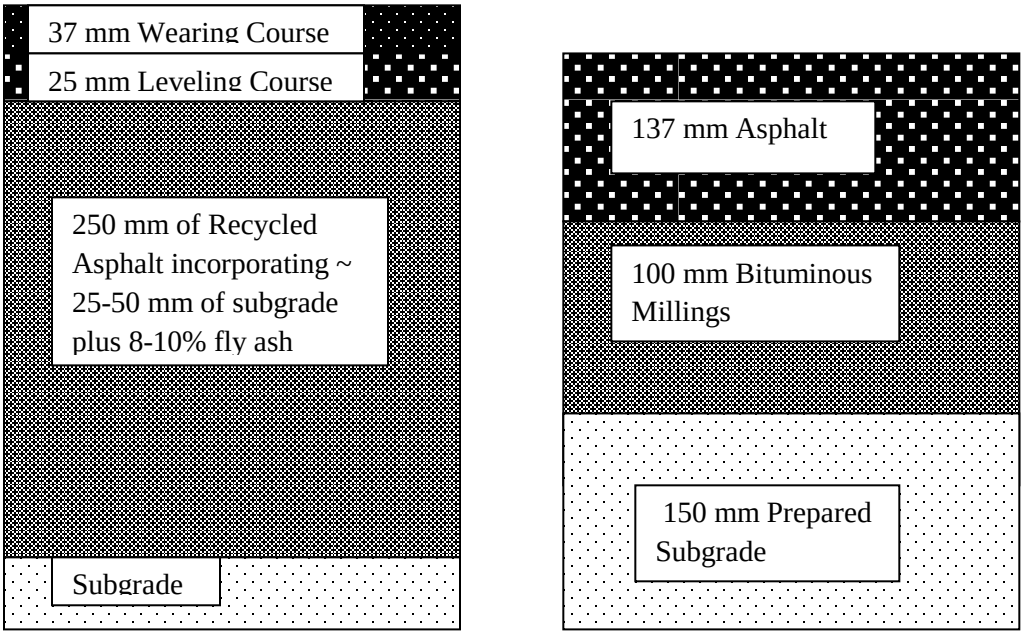
Costs per kilometer for the mill and overlay and reconstruction strategies were shown in Tables 1 and 2. When attempting to compare the cost of conventional flexible pavement with evolving rehabilitation strategies, pavement sections with equivalent traffic capacity and expected lifespan must be analyzed for the comparison to be valid. Figure 4 shows four pavement sections designed by Robert Rea, a co-author of this paper, which are typical of the rehabilitation strategies outlined herein. Each was designed for a different project, using a specific rehabilitation strategy based upon condition and thickness of existing pavement and subgrade conditions at the site. A partial depth in-place recycling pavement section was designed for Friend to Milford (NDOR CN 12581, 2002), the full depth in-place recycling section was designed for Niobrara River N-S (NDOR CN 80648, 2003), and the full depth reclamation section was designed for Brule to Ogalalla (NDOR CN 60893, 2005). The reconstructed pavement section, with its costs shown in Figure 2, was designed by Robert Rea for Ogalalla-West (NDOR CN 60750, 1999). All pavement sections were designed for similar traffic loading conditions (using an almost identical structural number) and identical expected life span (ten years), so long-term performance of these pavement sections should be very similar.



Partial Depth In-Place Recycling



Full Depth In-Place Recycling



Full Depth Reclamation **Reconstruction**

Figure 4. Equivalent sections of pavement using different rehabilitation strategies.

The pavement sections shown in Figure 4 were then transferred to the NDOR Pavement Design section, where the items and quantities of construction materials for a 7.3 m wide by one kilometer section of each pavement were calculated. Items and quantities were subsequently delivered to the Estimating Unit of the NDOR Construction Division, where each was priced out using the average unit prices for the August 2005 bid lettings. This process ensured identical costs were compiled for identical items of work on each of the five different projects. This process enabled a more accurate comparison of the relative cost for each alternative than if the actual costs from each contract had been compared. The cost for an identical section of pavement using each rehabilitation strategy in August 2005 dollars per kilometer is shown in Table 4.

Table 4. Cost/km for three evolving rehabilitation strategies.

Partial Depth In-Place Recycling

Item	Unit	Price ($/Unit)	Quantity	Total Cost
Asphaltic Concrete, Type SP4	Mg	25.50	1,300	$33,150.00
Performance Graded Binder (64-28)	Mg	290.00	70.2	$20,358.00
Tack Coat	L	0.35	3350	$1,172.50
Hydrated Lime for Asphalt Mixtures	Mg	308.70	13	$4,013.10
Hydrated Lime for Slurry Stabilization	StaM	1,476.00	10	$14,760.00
Hydrated Lime	Mg	121.30	25	$3,032.50

Emulsified Asphalt	L	0.30	42,730	$12,819.00
		Cost for 1 Km =		$89,305.10

Full Depth In-Place Recycling

Item	Unit	Price ($Unit)	Quantity	Total Cost
Asphaltic Concrete, Type SP4	Mg	25.50	1,070	$27,285.00
Performance Graded Binder (64-28)	Mg	290.00	57.78	$16,756.20
Tack Coat	L	0.35	3350	$1,172.50
Hydrated Lime for Asphalt Mixtures	Mg	308.70	11	$3,395.70
Cold In-Place (CIP) Recycling	StaM	820.00	10	$8,200.00
Repulverizaton and Aeration	StaM	525.00	10	$5,250.00
Emulsified Asphalt for CIP	L	0.25	117950	$29,487.50
Water for CIP Recycling	Kl	2.25	70	$157.50
		Cost for 1 Km =		$91,704.40

Full Depth Reclamation

Item	Unit	Price ($/Unit)	Quantity	Total Cost
Asphaltic Concrete, Type SP4	Mg	25.50	1,070	$27,285.00
Performance Graded Binder (64-28)	Mg	290.00	57.78	$16,756.20
Tack Coat	L	0.35	3,350	$1,172.50
Hydrated Lime for Asphalt Mixtures	Mg	308.70	11	$3,395.70
Fly Ash Stabilized Bituminous	Sta M	2790.00	10	$27,900.00
Fly Ash	Mg	35.80	420	$15,036.00
Water for Fly Ash Stabilized Bit	Kl	2.25	230	$517.50
Fog Seal	L	0.32	8,030	$2,569.60
		Cost for 1 Km =		$94,632.50

Recycling material to greater depths is obviously more expensive. From the information shown in Table 4, partial depth in-place recycling is slightly more economical ($2400/km) than full depth in-place recycling. If the lifespan of full depth in-place recycled pavement exceeds that of partial depth in-place recycled pavements by even a small margin, the latter strategy will prove to be more economically advantageous. Full depth in-place recycling is correspondingly less expensive per kilometer than full depth reclamation. All pavement recycling alternatives fall between mill and overlay and complete reconstruction in terms of cost. With the full range of rehabilitation options considered, mill and overlay remains the most economical while complete reconstruction remains the most expensive strategy.

5. Conclusions

Mill and overlay is the least expensive solution ($62,693/Km), but its cost advantage is offset by its relatively short lifespan. A shortened lifespan is much more probable if pavement distresses originate in the lower levels of the pavement or in the subgrade. Partial depth in-place recycling is the next most economical solution ($89,305/Km), but it has the limitation that the subgrade and/or lower pavement layers must retain sufficient strength to support the recycling train during construction.

Full depth in-place recycling ($91,704/Km) and full depth reclamation ($94,632/Km) provide pavements that are essentially equivalent to that provided by complete reconstruction. Either option could be used in lieu of complete reconstruction ($148,236/Km), resulting in significant savings.

Long term performance of recycled asphalt pavement on medium volume roads is anticipated to be satisfactory or better. McKeen et al. (1998) report that New Mexico has completed over 120 cold, in-place recycling (CIR) projects since 1984 and condition surveys indicate that most have or will exceed their ten year design life. Sebaaly et al. (2004) report that Nevada utilized CIR for three flexible pavement projects on US-50 and US-95. All are currently performing in a satisfactory manner. Morian et al. (2004) collected data from forty-four pavement sections in Northwestern Pennsylvania rehabilitated using CIR between 1983 and 1995 and discovered that many had documented service lives up to 160% of the ten year design life typically provided by the conventional mill and overlay strategy. All recycled pavement in Nebraska appears to be performing in a satisfactory manner, showing little distress beyond what was anticipated.

The NDOR has used one of the three rehabilitation strategies on more than sixty paving projects during the past five years. These pavements are currently being monitored to document actual performance and maintenance costs throughout their lifespan. Within a few years, sufficient data will have been collected so that a life cycle cost analysis can be completed for each pavement section. Comparison of life cycle costs among the different recycling alternatives and conventional strategies will be the subject of a future paper.

An additional advantage is that the two recycling strategies and one reclamation strategy significantly reduce the quantity of materials that must be transported to (or from) the construction site. Less material transportation allows the construction process to be completed in less time, decreasing the period of time that traffic must be diverted, thereby saving pavement wear on detour routes. The three rehabilitation strategies offer alternatives that are less expensive than reconstruction but provide pavement performance that is expected to be significantly greater than mill and overlay. Since rehabilitation strategies have an impact on both cost of individual roads and the quality of the overall road network, use of these strategies is expected to increase in the future.

6. Acknowledgements

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Chapter 5: Subgrade

5.1 Calculating Nebraska Group Index (NGI)

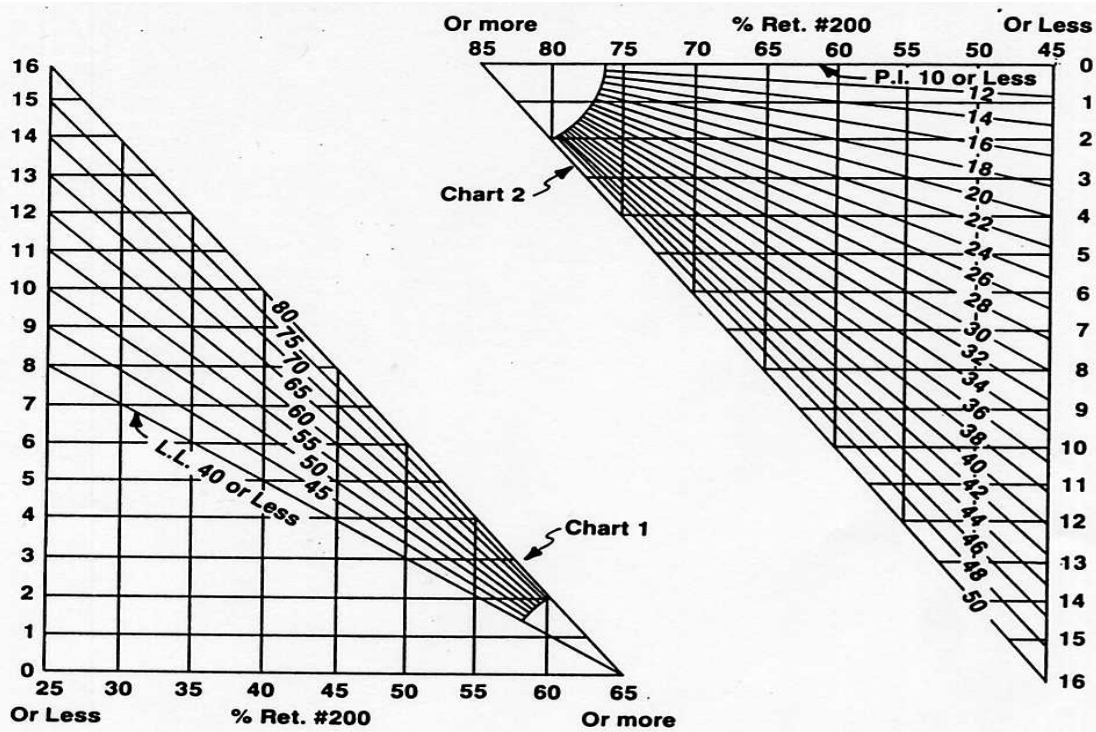
Date: 11/17/10
Source: Geotechnical Design Manual

Use Charts 1 and 2 when less than 65% retained on the 200 sieve

Required Data:

- % Retained on #200 Sieve
- Liquid Limit (LL)
- Plastic Index (PI)

Sum the values from the vertical axes of charts 1 and 2 to obtain the NGI.



Use Chart 3 when greater than 65% retained on the 200 sieve wire

	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.

Chart 3. Granular Soils have a NGI of zero or less

5.2 Resilient Modulus of Soils Based on NGI

Date: 1989

Source: ***Resilient Modulus Testing of 14 Nebraska Soils*, R. Sneddon, 1988 and *Dynamic Testing of Nebraska Soils and Aggregates*, G. Woolstrum, 1989**

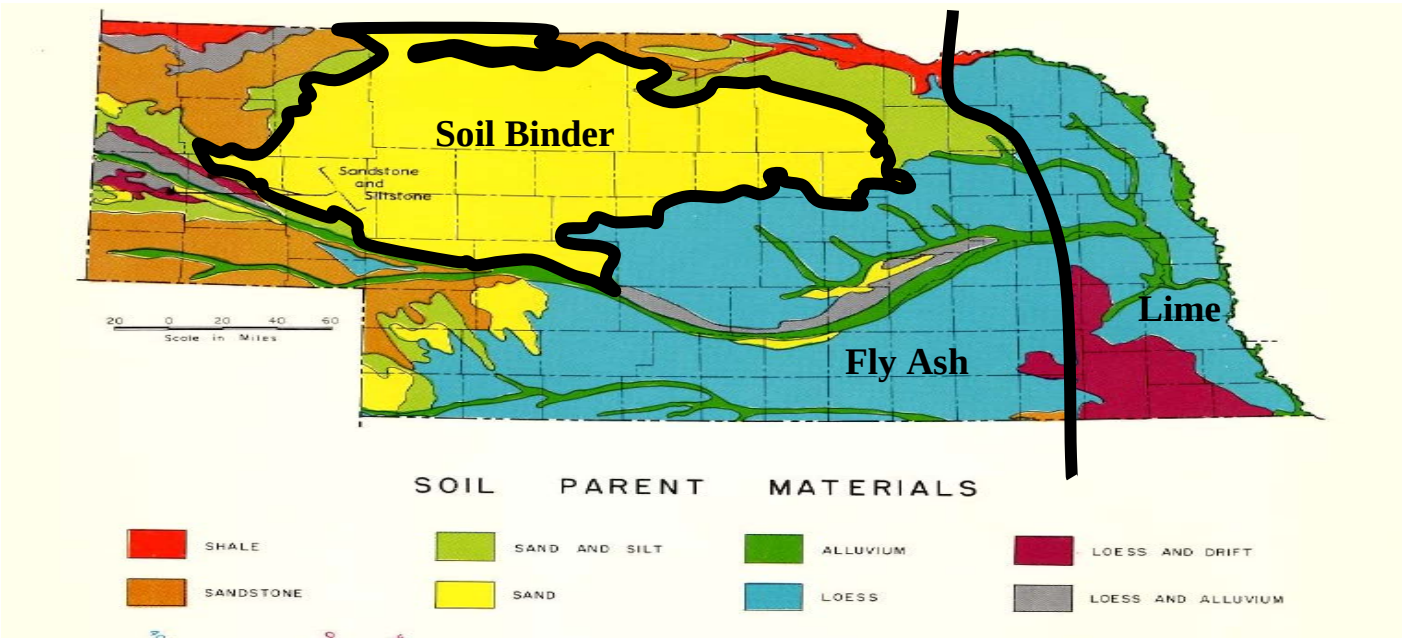
Soil Type	NGI
Gravel	-2
Fine sand	-1 to 1
Sandy silt	2 to 7
Loess	8 to 12
Loess/till	13 to 14
Till	15 to 21
Shale/alluvium	22 to 24

Tables of Nebraska Group indices, NGI

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

5.3 Subgrade Stabilization Agent Selection

Date: Revised 11/12/10
Source: Syslo



Above map shows general, statewide stabilizing agent use for reference only.
Project specific agent selection and required percentage is detailed below.

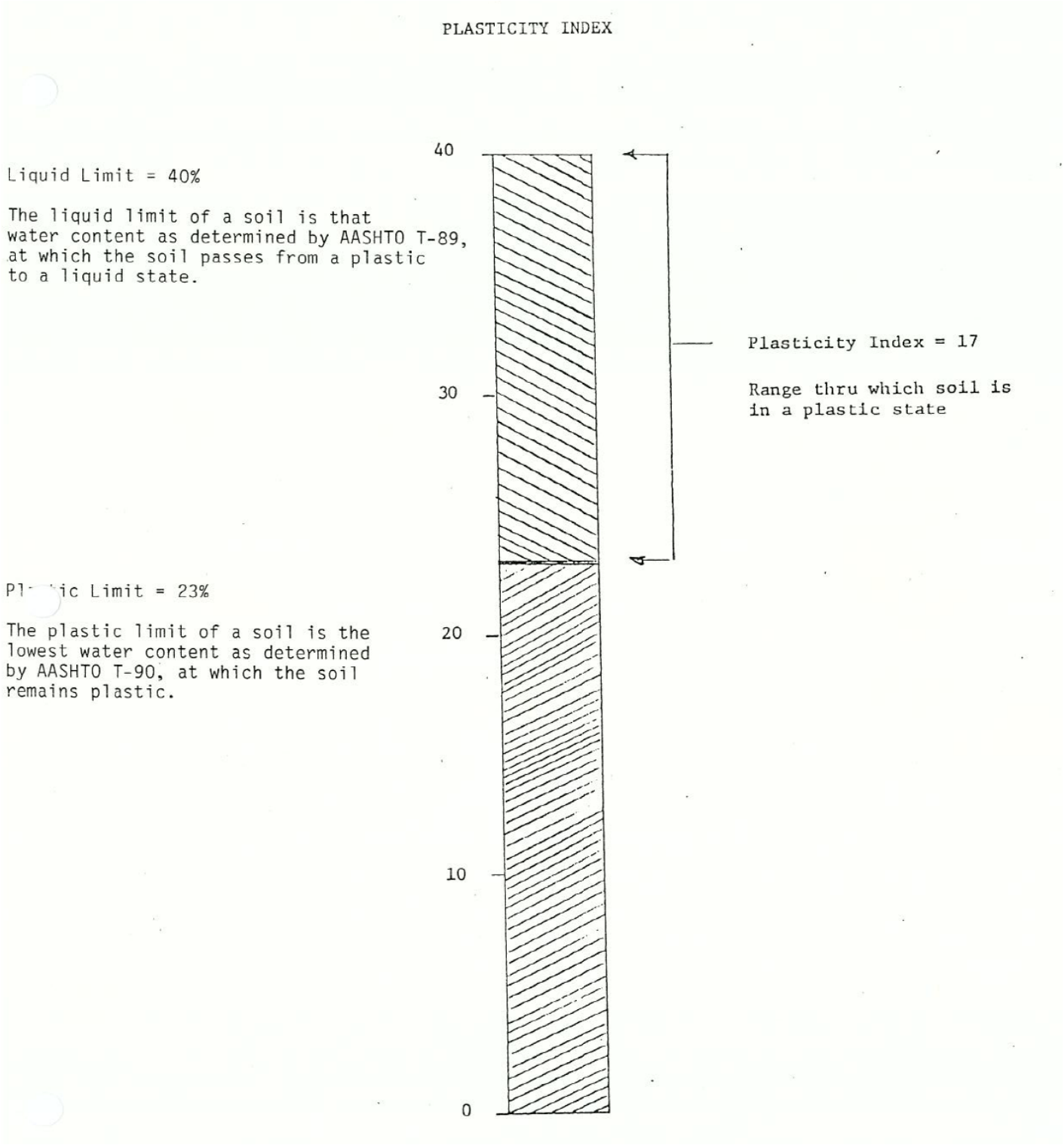
- Agent Selection
  - PI < 16 use Fly Ash (or CKD if available)
  - PI 16-20 use Fly Ash* or Lime (or CKD if available)
  - PI > 20 use Lime (or CKD if available)
    - *Fly Ash more economical then Lime in NE.
    - Use Fly Ash for small or time sensitive projects (no cure period)
    - Use Fly Ash (10%) under temporary pavement when required (no mix design required)

- Exact percentage of stabilizing agent determined through lab testing and M&R mix design. Typical percentages are:

  Fly Ash: 10-15%
  Lime: 3-6%
  CKD: 6-9%

5.4 Plasticity Index Description

Date: ?
Source: Geotechnical Section



5.5 NDOR Soil Identification and Description

Date: 2002
Source: Geotechnical Section

Modified Unified Description of soil sample (Soil and Foundation Workshop Manual NHI # 13212, July 1993) System shall be used by the geotechnical section in order to provide uniformity in the description and classification of soil in the field.
Soil description classification and other information obtained during the subsurface exploration are greatly relied upon throughout the remainder of the investigation program and during the design and construction phase of a project. It is therefore necessary that the method of reporting this data be standardized. Records of subsurface explorations should follow as closely as possible the standardized format presented here.
A detailed description for each material stratum encountered should be included on the log. The description should be sufficiently detailed to provide the engineer with an understanding of the material present at the site.

Two terms that are used in the site exploration process are **IDENTIFY and DESCRIBE.** Identification is the process of determining which components exist in a particular soil sample, i.e., gravel, sand, silt, clay, etc. Description is the process of estimating the relative percentage of each component and preparing a word picture of the sample. Identification and description are accomplished primarily with vision and touch.

During the progression of a boring, the drilling personnel should roughly identify and describe the soils encountered.

A typical soil description procedure, known as the Modified Unified Description is shown on the following pages. This procedure involves visually and manually examining soil samples with respect to texture, plasticity and color. This method presented for preparing a word picture of a sample for entering on a subsurface exploration log applies to soil descriptions made in the field and laboratory.

DEFINITION OF TERMS FOR GENERAL SOILS

Boulder	A rock fragment, usually rounded by weathering or abrasion, with average dimension of 12 inches or more.
Cobble	A rock fragment usually rounded or sub rounded, with an average dimension between 3 to 12 inches.
Gravel	Rounded, sub rounded, or angular particles of rock that will pass a 3-inch square opening sieve and be retained on a Number 4 sieve.
Sand	Particles that will pass the Number 4 sieve and be retained on the Number 200 sieve.
Silt	Material passing the Number 200 sieve that is nonplastic and exhibits little or no strength when dried.
Clay	Material passing the 200 sieve that can be made to exhibit plasticity (putty like property) within a wide range of water contents and exhibits considerable dry strength.

Fines The portion of a soil passing a Number 200 sieve.

Muck Finely divided organic material containing various amounts of mineral soil.

Peat Organic material in various stages of decomposition.

Organic Clay Clay containing microscopic size organic matter. May contain shells and/or fibers.

Organic Silt Silt containing microscopic size organic matter. May contain shells and/or fibers.

Coarse – Grained Soil Soil having a predominance of gravel and/or sand.

Fine – Grained Soil Soil having a predominance of silt and/or clay.

Mixed – Grained Soil Soil having significant proportions of both fine – grained and coarse – grained sizes.

VISUAL – MANUAL IDENTIFICATION

Gravel Identify by particle size. The particles may have an angular, rounded, or subrounded shape.

Sand Identified by particle size. Gritty grains that can easily be seen and felt. No plasticity or cohesion. Size ranges between gravel and silt.

Silt Identified by behavior. Fines that have no plasticity. May be rolled into a thread but will easily crumble. Has no cohesion. When dry, can be easily broken by hand into powdery form.

Clay Identified by behavior. Fines that are plastic and cohesive when in a moist or wet state. Can be rolled into a thin thread that will not crumble. When dry, forms hard lumps that cannot be readily broken by hand

Muck Black or dark brown finely divided organic material mixed with various portions of sand, silt, and clay. May contain minor amounts of fibrous material such as roots, leaves, and sedges.

Peat Black or dark brown plant remains. The visible plant remains range from coarse fibers to finely divided organic material.

Organic Clay Dark gray clay with microscopic size organic material dispersed throughout. May contain shells and/or fibers. Has weak structure, which exhibits little resistance to kneading.

Organic Silt Dark gray silt with microscopic size organic material dispersed throughout. May contain shells and/or fibers. Has weak structure, which exhibits little resistance to kneading.

Fill Man-made deposits of natural soils and/or waste materials.

SOIL SAMPLE IDENTIFICATION PROCEDURE

a) Is sample coarse-grained, fine-grained, mixed-grained or organic?

If mixed-grained, decide whether coarse-grained or fine-grained predominates.

b) What is the principal component?

Use a noun in the soil description. i.e. Sand, Silt, Clay

c) What is the secondary component?

Use as the adjective in the soil description. i.e. Silty Sand, Silty Clay, Clayey Silt

d) Are there additional components?

Use as additional adjectives. i.e. Silty Sand Gravelly, Clayey Silt Sandy

EXAMPLES OF DESCRIPTIONS OF THE SOIL COMPONENTS

Sand Describes a sample that consists of both fine sand and coarse sand particles.

Gravel Describes a sample that consists of both fine and coarse gravel particles.

Silty Fine Sand - Major component fine sand, with nonplastic fines.

Sandy Gravel - Major component gravel size, with fine and coarse sand. May contain small amount of fines.

Gravelly Sand - Major component sand, with gravel. May contain small amount of fines.

Gravelly Sand, Silty - Major component sand, with gravel and nonplastic fines.

Gravelly Sand, Clayey - Major component sand, with gravel and plastic fines.

Sandy Gravel, Silty - Major component gravel size, with sand and nonplastic fines.

Sandy Gravel, Clayey - Major component gravel size, with sand and plastic fines.

Silty Gravel Major component gravel size, with nonplastic fines. May contain sand.

Clayey Gravel - Major component gravel size, with plastic fines. May contain sand and silt.

Clayey Silt Major component silt size, with sufficient clay to impart plasticity and considerable strength when dry.

Silty Clay Major component clay, with silt size. Higher degree of plasticity and higher dry strength than clayey silt.

OTHER INFORMATION FOR DESCRIBING SOILS

1. Color of the Sample - Brown, Gray, Red, Black, Yellow, Blue, Green, etc.

2. Moisture Condition - Dry, Moist, Wet.

3. Examples of Material - Sand, Silt, Clay, Gravel, Sandstone, Siltstone, Ironstone, Topsoil, Organic, Ogallala, Shale, Limestone, etc.

4. Examples of Descriptions - Slightly, Contains, Considerable, Decayed, Grains, Clean, Clayey, Silty, Fairly, Numerous, Fractured, Weathered, Trace, Eroded, Mottled, Cemented, Extremely, Intermittent, Compact, etc.

EXAMPLES OF COMPLETE SOIL DESCRIPTIONS

Light Gray Silty Clay, moist, plastic, with ½ inch layers of wet gray silt

Red Brown Clayey Silt, moist, plastic

Brown Silty fine Sand, wet, nonplastic

Gray Sandy Gravel, Clayey, moist, low plastic

Fill – Brown Sandy Gravel, with pieces of brick and cinders, wet, nonplastic

Dark Gray Organic Clay, with shells and roots, moist, plastic

DEFINITION OF TERMS FOR NEBRASKA SOILS

Topsoil - Surface soil that supports vegetation. Usually, it is loamy and dark colored. Most generally described as brown silty clay.

Buried Topsoil – The remains of one-time surface soil buried under later deposits.

Redeposited Topsoil – Is topsoil accumulated on terraces or bottomlands as colluvium washed down by sheet erosion from adjacent uplands.

Subsoil - Usually, a compact zone resulting from the infiltration and accumulation of fines leached from the overlying topsoil. Most generally described as silty clay.

Claypan - An extreme condition of the subsoil when, in areas with delayed runoff, a dense impervious clay layer develops.

Buried Subsoil – The clay subsoil formed during a previous geologic age and now buried under later deposition.

Redeposited Subsoil – The subsoil when eroded from its original position and deposited again at a lower elevation.

Peorian Loess (Clayey Silt) – A prevalent type of parent soil material in Nebraska, wind deposited materials that blanket much of eastern, central, and southwestern Nebraska. Exposed slopes in loess have a tendency to stand in a near vertical position. Settlement can be expected in Peorian, even if it is dry or wet. Dry loess will settle faster. Embankment stability is usually good on dry peorian. Wet peorian may present stability problems requiring stage construction. The color is light brown to tan or light buff.

Redeposited Peorian – Is loess that has eroded out of position as in talus at the toe of exposed loess slopes. In this condition, the vertical slope character of true loess is lost.

Sandy Peorian – Describes loess mixed with sand as found in areas transitional between the sand hills and the typical Peorian mantle

Loveland Loess (Silty Clay) – A loess older than Peorian having a distinguishing reddish tint and is usually heavier textured than the Peorian. A buried solum occurs, occasionally, at the contact between Loveland and Peorian. This is often easily seen in fresh roadway cuts where the two are exposed.

Redeposited Loveland – Occurs when it has slumped out of its original position.

Sandy Loveland – A textural phase of Loveland.

Glacial Till (Silty Clay) – Largely heavy clay soil with intermixed sand, rocks, and silt. It varies widely in color but can usually be expected to contain some pebbles. For a general description the Kansan Till would be tan to orange in color, the Nebraskan Till would be gray.

Glacial Gravel – Made up of mixed sand, gravel, and boulders brought in by the glaciers.

Glacial Sand - Consists of local sand deposits associated with glacial till.

Fine Sand and Natural Sand – These are wind-blown dune sands covering the sandhill area of the state and water deposited fine sands, wherever they may occur. The natural sand contains more fines than does the fine sand. Sand settles very little and settles very fast. Embankment stability is not a problem. Beware of areas where sand is on top of shale if the shale is not flat. Water may be trapped on the top of the shale.

Brule Clay (Silty Clay) - Predominantly a massive compact pinkish silty clay. Occasionally, interbedded thin layers of volcanic ash are found. Brule can be found west of North Platte, it varies from all clay to varying percentages of clay, silt, and sand. Settlement is minimal and embankment stability is good as long as it is dry. Erosion can be a problem.

Redeposited Brule – Slumped and weathered Brule Formation. It is loose and mellow, very similar to loess in appearance and characteristics.

Ogallala Formation (Silty Clay) - Predominantly a massive compact silty clay white in color. Interbedded layers

of sand, gravel, stones or lime or a combination of these could be encountered. Ogallala can be found west of North Platte, it is most often cemented and varies from all clay to varying percentages of clay, silt, gravel, lime and sand. Settlement is minimal and embankment stability is good as long as it is dry. Erosion can be a problem

Pierre Shale (Silt Clay) – This formation is a dark gray massive clay, although it contains some chalk, bentonite, thin sandstones and may contain concretions. It is one of the most plastic clay soils, is a very poor subgrade material, and is conducive to slides on sidehill locations. Most major slides in Nebraska have involved shale. The shear strength of shale is greatly reduced by increased moisture. Avoid adding fill on shale if previous slides are noted in the area. Benching a hillside prior to embankment construction is more important on shale. Shale is the only soil that has minimal settlement and poor embankment stability.

Carlile Shale – Consists principally of gray shales containing a layer of fine-grained sandstone. It is not widespread at depths where it would be commonly encountered in Nebraska Highway construction.

Graneros Shale – A dark gray plastic shale with some thin calcareous layers, sand and sandy shale, and coal like materials.

Dakota Sandstone and Dakota Shales – Mainly of importance as a source of fine sand, this sand varies from loose clean fine or slightly coarse sand to highly cemented sandstone and “ironstone” requiring blasting or ripping to allow removal. The Dakota Shales are usually interbedded with the sands and are fine-grained silty clay shales, which generally have high swell characteristics, and are detrimental subgrade materials. They usually have a glossy or soapy appearance and are multicolored.

Alluvial Silts, Sands and Clays – Water deposited material occupying the stream flood plains. Zonal developments may be missing and local variations in texture are denoted for Silt, Sand and Clay. Muck and Peat would also fall in this category. These soils have large settlements and poor embankment stability. They are usually saturated and pore pressure can present embankment stability problems. Two stage grading and/or wick drains work well in these soils. Surcharges may create a stability problem. If the layer is less than 10’ thick, excavation should be considered.

5.6 Current NDOR Compaction Requirements

Date: Revised 12/10/08, Reviewed 2013

COMPACTION REQUIREMENTS
Project No. C.N. Project Name:
The following compaction requirements are recommended for the plans.
* *

COMPACTION REQUIREMENTS
Class III (See Specifications)

	SOIL TYPE	DEPTH BELOW FINISH SUBGRADE	PERCENT DENSITY	MOISTURE REQUIREMENTS MINIMUM	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 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 / crushed rock embedment	All	All depths	95 Min.	**	**
Embankment / Roadway Grading not to be surfaced	All	All depths	95 Min.	Opt. -3%	Opt. +2%
Subgrade Preparation, Shoulder Subgrade Preparation (Concrete Pavement)	Silt-Clay	The upper 6 inches of subgrade soil	98 Min.	Opt. -3%	Opt. +2%
	Granular	The upper 6 inches of subgrade soil	100 Min.	**	**
Subgrade Preparation, Shoulder Subgrade Preparation (Flexible Pavement)	Silt-Clay	The upper 6 inches of subgrade soil	100 Min.	Opt. -2%	Opt. +1%
	Granular	The upper 6 inches of subgrade soil	100 Min.	**	**
Embankment of driveways which are not to be surfaced	All	All depths	Class I	(See Specifications)	
Bituminous Pavement Patching	All	Underlying Material	100 Min.	(See Specifications)	
Foundation Course / Subgrade Stabilization	- -	- -	100 Min.	(See Specifications)	
Granular Structural Fill (MSE Walls, Granular Fill for bridges, Culverts, etc)	Granular	All depths	100 Min.	Opt. -3%	Opt. +3%

** Moisture as necessary to obtain density.
(A moisture target value at maximum density shall be established in the field by the Contractor during the compaction process. The acceptable moisture content shall be ± 2% of the target value.)
* *

Chapter 6: Concrete

6.1 Current NDOR Concrete Mixes (Table 1002.02)

Date: Revised 11/10/10
Source: NDOR Website

ENGLISH
TABLE 1002.02

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)	Required Strength (Min. psi) (6)
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 - 8.5	0.48	3500
47BD	1PF	494	164	0	0	0	658	2500	3000	30±3	Limestone	6.0 - 8.5	0.42	4000
PR1	I/II	752	0	0	0	0	752	2500	2950	30±3	Limestone	6.0 - 8.5	0.36	3500
PR3	III	799	0	0	0	0	799	2500	2950	30±3	Limestone	6.0 - 8.5	0.45	3500
SF	I/II	564	0	0	0	25	589	2850	3200	50±3	Limestone	6.0 - 8.5	0.36	4000
47BHE	1PF	564	188	0	0	0	752	2500	3000	30±3	Limestone	6.0 - 8.5	0.40	3500
BX(8)	1PF	423	141	0	0	0	564	2850	3150	0	0 (5)	6.0 - 8.5	0.48	3500
47BFS**(6)	1PF	338	113	113	0	0	564	2850	3150	30±3	Limestone	7.5 - 10.0	0.48	3500
47BFS***(6)	1PF	338	113	113	0	0	564	2850	3150	30±3	Limestone	6.0 - 8.5	0.48	3500
47BDFS(6)	1PF	396	131	131	0	0	658	2850	3000	30±3	Limestone	6.0 - 8.5	0.42	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 for 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.
FOR INFORMATION ONLY. The Contractor may develop a Quality Control Program to check the quantity of air content on any given project; such as checking the air content behind the paver.

(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.

(6) 47BFS is an acceptable substitute for 47B and 47BDFS is an acceptable substitute for 47BD.

(7) For acceptance of each class of concrete, refer to the specifications.

(8) For temporary surfacing, straight Type I/II cement is allowed.

(*) 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. Lithium Nitrate may be used in place of Class F fly ash, see Section 1007 of the Standard Specifications as modified in these Special Provisions.

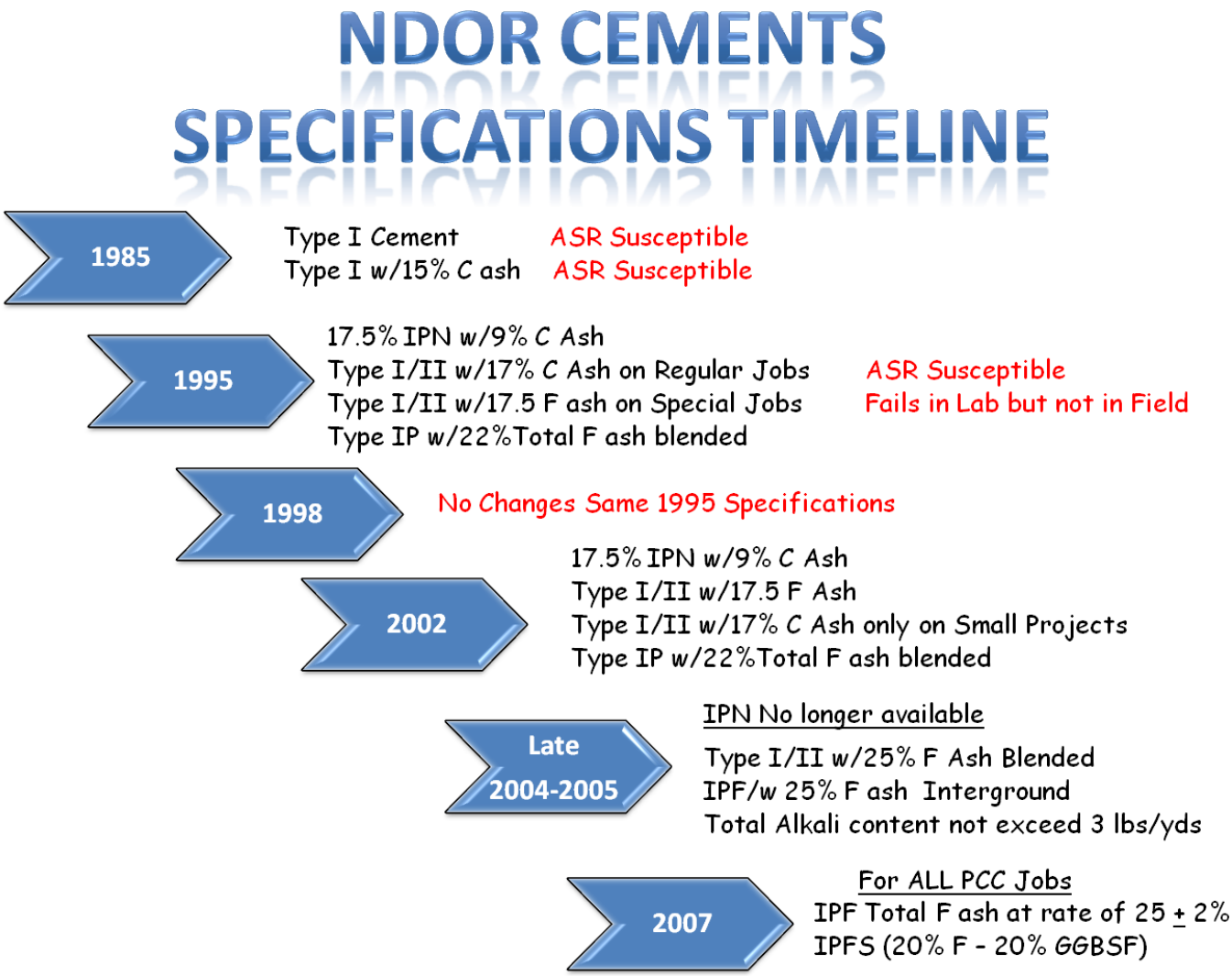
(**) For slip form applications.

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

(****) Quartzite aggregate can be used in place of limestone providing the aggregate meets Paragraph 3.b. of Subsection 1033.02.

6.2 Past NDOR Concrete Mixes

Date: ?
Source: Halsey



6.3 Evaluation of Potential ASR

(http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/pccp/03047/02.cfm)
The mechanism of ASR is described as certain aggregates containing reactive forms of silica in the aggregate (e.g. chert, quartzite, opal, and strained quartz crystals) that react with potassium, sodium, and calcium hydroxide from the cement to form a gel around the reacting aggregate particles. When this gel is exposed to moisture, it expands, creating forces that cause tension cracks to form around the aggregate. Once cracking has initiated, more moisture penetrates the concrete, thus accelerating ASR. The ASR evaluation is based on the standard test methods for potential Alkali Reactivity of Aggregates- ASTM C 1260 and ASTM 1567. ASTM 1260 determines and characterizes the reactivity of the aggregates within 28 days according to NDOR specifications and ASTM 1567 determines the mitigation of ASR with the use of supplemental cementitious materials (SCM).

Steps to Evaluate Concrete Susceptibility to ASR in Existing PCC (2013 Halsey/Heyen)

1. Drive Pathweb to identify any ASR staining and/or cracking.
2. Investigate the history of projects for the roadway. Gather the as-built plans, specifications and archived documents.
3. Based on the special provisions and the proportion report determine:
    a. Type of cement
    b. The percentage and type of fly ash used
    c. The percentage of natural pozzolans that was used
    d. The maximum cement alkali content that was permitted (lb/yd^3)
4. If the special provisions or specifications do not match the cement used on the project, verify whether there were change orders related to cement.
5. Based on the project location determine the likely watershed source for the sand and gravel (Figure 1), then find the watershed source (aggregate location) in the first column of Table 1.
6. Compare the minimum replacement level of SCM (supplementary cementitious material) to the level of SCM used to build the roadway. The alkalinity of Nebraska's Type I or II cement is 0.6% Na_2O_{eq} or less. According to FHWA – protocol, cement alkalis less than 0.7% Na_2O_{eq} allow the reduction of SCM by one prevention level or 5 to 10%. The green column in Table 1 shows the appropriate percent replacement of cement with fly ash type F for Nebraska cements.
7. Optional: Once a pavement has been identified as having the potential for ASR, testing of core samples can be done to verify that ASR exists. The test procedure is known as "Standard Method of Test for Rapid Identification of Alkali-Silica Reaction Products in Concrete" (AASHTO Designation: T 299-93 (2009). The sample is treated with Uranyl Acetate and signs of ASR fluoresce under black light.

Current Practice

The 2013 concrete proportion tables in special provisions require the use of IPF cement that contains 25% fly ash type F or 20% Fly Ash Type F and 20% ground granulated blast-furnace (GGBF) slag. Based on FHWA protocol, this should be effective at mitigating the potential for ASR in Nebraska aggregate with cements having an alkalinity of 0.6% Na_2O_{eq} or less.

Figure 1. Nebraska's Regions - Aggregate Reactivity Study – December 2012

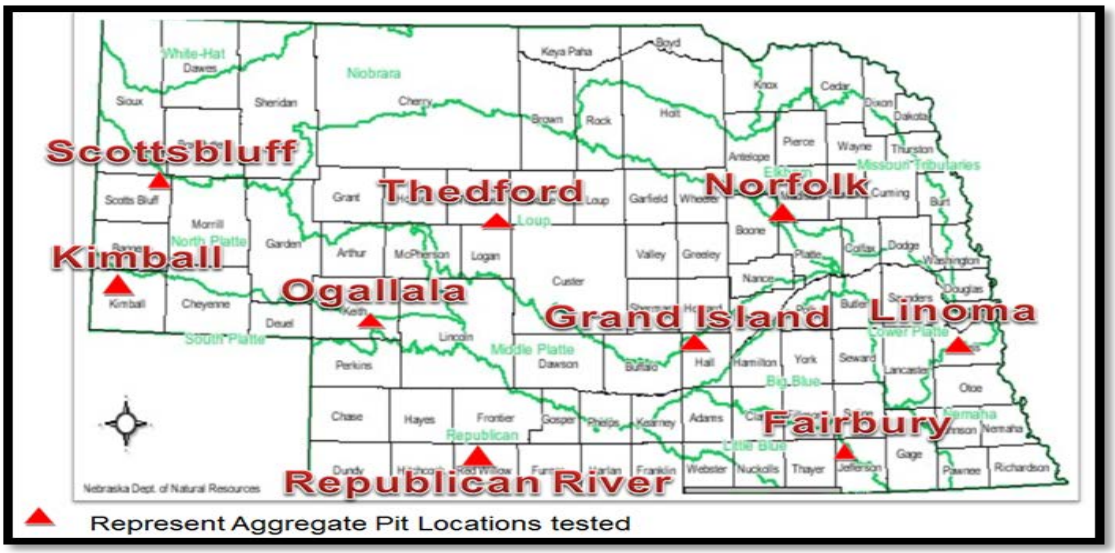
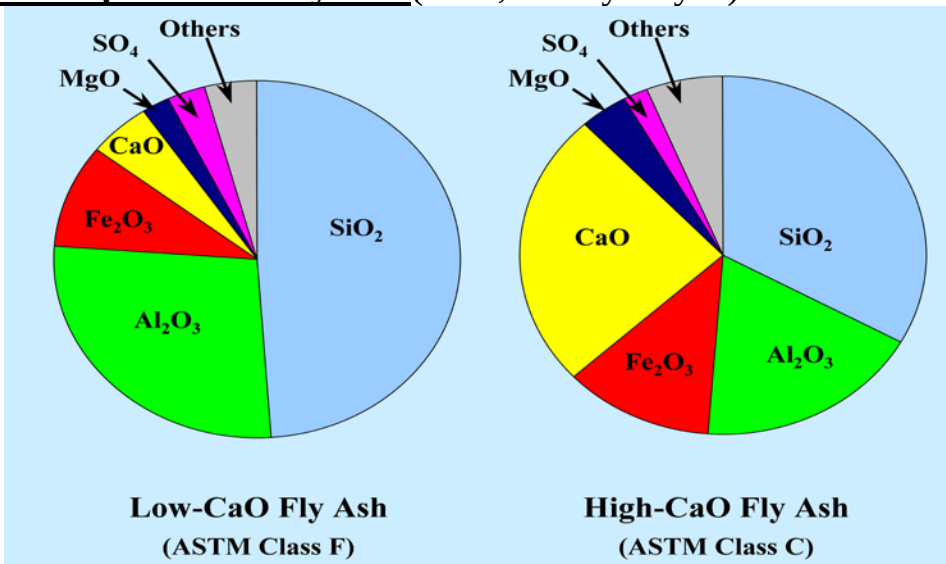


Table 1. Minimum SCM for Nebraska Aggregates

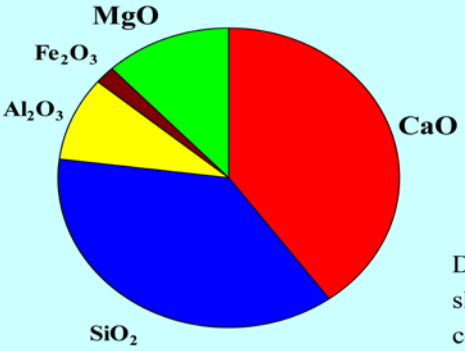
Aggregate Type Location	Description of Aggregate Reactivity	(Table 6- AASHTO PP 65-10) Min. Replacement Level of SCM	Type I/II Cement Low Alkalinity Min. Replacement Level of SCM Mitigate ASR	Nebraska's Spec Since Late 2004 IP with 25% Class F	
Platte River Grand Island	Moderately Reactive	20	15	✓	
Dry Pit Kimball	Highly Reactive	25	20	✓	
Republican River Indianola	Very Highly Reactive	35	25	✗	Non-Approved Aggregate
North Platte River Scottsbluff	Highly Reactive	25	20	✓	
South Platte River Ogallala	Moderately Reactive	20	15	✓	
Middle Loup River Thedford	Highly Reactive	25	20	✓	
Little Blue River Fairbury	Moderately Reactive	20	15	✓	
Elkhorn River Norfolk	Very Highly Reactive	35	25	✓	
PLatte River Linoma	Highly Reactive	25	20	✓	

Chemical Composition of Fly Ash (2013, Halsey/Heyen)



Chemical Composition of GGBF Slag

There is a much smaller range in the chemical composition of commercially available slags



Oxide	Range
SiO_2	32 – 42
Al_2O_3	7 – 16
CaO	32 – 45
MgO	5 – 15
S	0.7 – 2.2
Fe_2O_3	0.1 – 1.5
MnO	0.2 – 1.0

Despite the wide range in composition - slag from a given source tends to be of consistent composition

General Notes

- Type I/II cement without SCMs or Type I/II with Fly Ash Type C- ASR susceptible. Moderately Reactive Aggregate may develop ASR slowly.
- Type I/II cement with 17% Fly Ash Type F – Effective at mitigating ASR in moderately reactive aggregate, the development of ASR may be slow for Highly and Very Highly Reactive Aggregate.
- Type IPN cement 17.5% and 9% Fly Ash Type C – Effective at mitigating ASR in Moderately Reactive Aggregate, the development of ASR may be slow for Highly and Very Highly Reactive Aggregate.
- Type IP cement with 22% Fly Ash Type F - Effective at mitigating ASR for all but Very Highly Reactive Aggregate.
- Type I/II cement with low alkalinity and no SCMs – ASR susceptible but deterioration may be slow with Moderately Reactive Aggregate.
- Type IP cement- In Nebraska, the Fly Ash was exclusively Type F at 25% since 2007.

Understanding Fly Ash

Fly ash, slag, silica fume, natural pozzolans, and lithium admixtures are all effective at controlling ASR provided they are used in sufficient quantity.

The equivalent alkali in cement is defined as the sum of sodium oxide (Na_2O) and potassium oxide (K_2O) and expressed as sodium oxide equivalent alkali : $Na_20_{eq} = Na_2O + 0.658\ K_20$.

The upper acceptance limit for cement alkalinity is 0.6% in Nebraska. When Fly Ash and cement were combined an upper limit of 0.8% alkalinity was set in some past specifications. The combined total alkalinity of cement and Fly Ash is higher than that of cement alone because there is alkalinity added from the Fly Ash.

Fly Ash Type C is defined as having less than 50% Si_2O. It contains more CaO than Fly Ash Type F and hydrates faster.

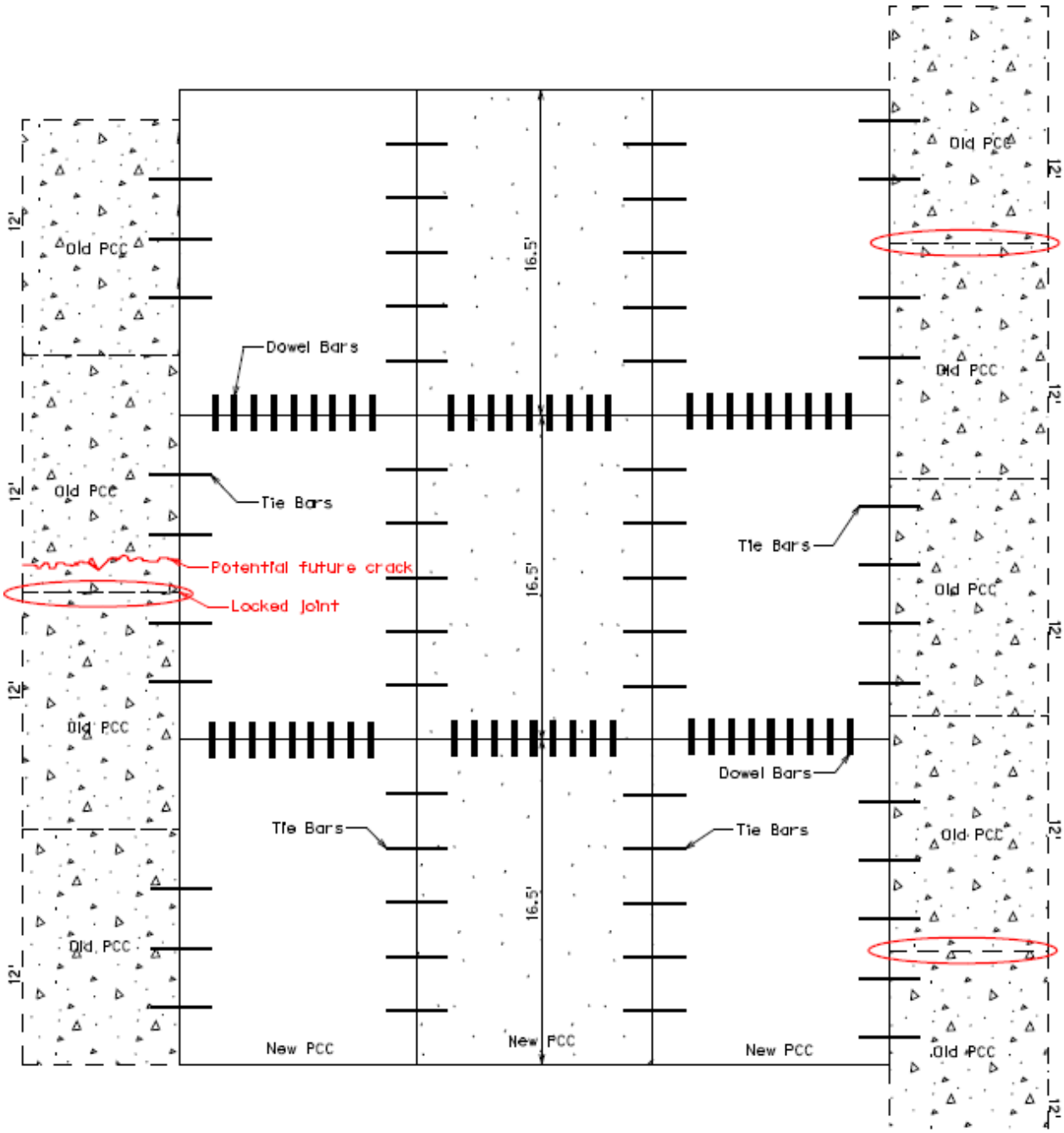
Fly Ash Type F is defined as having a minimum of 70% Si_2O. It contains more Si_2O to react with the aggregate limiting the aggregates future reactivity in the ASR process. Concrete hydration is slower.

6.4 Joint Design Example

Date: 2008
Source: Syslo

Below example taken from In Blair project. New ML = 10”, Existing Shlds = 6”.

Match ML to Shld joints where possible. When matching joints not possible, tie bar placement should be adjusted to avoid locked joints as much as possible.



6.5 Area of Steel Calculation

Date: 11/17/04
Source: A mechanistic-Empircal tie Bar Design Approach for Concrete Pavements, http://www.acpa.org

Current Tie Bar Design Practice

The most commonly cited basis for tie bar design in the United States is the subgrade drag theory, or SDT. This theory, which has its origins in the design of steel reinforcement for slab-on-grade concrete flooring, is explained in several textbooks and industry references (Yoder & Witczak, 1975; Huang, 1993; PCA, 2008). The SDT method of design is based on the concept of providing sufficient steel to allow the "dragging" of the concrete slab across the base course without yielding the steel or pulling out the tie bars. The basic concepts are as follows:

1. The maximum force a tie bar can sustain without yielding, F_{TB} (lb), is expressed as:

$$F_{TB} = a_s * f_s \qquad (1a)$$

where

a_s = cross-sectional area of one tie bar, in^2

f_s = the allowable stress in steel f_s, lb/in^2 (usually taken as two-thirds of the yield strength)

2. The force to drag a concrete slab across the base course, F_{drag} (lb), is computed as

$$F_{drag} = L_{slab} D_{fe} H_{PCC} WF \qquad (1b)$$

where:

L_{slab} = slab length, in

D_{fe} = distance to the closest free edge, in

Applied Research Associates, Inc 2

H_{PCC} = concrete slab thickness, in

W = unit weight of concrete, lb/in^3 (approximately 0.0868 lb/in^3 for a typical paving concrete mixture).

F = coefficient of friction at the slab-base interface (e.g., a value of 1.5 for unbound bases is recommended by the 1993 AASHTO *Guide for Design of Pavement Structures* or simply the 1993 AASHTO Guide)

3. If n is taken as the number of tie bars per slab length, then the equation of equilibrium of the SDT is:

$$nF_{TB} = F_{drag} \tag{2a}$$

4. From equation (2a), the total area of steel per slab can be determined as:

$$na_s = A_s = \frac{L_{slab} D_{fe} H_{PCC} WF}{f_s} \tag{2b}$$

where A_s (in^2) = total area of steel for a given slab length.

5. The required tie bar spacing, J_{TB} (in), can be determined as:

$$J_{TB} = \frac{L_{slab} a_s}{A_s} \tag{2c}$$

Example Application of the SDT Method for Tie Bar Design

Problem statement:
Compute the total area of steel (A_s) required for a 12-in concrete slab with a 15-ft transverse joint spacing over an unbound base for a highway consisting of two 12-ft lanes tied at the centerline joint. Assume Grade 60 steel (steel yield strength, f_y = 60,000 psi). Also compute the tie bar spacing required for #4 deformed bars. Assume the unbound base coefficient of friction to be 1.5.

Solution:
Area of steel calculation (variables previously defined)

$A_s = L_{slab} \cdot D_{fe} \cdot H_{PCC} \cdot W \cdot F / [f_y \cdot 2/3]$

A_s = [180 in · 144 in · 12 in · 0.0868 lb/in^3 · 1.5] / [60,000 psi · (2/3)]

= 1.01 in^2

Tie bar spacing calculation:
The area of a #4 bar is 0.20 in^2. Thus, and using equation (2c), a maximum spacing of 35.6 in should be used to drag the concrete slab over the unbound base course and while keeping the steel stress safely below its yield stress. This could practically translate to providing 6 #4 bars per slab at a 30 in spacing.

.

Area of Steel = (L_{Slab} x D_{fc} x H_{pcc} x W x F)/(f_y x $\frac{2}{3}$)

L_{Slab} = Length, in

D_{fc} = Width to free edge, in

H_{pcc} = Thickness, in

W = Unit Weight, $\frac{lbs}{in3}$

F = Coefficient of Friction, 1.5 for unbound

F_y = Yield Strength of Steel, psi

Ex: Conc. Shoulder: 6 ft x 12 ft (contraction joint spacing) x 6”

Area of Steel = (72 in x 144 in x 6 in x 0.0868 $\frac{\mathbf{lbs}}{\mathbf{in3}}$ x 1.5)/(60,000 $\frac{\mathbf{lbs}}{\mathbf{in2}}$ x $\frac{\mathbf{2}}{\mathbf{3}}$)

Area of Steel = 0.20 in^2 needed

Area of #4 bar = 0.20 in^2 therefore one #4 bar will hold

Chapter 7: Asphalt and Asphalt Binders

7.1 NDOR Asphalt Type Summary

Date: Revised 2/20/09
Source: Brhel

TYPE	DESCRIPTION/USE
11	This mix is designed to have a crushed value of 80% for the combined mineral aggregate, with a maximum of 60% limestone for skid resistance and a 75 blow Marshall design and a target field air void of 4.0%. For use on high volume road with a truck count of 350 or more.
11R	This mix is identical to the type 11 except that a recycled asphalt pavement (RAP) is used to supplement the virgin aggregate. All properties are the same as that of the type 11.
13	This mix is designed to have a crushed value of 80% and composed of a minimum of 50% quartzite or granite and a 75 blow Marshall design and a target field air void of 4.0%. Used on high volume roads usually capping a type 11 and urban projects when placing 2-2 1/2 inches.
13R	This mix is identical to the type 13 except that a (RAP) is used to supplement the virgin aggregate. All properties are the same as that of the type 13.
14	This mix is designed to have a crushed value of 60% for the combined mineral aggregate, with a maximum of 60% limestone for skid resistance and a 50 blow Marshall design and a target field air void of 4.0%. Used on medium volume roads with truck traffic between 125 and 350.
14R	This mix is identical to type 14 except that a (RAP) is used to supplement the virgin aggregate. All properties are the same as that of the type 14.
17	This mix is designed to have a crushed value of 0% for the combined mineral aggregate, with a maximum of 60% limestone for skid resistance and a 50 blow Marshall design and a target field air void of 3.5%. Used for shoulders off the Interstate and Expressway system.
17C	This mix is designed to have a crushed value of 20% or 40% for the combined mineral aggregate, with a maximum of 60% limestone for skid resistance and a 50 blow Marshall design and a target field air void of 3.5%. The 20% is used for shoulders on interstate and expressways and for mainline when traffic is detoured with 125 trucks or less. The 40% is used for mainline under traffic with 125 trucks or less.
17R	This mix is identical to type 17 except that a (RAP) material is used to supplement the virgin aggregate. All properties are the same as that of the type 17.

17RC	This mix is identical to the type 17C, 20% or 40% except that a (RAP) material is used to supplement the virgin aggregate. All properties are the same as that of the type 17C.
1	This mix is composed of a combined mineral aggregate of not less than 50% crushed rock, crushed mineral aggregates which contain no more than 15% naturally occurring fine retained on the 10 sieve, 60% maximum limestone permitted. Used for the same type of projects as type 11.
1R	This mix is identical to type 1 except that a (RAP) material is used to supplement the virgin aggregate. Used in the same type of projects as type 11.
3	This mix is composed of crushed quartzite or granite and mineral filler if required. Used for the same type of projects as type 13.
3R	This mix is identical to type 3 except that a (RAP) material is used to supplement the virgin aggregate. Used in the same type of projects as type 13.
4	This mix is composed of not less than 30% crushed rock, crushed mineral aggregates which contain no more than 20% naturally occurring fine aggregates retained on the No. 10 sieve and mineral filler if required, 60% maximum limestone permitted. Used for the same type of projects as type 14.
4R	This mix is identical to type 4 except that a (RAP) material is used to supplement the virgin aggregate. Used in the same type of projects as type 14.
7	This mix is composed of a combined mineral aggregate, 60% maximum limestone permitted. Used for the same type of projects as type 17.
7R	This mix is identical to type 7 except that a (RAP) material is used to supplement the virgin aggregate. Used in the same type of projects as type 17.
II	This mix is composed of mineral aggregate No. 2-A, mineral aggregate No. 5 (fine sand) and mineral filler.
IIR	This mix is identical to type II except that a (RAP) material is used to supplement the virgin aggregate.
A	This mix is composed of crushed rock, mineral filler and 3-A crushed sand gravel. This mix was used as both a base and surface course.
A Special	This mix is composed of crushed rock, mineral filler and 3-A crushed sand gravel. This mix was used as a base course. The gradation of the crushed rock was slightly coarser and the percentage content of crushed rock in the mix higher than the A mix.
AX	This mix is composed of crushed rock, fly ash and mineral aggregate. It was used as both a base and surface course on the interstate.
AX Special	This mix is composed of the same material as type AX only this mix has a higher percentage of crushed rock. It was used as a base course on the Interstate.

Q	This mix is composed of crushed quartzite or crushed granite. This was used as a surface layer on the Interstate.
RQ	This mix is identical to type Q except that a (RAP) material is used to supplement the virgin aggregate. Used on same type of projects as Q.
MQ	This is an open graded mix composed of quartzite or granite gravel sand aggregate and mineral filler. Used on the surface layer of the Interstate.
CC, CC1 & CC2	These mixes are composed of crushed concrete, 3-A sand and mineral filler.
RCC	This mix is composed of (RAP), approximately 82% crushed concrete and 18% 3-A sand gravel. Used as a base course on the Interstate.
RAX	This mix is identical to the type AX except that it has a RAP material added to supplement the virgin aggregate. Used in the same line as type AX.
RAX Special	This mix is identical to the type AX Special except that it has a RAP material added to supplement the virgin aggregate. Used along the same lines as type AX Special.
SMA	Experimental European Mixture Stone Mastic Asphalt composed of crushed rock, 3A crushed sand gravel and mineral filler. Used on high traffic volume roads.
SUPERPAVE	This is a mix design system for specifying asphalt binders and mineral aggregates, developing and analyzing asphalt mixtures and establishing pavement performance prediction, based on cumulative equivalent single axle loads. In general SP4 and SP5 will be used on mainline pavements and SPS will be used on shoulders.
SPS	This is a Surfacing for Paved Shoulder mix. This mix uses PG 58-28 (52-34 as of 2010) at a content to yield a target air void of 1.5%. It promotes the use of RAP at a content of 35 to 50% and thus reduces the amount of added binder and aggregates by as much as half. It contains no lime.
GGCRM	This is a Gap Graded Crumb Rubber Modified mix. Placed as a surface mix, usually 1.5” to 2.5” in thickness. This has the resemblance of a SMA (Stone Mastic Asphalt) mix. It is a high binder, rut and crack resistant surface Used on high volume roadways.
GGCRMLV	This is a Gap Graded Crumb Rubber Modified Low Volume mix. Placed as a surface mix, usually 1.5” to 2.5” in thickness. This has the resemblance of a SMA (Stone Mastic Asphalt) mix. It is a high binder, rut and crack resistant surface Used on low to medium volume roadways.
LC	This mix is used as a type of SAMI (stress absorbing membrane interlayer). It is a fine graded mix. This leveling course was intended to slow down reflective cracking from the existing pavement and to provide an impermeable layer to resist the flow of water in the asphalt mix. This mix uses a high binder content and has a low air voids this produces a dense mixture.

RLC	This mix was used as a leveling course for HLSS, FDR, and overlay projects. This mix is the same gradation as an "LC" but uses standard PG binder types and contents, and targets regular mainline volumetrics.
OGFC-CRM	This is an Open Graded Friction Course mix. Placed as a surface mix, usually 1" to 1.5" in thickness. This is coarser than a regular OGFC and contains higher binder amounts. This mix uses 58-28 binder that is modified with crumb rubber. Provides a high friction, drained and quiet pavement section. Used on mainline roadways and ramps.
HRB	This is a High Rap Base mix. It is a very fine graded, single aggregate mix used in lower lifts only. It contains a minimum 25% or 35% RAP as specified and a maximum 50% RAP. The mix contains no lime and a minimum 5.5% of PG 64-22 (64-34 as of 2010) binder. It is a very stiff mix used on low to medium volume roadways. HRB was constructed for approximately 2 seasons before being replaced with SPR.
SPL	This Static Pressure Loading mix is a well graded Marshall mix. There is a fine mix and a course mix. The mixes are used primarily for camper pads, parking lots, lower lifts, and temporary pavement. RAP is not required but often needed to achieve the required 230 psi bearing capacity. It contains no lime and a minimum 5.2% of PG 64-22 (64-34 as of 2010) binder. SPL has been replaced with SPR.
SPR	This stands for Superpave Regular and/or Recycle mix. This mix is the Superpave Gyratory version of its predecessor SPL – Static Pressure Loading mix. This is a coarse but well graded mix used in lower and surface lifts on low to medium volume roadways. It requires lime / WMA. This mix combines high quality angular aggregates with typically 45 to 50% RAP. High quality and highly polymerized PG 64-34 binders are used along with improved dust to asphalt ratios, giving this mix high mastic and film thickness's and high strength modulus values that provide rut resistance.
SPH	This stands for Superpave Heavy-load mix. This mix is used in heavy truck applications such as interstates, expressways, and large volume urban corridors. This mix replaces the SP-4's and SP-5's and consists of high angularity aggregates and typically 15 to 25% RAP, the gyratory compaction levels have been modified to be consistent with today's performance requirements in order to improve binder contents and dust to asphalt ratios. This will provide better long term durability, reduced permeability and improved in-place density. This mix utilizes the highest polymer modifications in binders.

7.2 NDOR Emulsion Summary

Date: Revised 11/10/10
Source: Syslo

Work Description	Type & Grade	Type
Armor Coat	CRS-2P	Polymer Modified
Bituminous Sand Base Course	HFE-300	Non-Polymer
Chip Seal	CRS-2P	Modified or Non
Cold In-Place Recycling	HFE-300	Non-Polymer
Fog Seal:	CSS-1H	Non-Polymer
Hot In-Place Recycling	Rejuvenating Agents	
	Reclamite or ARA-1P	Non-Polymer
	Approved Products List	
Hydrated Lime Slurry Stabilization	CSS-1, CSS1-H	Non-Polymer
Microsurfacing	CSS-1H	Non-Polymer
Scrub Seal	CRS-2P	Polymer Modified
Tack Coat	SS-1, SS-1H, CSS-1, CSS-1H	Non-Polymer

CRS-Cationic Rapid Set

CSS- Cationic Slow Set

HFE – High Float Emulsion

Trailing Number 1 is a low relative viscosity and 2 is a high relative viscosity, Trailing letters H=Hard and S=Soft for the base asphalt after evaporation

Trailing letters P=Polymer Modified Emulsion, L=Latex

8.1 Sealant Work Schedule

Date: 2008, Reviewed 2013
Source: Brill

AC & PCC SEALING CALENDAR WORK SCHEDULE

The following is a list of pavement maintenance treatments and the time of year in which the work is performed. Hopefully this will be helpful with selecting the proper letting date for the project.

CONCRETE

TYPE OF WORK		TYPICALLY DONE BETWEEN
Sealing joints		April 1 – November 30
Sealing cracks		April 1 – November 30

ASPHALT

TYPE OF WORK		TYPICALLY DONE BETWEEN
**Crack sealing bituminous surface		November 1 – March 31
Joint Sealing, Asphalt to Concrete		November 1 – March 31

	TYPE OF WORK & WHEN IT IS TYPICALLY DONE				
DISTRICT	**FOG SEAL	ARMOR COAT	CHIP SEAL	MICROSURFACING	SLURRY SEAL
1	6-15 to 9-1	7-5 to 9-1	6-1 to 9-15	6-1 to 9-15	6-1 to 9-15
2	6-1 to 9-1	6-15 to 9-1	6-1 to 9-15	6-1 to 9-15	6-1 to 9-15
3	6-1 to 9-1	6-1 to 9-1	6-1 to 9-15	6-1 to 9-15	6-1 to 9-15
4	6-1 to 9-1	6-15 to 9-15	6-1 to 9-15	6-1 to 9-15	6-1 to 9-15
5	6-1 to 9-1	7-22 to 9-1	6-1 to 9-15	6-1 to 9-15	6-1 to 9-15
6	6-15 to 8-15	7-15 to 9-1	6-1 to 9-15	6-1 to 9-15	6-1 to 9-15
7	6-1 to 9-1	7-5 to 9-15	6-1 to 10-1	6-1 to 10-1	6-1 to 10-1
8	6-1 to 9-1	7-5 to 9-1	6-1 to 9-15	6-1 to 9-15	6-1 to 9-15

**On some projects both Fog Sealing and Crack Sealing Bituminous Surface are specified. For these projects I would recommend a late spring or early summer letting. This will allow for the fog seal to be completed late summer (6-1 to 9-1) and then the crack sealing could be done in the winter (11-1 to 3-31).

8.2 Sealant Selection Chart

Date 10/11/10
Source: Byre

SEALANT SELECTION CHART					
	NE-101	NE-CR22	NE-CR18B	NE-3405	NE-3405LM
CAN BE USED FOR ASPHALT SURFACES	X	X	X	X	X
CAN BE USED FOR CONCRETE SURFACES				X	X
ROUTING RECOMMENDED	X	X	X	X	X
ROUTING REQUIRED				X	X
HEAT LANCE RECOMMENDED	X	X	X		
SQUEEGEE REQUIRED	X	X	X		
CAN BE USED ON TRANSVERSE CRACKS	X	X	X	X	X
RECESS MATERIAL BELOW PAVEMENT SURFACE				X	X
CAN BE USED ON LONGITUDINAL CRACKS	X	X	X		
VISCOSITY - LOW=THIN, HIGH=THICK	MED	HIGH	MED-HIGH	MED-LOW	LOW
COLD TEMPERATURE PROPERTIES	FAIR	POOR	AVERAGE	ABOVE AVERAGE	EXCELLENT
RECOMMENDED CRACK WIDTH IF NOT ROUTING	LESS THAN 1/8" TO 1/4"	MORE THAN 1/2"	MORE THAN 3/8"	ROUTING REQUIRED	ROUTING REQUIRED

Under Revision

8.3 Sealant Descriptions

Date: 9/2/10
Source: Syslo

Under Revision

CR-18B
Contains about 18% crumb rubber. Is a thinner, more adhesive sealer with "healing" properties. Better used for asphalt applications. Good for transverse or longitudinal cracks and able to get into smaller cracks.

NE-101
Vary similar to CR-18B for uses; however, only typically has 10-15% crumb rubber and uses more polymers. Typically a little more expensive since more additives. Is a thinner, more adhesive sealer with "healing" properties. Better used for asphalt applications. Good for transverse or longitudinal cracks and able to get into smaller cracks.

NE-3405
Similar to both the CR-18B & NE-101, but does not have the flexibility requirements in the specification. This is because no crumb rubber is required. This is not recommended for longitudinal cracks or joints. It should be used for transverse only.

CR-22
Contains 22-26% crumb rubber. Thicker & less adhesive due to more crumb rubber. Better suited for larger cracks. Since less adhesive it typically won't grab tires, so is a good product for longitudinal joints (especially asphalt-concrete joints).

See approved product list @ http://www.nebraskatransportation.org/mat-n-tests/hotpoursealers.htm

Chapter 9: Cost and Quantity Estimates

9.1 Estimated Costs Per Mile

Date: Revised 10/16/12
Source: Debutts

ESTIMATED COSTS PER MILE

Costs include a 1.32 factor (E&C)
Asphalt quantities are SPR and SPH w/PG 64-34 Binder and Shoulders are SPS w/PG 52-34

PG 52-34 $625/ton

PG 64-34 $735/ton

No.	STRATEGY DESCRIPTION	/MILE
1.	4" Hydrated Lime Slurry w/3" SPR	$308K
	4" HLSS w/Trench Widening & 3" SPR (28' top)	$347K
2.	Mill 1.5", Place 2" SPR	$138K
3.	Class 1 Mill, Place 4" SPR	$266K
4.	Class 3 Mill 2", Place 4" SPR	$270K
5.	Class 3 Mill 4", Place 4" SPR	$263K
6.	Class 3 Mill 4", Place 6" SPR	$382K
7.	10" Fly Ash Stabilized Bituminous w/ 3" SPR	$312K
8.	Dowel Bar Retrofit & Diamond grind driving lanes, then joint seal (14' width one direction)	$187K
9.	Interstate – 30' ML: Mill 4", Place 4'' SPH 7' Outside Shld: Mill 1.5", Place 1.5'' SPS	$396K x 2 for 4-lane
10.	Interstate 27' (ML & Inside 3' Shld) Mill 2", Place 5/8'' LC & 1 5/8" SPH	$203K x 2 for 4-lane
11.	New Build SPR on stabilized subgrade 24' wide 6" thick	$587K
	9" thick	$644K
	10" thick	$702K
12.	New Build Dowelled PCC 30' wide *($31.7/sy)* 8" thick	$961K
	(Includes 4" F.C., Prep, 6" surf shldr, shldr constr) *($32.7/sy)* 9" thick	$984K
	($33.6/sy) 10" thick	$1,007K
	($37.27/sy) 12" thick	$1,089K
	($40.2/sy) 14" thick	$1,158K
13.	8" Cold In-place Recycling (CIR) *no overlay included* 5"x24' Cold In-place Recycling w/ foamed Asphalt, 5" Paver Laid, no overlay	$212K $98K
14.	5" x 24' Non Doweled PCC Whitetopping (No special traffic control or bond breaker included)	$476K
15.	Hot In-Place Recycling & Armor Coat *($21K/mi)*	$112K
16.	Mill 1", Hot In-Place 2", Place 1.5" SPR	$194K

ADDITIONAL ITEMS

A.	**Shoulder Overlay 16' of width Type SPS**	**1" thick**	**$32K**
		2" thick	**$65K**
		3" thick	**$97K**
		4" thick	**$130K**
		5" thick	**$162K**
		6" thick	**$195K**
B.	**Shoulder Fog Seal 16' wide**		**$3K**
C.	**Shoulders Armor Coat 16' wide**		**$17K**
D.	**Trench Widen 6" & fill with recycle, Place 3" SPR**		**$39K**
E.	**Trench Widen 4" & fill with SPR, Place 4" SPR**		**$81K**
F.	**Class 3 milling 24' wide**	**1" deep**	**$12K**
		2" deep	**$14K**
		3" deep	**$19K**
		4" deep	**$24K**
		5" deep	**$31K**
		6" deep	**$37K**
G.	**Diamond Grind 12' wide**		**$23K**
	Concrete Surface Mill 1" x 24'		**$28K**
H.	**Full width fabric 24' wide**		**$37K**
I .	**6" Shoulder Surfacing 5' wide**		**$107K**
J.	**Concrete Shoulders 14' wide**	**5" thick**	**$263K**
		6" thick	**$306K**
		7" thick	**$317K**
		8" thick	**$339K**
		9" thick	**$350K**
		10" thick	**$361K**
		12" thick	**$398K**
		14" thick	**$431K**
K.	**SPR overlay 24' wide**	**1" thick**	**$76K**
	(for overlays on existing pavements)	**2" thick**	**$128K**
		3" thick	**$189K**
		4" thick	**$243K**
		5" thick	**$301K**
		6" thick	**$360K**

9.2 Preventative Maintenance Costs Per Mile

Date: Revised 2/25//13
Source: Debutts

Preventative Maintenance
Apr-12
Cost per Mile includes: Traffic Control, Mobilization, Contingency and Construction Engineering

Description	Cost / Mile	Cost / Lane Mile
Class 1 Milling - 24' Roadway	$14,300	$7,150
Armor Coat - 24' Roadway (Does not include Class 1 Milling)	$24,000	$12,000
Asphalt Overlay - Mill 3/4" x 24' Roadway with 3/4" Overlay	$73,500	$36,750
Chip Seal - 24' Roadway	$25,100	$12,550
Crack Sealing - 8 Mile x 24' Roadway	$5,800	$2,900
Diamond Grinding & Concrete Repair - 24' Roadway	$79,200	$39,500
Fog Seal - 24' Roadway	$5,200	$2,600
Fog Seal - 16' (2 - 8' Shoulders)	$3,400	$1,700
Fog Seal - 40' (24' Roadway & 8' Shoulders)	$8,600	$4,300
Microsurfacing - 24' (1/4" Rut)	$54,800	$27,400
Microsurfacing - 24' (1/2" Rut)	$68,000	$34,000
Microsurfacing - 24' (3/4" Rut)	$81,300	$40,650

9.3 Concrete Repair Costs Per Mile

Date: 4/26/10
Source: Masek

ESTIMATED COST FOR CONCRETE REHABILITATION
(1.32% E & C AND FCR IS INCLUDED PER MILE, 24' WIDE)

CONCRETE PAVEMENT (TYPES A, B AND C) AND JOINT REPAIR, FULL DEPTH

1. Existing (Plain/Reinforced) Concrete w/ASR (Built 1984 or later) = **$ 80,000**
   (After viewing Pathway and bad condition, use **$100,000**)

2. Existing (Plain) Concrete w/little or no ASR (Built before 1984) = **$55,000**

3. Concrete (Plain) w/existing AC Overlay = **$40,000**

4. Concrete (Reinforced) w/existing AC Overlay = **$66,000**

5. Crack & Seated Concrete w/existing AC Overlay = **$27,000**

DIAMOND GRINDING AND TEXTURING CONCRETE PAVEMENT

1. Concrete with 2 lanes and AC shoulders = **$52,000**

2. Concrete with 2 lanes and Concrete Shoulders = **$56,000**

3. Concrete with 4 lanes and Concrete Shoulders = **$30K** (Driving Lane Only/mile) or x2= **$60K**

4. Concrete with 4 lanes and AC Shoulders = **$28** (Driving Lane Only/mile) or x 2 = **$56K**

JOINT SEALING – ASPHALT TO CONCRETE (INTERSPLICE)

1. Concrete with AC Shoulders on 2 lane or 4 lane, 2 shoulder joints counted = **$8,400**

SEALING JOINTS

1. Concrete with 2 lanes and AC Shoulders = **$17,530**

2. Concrete with 2 lanes and 8' Concrete Shoulders = **$32,000**

3. Concrete with 4 lanes and 10' Concrete Outside/3' Inside Shoulders = **$30,500**

SEALING CRACKS (CONCRETE PAVEMENT)

1. After viewing Pathway, if not a huge amount of longitudinal cracking is present, use an average of 500'/mile = **$1,815**

CRACK SEALING BITUMINOUS SURFACING

1. This is a total "guesstimate" until cracks are actually counted in field = $**11,000**

EXAMPLE: Concrete Repair, Grind and Seal

$55,000 (Plain concrete pavement repair)
$30,000 (Grinding driving lane/1' passing lane/1'outside shoulder)
$ 1,815 (Sealing cracks)
$30,500 (Sealing 2 longitudinal joints/skewed transverse joints/3' & 10' shoulders)

$117,315 / mile

9.4 Estimating Quantities Worksheet

Date: Revised 11/7/12
Source: Debutts

Estimating Quantities in English & Metric

Reference to 2008 NDOR Standard Specifications for Highway Construction

General Information:

Items are listed in alphabetical order.
Conversion factors are in English and metric.
R.A.P. is an acronym for Recycled Asphalt Pavement other term used bituminous millings.
Weight of RAP – 144 lbs/ft^3
One gallon of emulsified asphalt or water weighs 8.333 lbs.

Asphaltic concrete projects. Add the following equipment rental items and hours.
"Rental of Loader, Fully Operated" – 50 Hour
"Rental of Motor Grader, Fully Operated" – 50 Hour
"Rental of Dump Truck, Fully Operated" – 50 Hour
"Rental of Skid Loader, Fully Operated" – 50 Hour

Armor Coat – Section 515

"Armor Coat Aggregate" – Cubic Yard (meter)	23 lb/yd^2	conversion factor 1.3 tons = 1 yd^3
	14.1 kg/m^2	conversion factor 1.54 Mg = 1 m^3
"Armor Coat Emulsified Asphalt" – Gallon (kiloliters)	0.28 Gal/yd^2	(0.9 L/m^2)

Asphaltic Concrete – Section 503, Section 1028 & Special Provision

"Asphaltic Concrete, Type "___" – Ton (megagram) Tables on pages 6 & 7 for types and weight
"Hydrated Lime/WMA" – Each Table on page 6
"RAP Incentive Payment" – Each Asphaltic Concrete Type "**" tons x 1.7 = Each

Asphaltic Concrete Curb – Section 505

"Constructing Asphaltic Concrete Curb" – Linear Foot (meter)

Factor for 3" (75 mm) Curb	1.35 Tn/Sta	(4.0 Mg/Sta)
Factor for 4" (100mm) Curb	2.00 Tn/Sta	(6.0 Mg/Sta)
Factor for 6" (150mm) Curb	2.10 Tn/Sta	(6.25 Mg/Sta)
Factor for Tack Coat	8 Gals/Sta	(100 L/Sta)

Asphaltic Concrete For Patching – Section 516

"Asphaltic Concrete for Patching, Type "___""– Ton (megagram)

Bituminous Patching of Concrete Pavement – Section 520

"Bituminous Patching" – Ton (megagram)

Bituminous Sand Base Course – Section 509

"Bituminous Sand Base Course Asphaltic Oil" – Gallon (liter)	1000 Gal/Sta for (5" x 24') [12400 L/Sta for (130 mm x 7.3 m)]
"Bituminous Sand Base Course Emulsified Asphalt" – Gallon (liter)	1200 Gal/Sta for (5" x 24') 6% residual [14900 L/Sta for (130 mm x 7.3 m) (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)

Cement Stabilized Bituminous – Special Provision

"Cement Stabilized Bituminous" – Station	
"Cement" – Ton (megagram)	5% weight of RAP
"Water for Cement Stabilization" – Mgallon (kiloliter)	5% weight of RAP & Cement
"Fog Seal" – Gallon (liter)	0.24 Gal/yd² (1.1Lm²)
Note: If trimming is required. Estimate 2 applications.	

Chip Seal – Special Provision

"Chip Seal Aggregate" – Cubic Yard (cubic meter)	25 lb/yd² (aggregate weight 1.4 tons = 1 yd³) [11.0 kg/m² (aggregate weight 1.54 Mg = 1 m³)]
"Chip Seal Emulsified Asphalt" – Gallon (liter)	0.36Gal/yd² (1.4 L/m²)

Cold In-Place Recycling (w/High Float Emulsion) – 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 asphalt
Note: 1 Megagram = 1000 Liters	

Cold In-Place Recycling (w/Foamed Asphalt) – Special Provision

"Cold In-Place Recycling" – Station or Square Yard (square meter)
"Performance Graded Binder (52-34)" - Ton 2% weight of RAP

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 Slurry Injection – Special Provision

"Fly Ash Slurry Injection" – Ton	250 lbs/hole
"Injection Holes" – Holes	4 holes per 24' width
Note: Estimate 50 feet interval between thermal cracks.	

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/yd² (1.1Lm²)
Note: If trimming is required. Estimate 2 applications.	

Fog Seal – Section 513

"Fog Seal" – Gallon (kiloliter) / GSB	0.12 Gal/ yd² (0.54 L/m²)
Note: Use GSB on Interstate & District 4 projects	
"Fog Seal" – Gallon (kiloliter) / CSS-1 & CSS-1H	
Factor for mainline & shoulder	0.12 Gal/ yd² (0.54 L/m²)
Factor for open graded friction course	0.16 Gal/ yd² (0.72 L/m²)
Factor for milled surface of Asph. Conc.	0.07 Gal/ yd² (0.32 L/m²)
Factor for milled surface of Bit. Sand	0.10 Gal/ yd² (0.45 L/m²)

Foundation Course – Section 307

"Bituminous Foundation Course _____" – Square Yard (square meter)
In place weight = 123 lb/ft³ or 1.66 Tn/yd³ (1.98 Mg/m³)
Stockpiled Bituminous = 1.43 Tn/yd³

"Crushed Concrete Foundation Course _____" – Square Yard (square meter)
In place weight for 4"+1/4" trimming = 0.190 Tn/yd³ (100 mm + 5 mm trimming = 0.2079 Mg/m³)
Stockpiled crushed concrete = 1.35 Tn/yd³ (1.61 Mg per m³)
Concrete Pavement in Place = [yd³ x 1.94 Tn/yd³ x 90% (10% loss)] = tons of crushed concrete available
{ [m³ x 2.31 Mg/m³ x 92% (8% loss)] = Mg of crushed concrete available}

"Aggregate Foundation Course "D"_____" - Square Yard (square meter)
"Aggregate Foundation Course _____" - Square Yard or Ton (square meter or megagram)
In place weight for 4"+1/4" trimming = (yd³ x 0.2222 Tn/yd³) = Tons
[100 mm + 5 mm = (m² x 0.2415 Mg/m²) = Mg]

Gravel Embedment – Special Provision

"Gravel Embedment" – Station
"Gravel" – Cubic Yard (cubic meter) (Designer's item)
Note: Design is usually 2" (50mm) gravel embedded in the upper 4" (100mm) & cap with 1" (25mm).

Granular Subdrains - Section 915

"Granular Subdrains" – Each

Guardrail Surfacing – Special Provision

"Surfacing Under Guardrail" – Square Yards (square meters)
Note: Pay item includes asphalt or concrete surface (contractor's option) and subgrade preparation.

Hot In-Place Recycling – Special Provision

"Hot In-Place Recycling" – Station
"Emulsified Asphalt for Hot In-Place Recycling" - Gal 1.0% weight of RAP

Hydrated Lime Slurry Stabilization – Special Provision

"Hydrated Lime Slurry Stabilization" – Station
"Hydrated Lime" – Ton 1.50% weight of RAP (4"x24' = 0.9 tons/sta) (5"x24' = 1.1 tons/sta)
"Emulsified Asphalt For HLSS" – Gal. 1.75% weight of RAP & Lime (4"x24' = 245 gal/sta)(5"x24' = 307 gal/sta)
"Fog Seal" – Gallon 0.10 Gal/yd²
Note: Growth factor approx. ¾" for a depth of 3" to 5". 1" for a depth of 6"

Intersections and Driveways – Section 302 & Section 503

"Preparation of Intersections and Driveways" – Square Yards (square meters)
"Placement of Asphaltic Concrete For Intersections and Driveways" – Square Yards (square meters)
Note: Asphaltic concrete paid for by roadway tonnage or megagrams.

Joint Sealing Asphalt to Concrete – Section 508

"Joint Sealing – Asphalt to Concrete" – Station (one side)

Microsurfacing – Section 514

"Microsurfacing Placement - Station	
"Emulsified Asphalt for Microsurfacing" – Gallon (liter)	12.0% of total tons 240 Gal = 1 ton (1000L=1Mg)
"Aggregate for Microsurfacing" – Ton (megagram)	83.8% of total tons (Mg)
"Mineral Filler for Microsurfacing" – Ton	1.7% of total tons (Mg)
Note: Weight Factor is 6.6 Tn/100 ft² (2.1 Mg/m²)	

Note: Lift thicknesses are ¼" and calculate rut depth if applicable.

Performance Graded Binder (-**) – Special Provision**

Use the table on page 5 to estimate the tons.

Removal and Processing of Concrete Pavement – Section 312

"Crush Concrete Pavement" – Square Yard (square meters)

Rubblization of Concrete Pavement (Resonant Breaker) – Special Provision

"Rubblization of Concrete Pavement (Resonant Breaker)" – Square Yard (square meters)
Note: Also include quantity for "Asphaltic Concrete for Patching, Type "___""

Rumble Strips – Special Provision

"Rumble Strips" – Station

Shoulder Subgrade Preparation – Section 302

"Shoulder Subgrade Preparation" – Station	
"Water" – MGallon (kiloliter)	0.5 MGal/Sta (6.0 kL/Sta)
Note: Shoulders are measured separately	

Special Surface Course – Special Provision

Note: Use this item if placing millings on driveways or under guardrail

"Special Surface Course" – Square Yard (square meter)	
"Fog Seal" – Gallon	2 applications, 0.20 Gal/yd² for soil and 0.30 Gal/yd² for the surface
(liter)	(2 applications, 0.91 L/m² for soil and 1.36 L/m² for the surface)

Subgrade Preparation – Section 302

"Subgrade Preparation" – Station or Square Yard (square meter)	
"Water" – MGallon (kiloliter)	1.0 MGal/Sta (12.0 kL/Sta) or 0.003 MGal/yd² (0.014 kL/m²)

Subgrade Preparation for Widening – Special Provision

Note: Use for concrete pavement widening	
"Subgrade Preparation for Widening" – Station (one side)	
"Water" – MGallon (kiloliter)	0.5 MGal/Sta (6.0 kL/Sta)

Subgrade Stabilization – Section 303

"Subgrade Stabilization" – Station or Square Yard (square meter)		
"Soil Binder" – Cubic Yard (cubic meter)	12.5 yd³/Sta for (6" x 30')	[31 m³/Sta for (150mm x 9m)]
"Water" – MGallon (liter)	1 MGal/Sta or 0.003 MGal/yd²	(12.0 kL/Sta or 0.014 kL/m²)

Note: Quantity of soil binder will vary depending on soil conditions.

Surfacing – Special Provision

"Surfacing "___"" – Square Yard (square meter)

Note: Contractor's choice for pavement type, asphaltic concrete or portland cement concrete.

Stabilized Subgrade (8"depth) – Special Provision

"Stabilized Subgrade Type Cement" – Square Yard		use if PI of soil is 20 or more
"Cement" – Ton	46 lbs/yd²	hydrated lime quantity is **7% of soil tons
"Stabilized Subgrade Type Fly Ash" – Square Yard		use if PI of soil is 19 or less
"Fly Ash – Ton	66 lbs/yd²	fly ash quantity is **10% of soil tons
"Stabilized Subgrade Type Lime" – Square Yard		use if PI of soil is 20 or more
"Hydrated Lime" – Ton	33 lbs/yd²	hydrated lime quantity is **5% of soil tons
"Water" – MGallon	1 MGal/Sta or 0.003 Mgal/yd²	

***Soil weight compacted in place, 110 lbs/ft³*

Tack Coat – Section 504

"Tack Coat" – Gallon (liter)	
Factor for existing surface	0.150 Gal/yd² (0.680 L/m²)
Factor for between lifts	0.050 Gal/yd² (0.230 L/m²)

Temporary Surfacing – Special Provision

"Temporary Surfacing"___"" – Station or Square Yard (square meter)

Note: Contractor's choice for pavement type, asphaltic concrete or portland cement concrete.
Note: Subgrade Preparation, earth shoulder construction all water applied and removal are subsidiary.

Trenched Widening – Special Provision

"Trenched Widening" – Station (one side)

Note #1– Use this item when you have an existing 24' road widen to 28' (2' per side)
Note #2– Pay for "Earth Shoulder Construction"

Widening – Special Provision

"Widening" – Station (one side)

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
LC	64 ~~(70~~-34)	NA	NA	7.0%
RLC	(64-34)	NA	NA	7.0%
SPR	(64-34)	3.4	NA	NA
SPR (Fine)	(64-34)	NA	3.4	NA
SPS	(52-34)	3.2	NA	NA
SPH	64 ~~(70~~-34)	3.8	3.8	NA
UTBA Wearing Course	(64-34)	5.6%	NA	NA

Temporary Interstate/ some expressway PG 70-16
Temporary for all other highways PG 64-22

Hydrated Lime/WMA

Example: If you comp.10534 tons of Asphaltic Concrete Type "SPR" there will be 10534 Each of "Hydrated Lime/WMA".

Asph. Conc. Type	"Hydrated Lime/WMA" Pay item is "Each" multiply tons of asphalt by
GGCRM	1
GGCRNLV	1
LC	1
RLC	1
SPR	1
SPR (Fine)	1
SPS	NA
SPH	1
UTBA	1

Asphaltic Concrete Tonnage Table

Asphaltic Concrete Types

	Bit			UTBA					Soil	
	Sand	Bit		Wearing			SPR(Fine)	LC	Agg	
	Base	Fnd		Course			SPR	RLC	Base	
	Crse	Crse	OGFCCRMM	GGCRM	GGCRMLV	SPH		SPS	Crse	HRB

Tons per 100 Cubic Feet

	6.0	6.2	6.3	6.75	6.95	7.15	7.25	7.30	7.35	7.40

Pounds per Cubic Foot

	120	124	126	135	139	143	145	146	147	148

Tons/SqYd/Inch

Inches										
1	0.045	0.050	0.050	0.051	0.052	0.054	0.054	0.055	0.055	0.055
1.5										
2	0.090	0.093	0.095	0.101	0.104	0.107	0.109	0.110	0.110	0.111
2.5										
3	0.135	0.140	0.141	0.151	0.156	0.161	0.163	0.164	0.165	0.166
3.5										
4	0.180	0.186	0.189	0.202	0.208	0.214	0.218	0.219	0.221	0.222
4.5										
5	0.225	0.233	0.236	0.253	0.260	0.268	0.272	0.274	0.276	0.278
5.5										
6	0.270	0.279	0.284	0.303	0.313	0.322	0.326	0.329	0.331	0.333
6.5										
7	0.315	0.326	0.331	0.354	0.365	0.375	0.381	0.383	0.386	0.388
8	0.360	0.372	0.378	0.405	0.417	0.429	0.435	0.438	0.441	0.444
9	0.405	0.419	0.425	0.456	0.469	0.483	0.489	0.493	0.496	0.500
10	0.450	0.465	0.473	0.506	0.521	0.536	0.544	0.548	0.551	0.555

Asphaltic Concrete Megagram Table

Asphaltic Concrete Types

	Bit Sand Base Crse	Bit Fnd Crse	SPH		SPR(Fine) SPR	LC RLC SPS	Soil Agg Base Crse

Megagrams per Cubic Meter

	1.922	1.986	2.291	2.307	2.323	2.339	2.355

Megagram per Square Meter - Millimeter

mm							
13	0.0250	0.0258	0.0298	0.0300	0.0302	0.0304	0.0306
25	0.0481	0.0497	0.0573	0.0577	0.0581	0.0585	0.0589
30	0.0577	0.0596	0.0687	0.0692	0.0697	0.0702	0.0707
40	0.0770	0.0795	0.0916	0.0923	0.0929	0.0936	0.0942
45	0.0865	0.0904	0.1031	0.1038	0.1045	0.1053	0.1060
50	0.0962	0.0994	0.1146	0.1154	0.1162	0.1170	0.1178
60	0.1154	0.1193	0.1375	0.1385	0.1394	0.1404	0.1414
80	0.1539	0.1590	0.1833	0.1846	0.1858	0.1872	0.1885
90	0.1732	0.1789	0.2062	0.2077	0.2091	0.2106	0.2120
100	0.1924	0.1988	0.2291	0.2308	0.2323	0.2340	0.2356
105	0.2018	0.2085	0.2406	0.2422	0.2439	0.2456	0.2473
120	0.2309	0.2386	0.2749	0.2770	0.2788	0.2808	0.2827
130	0.2501	0.2584	0.2978	0.3000	0.3020	0.3042	0.3063
135	0.2595	0.2681	0.3093	0.3114	0.3136	0.3158	0.3179
150	0.2886	0.2982	0.3437	0.3462	0.3485	0.3510	0.3534
180	0.3463	0.3578	0.4124	0.4154	0.4181	0.4212	0.4241
205	0.3940	0.4071	0.4697	0.4729	0.4762	0.4795	0.4878
230	0.4425	0.4572	0.5269	0.5308	0.5343	0.5382	0.5419
255	0.4901	0.5064	0.5842	0.5883	0.5924	0.5964	0.6005
280	0.5387	0.5566	0.6415	0.6462	0.6504	0.6552	0.6597
305	0.5862	0.6057	0.6988	0.7036	0.7085	0.7134	0.7183
330	0.6343	0.6554	0.7560	0.7613	0.7666	0.7719	0.7772
355	0.6823	0.7050	0.8133	0.8190	0.8247	0.8303	0.8360

Chapter 10: Lab Procedures

10.1 NDOR Testing and Sample Preparation

Date: 1/5/07
Source: Syslo

TESTING AND SAMPLE PREPARATION FOR:

1) Lime Modified Subgrades

2) CKD Modified Subgrades

3) Fly Ash Modified Subgrades

4) Full Depth Reclamation with Fly Ash

5) Full Depth Pavement Pulverization using subbase material

LIME MODIFIED SUBGRADES (using pebble quicklime)

1) Perform Eades and Grim test on soil to find target lime content (12.4 pH)
2) Perform soluble sulfates test on soil (<0.2% soluble sulfates in 10:1 H2O to Soil)
3) Prepare specimens at 4% over optimum moisture (virgin soil)
4) Prepare specimens at target lime content and 1% over and 1% under
5) Compact specimens
6) Cure in sealed container at 75 degrees near 100% humidity for 6 days
7) Cure in exposed atmosphere at 75 degrees for 24 hours
8) Perform unconfined compression tests
9) Report : virgin soil PI
   virgin soil compressive strength
   virgin soil optimum moisture & density
   modified soil PI
   modified soil compressive strength
   modified soil density

CKD MODIFIED SUBGRADES (minimum 20% free lime material)

1) Perform soluble sulfates test on soil (<0.2% soluble sulfates in 10:1 H2O to Soil)
2) Prepare specimens at 2% over optimum moisture (virgin soil)
3) Prepare specimens at 4, 6 & 8% CKD
4) Compact specimens
5) Cure in sealed container at 75 degrees near 100% humidity for 6 days
6) Cure in exposed atmosphere at 75 degrees for 24 hours
7) Perform unconfined compression tests
8) Report : virgin soil PI
   virgin soil compressive strength
   virgin soil optimum moisture & density
   modified soil PI
   modified soil compressive strength

FLY ASH MODIFIED SUBGRADES (using class C fly ash)

1) Prepare specimens at 2% over optimum moisture (virgin soil)
2) Prepare specimens at 10, 12 & 15% Fly ash
3) Compact specimens
4) Cure in sealed container at 75 degrees near 100% humidity for 6 days
5) Cure in exposed atmosphere at 75 degrees for 24 hours
6) Perform unconfined compression tests
7) Report : virgin soil PI
   virgin soil compressive strength
   virgin soil optimum moisture & density
   modified soil PI
   modified soil compressive strength
   modified soil density

FULL DEPTH RECLAMATION (using class C fly ash)

1) Prepare samples by adding water to make the sample friable (millings and soil)
2) Prepare specimens at 6, 8, & 10% Fly ash
3) Add water 4% by weight of Rap + Ash
4) Add soil based on thickness of soil incorporated in reclamation process
5) Dry back small sample of blended material to determine total moisture content
6) Compact specimens
7) Cure in sealed container at 75 degrees near 100% humidity for 6 days
8) Cure in exposed atmosphere at 75 degrees for 24 hours
9) Perform unconfined compression tests
10) Report : compressive strength
    moisture & density

FULL DEPTH PAVEMENT PULVERIZATION (using subbase material)

1) Prepare samples by adding water to make the sample friable (millings and soil)
2) Add water 4% by weight of Rap
3) Add soil based on thickness of soil incorporated in reclamation process
4) Dry back small sample of blended material to determine total moisture content
5) Compact specimens
6) Cure in sealed container at 75 degrees near 100% humidity for 6 days
7) Cure in exposed atmosphere at 75 degrees for 24 hours
8) Perform unconfined compression tests
9) Report : compressive strength
   moisture & density

EXAMPLE

Full Depth Reclamation Project using fly ash

Plan is 10” full depth reclamation.
Pavement is approximately 8” and therefore 2” of soil will be reclaimed as well
Prepare 2500 to 3500 gram batches

Three fly ash blends	6%	8%	10%
RAP (just use 2500g)	2500g	2500g	2500g
Fly Ash (by weight of RAP)	150g	200g	250g
Water (4% by weight of RAP plus Ash)	106g	108g	110g
Soil	521g	521g	521g

This is the tricky one. Using the unit weights below, in one square foot of roadway there is 96 lbs of millings, and 20 lbs of soil. So now use a ratio, 20 is to 96 as X is to 2500 or in equation form → $\frac{20}{96} = \frac{X}{2500}$; so X = (20 / 96) x 2500 = 521 grams

Also note that the amount of soil is affected by the ratio of the thickness of the existing asphalt to the thickness of the soil planned on being reclaimed. For instance in the example above you are using 521 grams to make the batch. If you had 12 inches of RAP and were only going 1 inch into the subbase material, the soil in that batch design would be 174 grams, significantly lower but with the same amounts of Rap, Ash and Water.

Unit Weights
Asphalt 144 lbs/cu. ft.
SABC 110 lbs/cu. ft.
Soil 120 lbs/cu. ft.

Chapter 11: Historical Data

11.1 Super Pave Asphalt Mix Requirements

Date: 1999

COARSE AGGREGATE ANGULARITY
ASTM D5821

	TRAFFIC, ESAL's	DEPTH FROM SURFACE	
		<100 mm	>100 mm
SP 1	< 300,000	55	----
2	< 1,000,000	65	----
3	< 3,000,000	75	50
4	< 10,000,000	85/80	60
5	< 30,000,000	95/90	80/75
6	<100,000,000	100/100	95/90
7	≥100,000,000	100/100	100/100

FINE AGGREGATE ANGULARITY
AASHTO TP33, METHOD A

	TRAFFIC, ESAL's	DEPTH FROM SURFACE	
		<100 mm	>100 mm
1	< 300,000	----	----
2	< 1,000,000	40	----
3	< 3,000,000	40	40
4	< 10,000,000	45	40
5	< 30,000,000	45	40
6	<100,000,000	45	45
7	≥100,000,000	45	45

FLAT, ELONGATED PARTICLES
ASTM D4791

	TRAFFIC, ESAL's	PERCENT, MAXIMUM
SP 1	< 300,000	----
2	< 1,000,000	----
3	< 3,000,000	10
4	< 10,000,000	10
5	< 30,000,000	10
6	< 100,000,000	10
7	≥ 100,000,000	10

CLAY CONTENT
AASHTO T176

	TRAFFIC, ESAL's	SAND EQUIVALENT, MINIMUM
1	< 300,000	40
2	< 1,000,000	40
3	< 3,000,000	40
4	< 10,000,000	45
5	< 30,000,000	45
6	< 100,000,000	50
7	≥ 100,000,000	50

Source: Rea

	GYRATORY COMPACTION EFFORT			
	DESIGN ESAL's (MILLIONS)	Nini	Ndes	Nmax
1	< 0.3	7	68	104
2	0.3 - 1	7	76	117
3	1 - 3	7	86	134
4	3 - 10	8	96	152
5	10 - 30	8	109	174
6	30 - 100	9	126	204
7	> 100	9	142	233

MIXTURE DESIGN REQUIREMENTS

VMA CRITERIA	
NOMINAL MAXIMUM AGGREGATE SIZE,	MINIMUM VMA, PERCENT
9.5 mm	15.0
12.5 mm	14.0
19.0 mm	13.0
25.0 mm	12.0
37.5 mm	11.0

	VFA CRITERIA	
	TRAFFIC, ESAL's	DESIGN VFA, PERCENT
1	< 300,000	70 - 80
2	< 1,000,000	65 - 78
3	< 3,000,000	65 - 78
4	< 10,000,000	65 - 75
5,6,7	≥ 10,000,000	65 - 75

11.2 Layer Coefficient Data

Date: 7/28/71 & 1998
Source: Inghram & Rea

FYI ONLY

July 28, 1971

Donald Inghram

L. J. Bryant

DESIGN COEFFICIENTS FOR FLEXIBLE PAVEMENT

In connection with setting up a computer program for design, we feel that it would be desirable to have a list of standard coefficients for various pavement components which would be acceptable to everyone concerned. Consequently, Rosecrans has prepared the following list for consideration. These values are based on Table 8, page 438, of the AASHO Road Test report SR-73.

Surface Course	New Surface	Existing Surface
Asph. Conc. Type A	0.44	0.24
Asph. Conc. Type B	0.40	0.24
Asph. Conc. Type C	0.44	0.24
Asph. Conc. Type D	0.40	0.24
Asph. Sand	0.30	0.18
Armor Coat	--	--
Bit. Sand Base	0.20	0.12
Mixed-in-Place	0.15	0.09

Base Course	New	Existing
SABC	0.14	0.14
Bit. Sand Base	0.20	0.20
Lime Treated Subgrade	0.14	0.14
Mixed-in-Place	0.15	0.15
Granular Subbase	0.11	0.11
Crushed Rock	0.14	0.14
P. C. Concrete	0.50	0.40

It is recognized that some of the figures are somewhat controversial and that changes will probably have to be made before agreement is reached. AASHO states that the 0.44 for high stability asphaltic concretes and the 0.11 for subbase are the only values based on data and that all the others are assumptions.

BIT MILLINGS BASE	.20	50,000 PSI
SABC	.14	22,000 PSI
EXISTING AC	.24	450,000 PSI
NEW AC	.44	450,000 PSI
BIT SAND	.20	150,000 PSI
FOAMED ASPHALT	.18	

FYI ONLY

L. J. Bryant
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July 28, 1971

The 0.40 for Type B and Type D is a departure from our usual practice, but this is based on the fact that it usually has a Marshall Stability between 1000 and 1200. On the other hand, the only asphaltic concrete given a value of 0.44 is that with a stability of 2000 or over, and for Type A and C this may be stretching it somewhat. In any event these and several other factors will need to be reviewed.

Donald Inghram
Bituminous Materials Engineer

DIInghram:mf

cc: OLLund
CRosecrans

Nebraska

Department of Roads

Memorandum

FYI ONLY

Date: November 18,1998

To: Bob Rea

From: Dan Nichols DN

Subject: Structural Coefficient for Bituminous Millings Base (Pavement Design)

Initial results from the studies conducted at Kansas State's accelerated testing laboratory indicate that .26 is a reasonable value to use for the structural coefficient for a bituminous millings base. We expect the final report to be available within the next two to three months and we will provide you with a copy of that report.

xc: G.V. Woolstrum

ANOTHER KANSAS STUDY SHOWED FOAMED ASPHALT HAS STRUCTURAL COEFFICIENT OF 0.18.

printed on recycled paper

11.3 History of NDOR Asphalt

Date: 9/12/07
Source: Koves

ASPHALT THROUGH THE YEARS IN NEBRASKA

FIFTIES TO EARLY SIXTIES

During the fifties and early sixties, what was called a Low Type asphaltic concrete was produced. It consisted of gravel, sand and limestone dust filler. The mix design was made by the Bituminous Engineer and in the lab after mixing, a 4" x 4" asphalt cylinder was made on a compression machine. It consisted of a 4" mold with a double plunger. With the bottom plunger in place and the molding cylinder supported temporarily on the two steel bars, the hot mixture was added to the mold. The mixture was spaded two or three times around the inside of the mold with a heated spatula to reduce surface "honeycomb." It was then compressed between the top and the bottom plungers under an initial load of about 150 psi. to set the mixture against the sides of the mold. The pressure was then released and the support bars removed to permit full double plunger action and the entire load of 3000 psi. was applied and maintained for two minutes. After removal from the mold specimens were cooled and a density was run by weighing in air and then weighing in water. The special provisions provided that the mixture be compacted to a percentage of the control density. During production a 2" mold was used to control density and had to be a certain percentage of the original 4 x 4 puck. These densities were made every 500 tons and everything was molded at 255°F $\pm$5.

EARLY SIXTIES TO MID SEVENTIES

As more earth roads are converted to gravel, more counties are showing an increased interest in bituminous surfacing. Counties with sufficient funds were matching them with Federal aid funds to provide a higher type of improvement; others are hiring contractors, or purchasing equipment and doing the work with their own forces. When this is done under competent and skilled supervision, good results are noted. The early 60's saw the culmination of many efforts, and high type bituminous road construction will reach nearly fifty miles, more than half the total of gravel roads constructed with Federal funds in the same period.

July 1, 1964 to June 30, 1965, 144.8 miles of asphaltic concrete was contracted for work. The specifications and testing of asphaltic concrete was getting under way and by June 30, 1966 another 156.7 miles was let.

Testing of asphalt materials has come a long way at the NE Dept. of Roads. The first mix designs of the sixties and early seventies were created by the Flexible Pavement Assistant Engineer (FPAE). The mixes, much like today, were based on the amount of traffic.

For higher traffic a mix called Type "A" was used. It contained crushed limestone, crushed gravel and limestone dust for filler with about 15% retained on the 3/8" sieve. For lower traffic roads the mix was Type "B" and contained mostly river gravels, sand and limestone dust filler and retained about 22% on the #4 sieve. And finally we had a mix used for leveling courses and bridge wedges called a Type "C". It contained about 100% crushed road gravel, had about 8% retained on the #4 sieve and an asphalt content of around 6.0 to 7.0%. It worked very well for leveling courses and also from keeping moisture from getting to the surface from below. After the mix type was decided upon and bids received by the contractors, the lowest bid were accepted. The contractor would then submit the materials for use and the aggregate was tested for quality and gradation. Then the FPAE would design the mix. He would take the gradations of the aggregate and come up with certain percentages of each, totaling 100%. After figuring out the percentages it was sent to the lab for mixing and testing. At least 2 to 3 designs were always made, one with high asphalt content and one about a percent lower. On each design a variety of testing was done. The testing done on these 2 to 3 designs were our verification that when production on the project started, that everything would meet specification. During construction the NDOR labs ran all the tests

below on each sample but the state person in the contractors lab was the key. Their test results were how the job ended up being paid for. Their AC contents, gradations and densities were what controlled the project. The NDOR labs were more or less used for disputes.

The asphalt cement used was penetration graded (hardness) and normally was 85 -100. All designs were mixed at 300°F and all Marshall specimens were compacted at 250°F ± 5. Three 4" X 2 ½" specimens were molded using a Marshall hammer. This test was a 10 lb. slide hammer attached to a 4" round, slightly angled, foot. The heated material was placed into the mold and then the whole assembly was placed on a rotating base. The 10 lb. slide hammer was inserted into the mold and the hammer would pound the asphalt a certain number of times, usually 50 blows. The sample was then flipped over and the routine repeated. After slight cooling, the samples were extruded and set aside to cool. When samples were at room temperature (approx. 1 hour), samples were weighed in air, weighed in water and saturated surface dried with a damp towel and weighed again. The densities were then figured and an average was obtained. All three samples were then placed in a 140° F water bath for 30 minutes ±5 and stability and flow was obtained.

Also from our design a Voidless Density (zero percent air voids) was obtained. It consisted of a sample approximately 800 – 1000 grams which was cooled and broken into individual pieces. When cooled it was placed into a calibrated glass container and weighed, covered with water at least an inch over the surface of the mix and placed under vacuum of about 28 mm Hg. After about 10 minutes the pressure was released and the sample was carefully placed into a water bath and weighed again. A maximum specific gravity was then figured.

Next an extraction sample of about 1000 gr. was weighed and a placed into an aluminum bowl. Perchloroethylene(a very strong degreaser) was then added and the sample was stirred until broken down. From there the sample was lidded and placed into the Rotorex (a centrifuge) where the liquid and asphalt was spun off into a calibrated flask. Perchloroethylene was then added in small portions and spun until liquid became straw colored. The clean sample was then scraped from the bowl and placed into an oven to dry. The liquid in the flask was also weighed and the temperature was taken. After the aggregate was dried and weighed, an asphalt content could be calculated. The oven dried sample was then washed, dried again and the gradation was obtained to ensure the specification of design.

The last test run was a Dry Displacement on the combined virgin aggregate. With the results from this and a similar test called a Volumetric test, was how the production was controlled in the field. A 1000 ml flask was used and a 1000 gram sample of the combined virgin aggregate was added. Perchloroethylene was added to a pre-determined line on the flask and the flask was then corked, rolled and bounced on a rubber pad for 10 minutes to remove all the air. After ten minutes, the flask was filled back to the line and a siphon was used to remove solvent to a calibrated limit, weighed and a temperature was taken. The volume displaced by the virgin aggregate was then figured. During production in the field they used the same test, only with the asphalt coated roadway material. A random sample was taken and a 1000 gram sample was split out from that. The testing was done the exact same way, called a Volumetric and when completed the two numbers were algebraically compared and an asphalt content was determined. The aggregate was then washed with solvent and a gradation was run.

After all the tests were run and the results were all figured, the engineers from the Flexible Pavement and the lab supervisor would all gather and look at the results to decide the asphalt content for production. They looked at the stability and flow of the Marshalls, how the mix looked, air voids, voids filled with asphalt (VFA) and then each voted on a percent binder to be added and the results were averaged. The required asphalt content, aggregate proportions and combined gradation to be maintained was then sent to the contractor and construction could begin. During production the contractor furnished a lab for a state employee to be on the job. The state employee ran all Volumetric test and gradations out of that lab. Production sample were also sent to the Branch lab closest to the job sight for testing but the only pay factor items were for asphalt content, gradation and density.

Always trying new things and experimenting with different materials in asphalt was also big during this time period. We had already experimented using crushed glass as a replacement for aggregate and in the late sixties, the first of a few asbestos roads were built, using approx 2% asbestos to replace the mineral filler. In the early 70's we tried to use crushed Bakelite and there are even a couple of roads that contain shredded asphalt shingles. It seemed like everyone thought that waste products could be used in asphalt.

The asphalt cement (AC) during this era was penetration (hardness) and viscosity graded and the penetration most used was an 85 -100. Voids in the asphaltic concrete surface (field density) varied from 3.5% to 12.0% depending on how much AC it contained and there were no real minimum or maximum requirement. Laboratory voids on Marshall specimens were running about 1.2% to 4.5%.
One other thing that should be noted during this time period is the crushing of our river gravels. During the sixties and seventies and even some into the eighties the specification for the crushing of gravels was gradation limits before and after crushing. Most notably, the crushing specification for gravels was 70 $\pm$ 30% retained on the #4 sieve before crushing and after crushing the specification was 8 $\pm$ 8 retained on the #4 sieve. This made a highly angular material and worked quite well in our Type "A" mix designs for durability on our higher traveled roadways with the tire pressures and truck traffic at the time.

MID SEVENTIES THROUGH THE EIGHTIES
Prior to 1977, limestone dust had been used exclusively as mineral filler for asphaltic concrete. In 1977 that changed, as soils and fly ash, were tried and then used as mineral filler, both of which were cheaper to use. Soil was readily available everywhere and fly ash was a waste product of cement plants. Also tried but with not much success, were stack dust, beet lime and volcanic ash. Soil seemed to work quite well as filler but one had to be careful not to get into any clay deposits. Light Peorian soil worked best and was easily broken down into a fine dust. If the clay content was too high it would ball up and leave pock marks in the surface after a rain.

In about 1977, the department started to read about the highways in Europe and how well they were performing. The Europeans were using an open-graded mix on their high speed roadways. Nebraska's first attempt at this, was placed on East "O" Street from 84th Street to the Lancaster county line in 1978. It contained Platte River gravel graded mostly to be retained on the 3/8" and #4 sieve and fly ash for filler. It was called "M-1", laid 1" thick and contained an AC of 4.70%. It was laid on top of a 2" mix called "Stone-filled" which contained about 60% large limestone (mostly + ½") some crushed gravel and fly ash filler with a AC of 3.0%. This design worked quite well for several years and being so open was also very drainable. The only problem was that with the rounded river gravels, it would eventually not have much skid resistance. In 1979, this mix was redesigned on the Alvo spur to N-50 project. To increase skid resistance, crushed limestone, crushed gravel and fly ash were added, all the round river gravel removed and the mix was mostly retained on the #4 sieve.

Another new technique in the early 80's was milling of the roadway and using the millings back into the mix as aggregate. The first full fledged design of this nature was F-281-1(101) Cowles Spur North and 50% of the design was the milled material. The rest was made up of Platte River gravel. This design was a little different because the aged binder, already in the millings, had to be accounted for. The millings had to be extracted, now using Trichloroethylene instead of Perchloroethylene, and the amount of asphalt figured into the total. During the early designs we would also have the lab run a penetration on the aged asphalt. This was done by taking the liquid from our extracted material and boiling the solvent off till just the raw asphalt was left. The raw asphalt was then poured into a small tin and cooled. After cooling the sample was placed in a 77° F water bath for one hour and then a penetration was run. This told us how hard the old asphalt was and what grade of asphalt cement to use. In the eighties, we went to viscosity graded asphalt and AC-10 was comparable to an 85 -100 which is what was used for most virgin mixes. Since the asphalt was a lot harder in the millings, it was thought that using a softer grade would blend with the aged asphalt and create the desired grade. An AC-5 was used, which when pen graded,

would be like a 120 -150. For this design, 2.50% of new asphalt was added for a total of 5.10%. By introducing the millings into the design it was a great cost savings to the State because of owning the millings. The project special provisions allowed the contractor to select the method for removal and pulverization of the old bituminous material. The only two requirements were that all of the removed material had to be reduced in size to pass a 2" sieve and that including any of the underlying base course should be avoided. No major problems were encountered during the production and lay down of the recycled mixture. Actually the material appeared to be somewhat more stable than a design, using virgin materials of the same gradation.

In the 70's and early 80, the mix designs were still made by the department, field testing was still done by the state and the asphalt cement was still tested for penetration and viscosity but the department was moving forward. We were always looking at new technologies, test methods and designs around the country. As trucks got heavier, tire pressure increased and traffic got higher, the designs had to get more structurally sound also.

LATE EIGHTIES TO MID-NINETIES

During the eighties the Interstate was being overlaid and we needed some high performing designs that would withstand the increase in traffic. After reviewing the results of previous designs and how well some seemed to be working, it was decided to try a modification of the Alvo to N-50 mix. Instead of limestone, quartzite, a ledge rock from South Dakota was tried. The quartzite material was pink and very hard and angular and the "MQ" was born. "MQ" was open-graded, with a thick coating of asphalt, very drainable and laid in a thickness of 1". This meant that during a rainstorm, the water would drain off the pavement and not be thrown onto the windshield of the vehicle behind. The "MQ" contained about 65% quartzite, 25% crushed gravel and about 5 -10% fly ash. Eventually the "MQ" covered the Interstate and performed very well for many years.

Also during the eighties, more recycling work was done, this time with crushed concrete. Stockpiles of milled crushed concrete were showing up around the state and since our recycled asphalt pavement (RAP) jobs were working well, why not try this also. The problems encountered were minimal but there were things to be worked through. Crushed concrete was very absorptive and no matter how much asphalt was added the mix always looked dry. One other problem encountered throughout the years was that the piles of crushed concrete would set up and harden again over the winter and in the spring would have to be broken into again and recrushed. Recycled crushed concrete was tried for a few years but never really took off for asphalt use.

During the early 90's things began to change a little but always remember that in order to go forward you sometimes have to take one step back. In 1988 the FHWA issued a Technical Advisory (TA) about the asphalt design and field control of the mixes. The Technical Advisory's purpose was to set forth guidance and recommendations relating to asphalt concrete pavement, covering the areas of material selection, mix design and mixture production and placement. The TA was directed primarily toward developing quality asphalt concrete pavements for high-type facilities. It covered such things as different materials, quality of the aggregates, how crucial dust to asphalt was, film thickness, properties of the binder, stripping, proper mix design and the control limits, etc.

In 1993, 94 and 95 a consultant was hired by the department to conduct training on mix designing, properties of the mixes, what to look for and how to get the desired volumetric properties with Nebraska aggregates. Voids, voids in the mineral aggregate (VMA), minimum AC and many other things were learned that needed to be done to conform to what the FHWA's technical advisory deemed necessary for better roadways. New designs were initiated, crushing values of materials were looked at, target field voids were put at 3.5 - 4.0% and different Marshall blows for higher traffic roads. Even any millings that were used in the designs were given crushed values. Our new designs were as follows:

Type 1	80% crushed value for combined mineral aggregate 75 blow Marshall design A maximum of 60% limestone in the mix 4.0% target field air voids
Type 2	60% crushed value for combined mineral aggregate 75 blow Marshall design A maximum of 60% limestone in the mix 4.0% target field air voids
Type 3	80% crushed value for the mineral aggregates 75 blow Marshall design A minimum of 50 % quartzite, granite or crushed gravel meeting 100% crushed value criteria. 4.0% target field air voids
Type 4	60% crushed value for the combined mineral aggregate 50 blow Marshall design A maximum of 60% limestone in the mix 4.0% target field air voids
Type 5	80% crushed value for the combined mineral aggregate 50 blow Marshall design A minimum of 50% quartzite, granite or crushed gravel meeting the 100% crushed value criteria. 4.0% target field air voids
Type 7C	Roadway mix constructed under traffic and parking areas 20% crushed value for the combined mineral aggregate 50 blow Marshall design A maximum of 60% limestone in the mix 3.5% target field air voids
Type 7	Roadway mix when closed to traffic or shoulder mix 0% crushed value for the combined mineral aggregate 50 blow Marshall design A maximum of 60% limestone in the mix 3.5% target field air voids

Perhaps, a couple of these previously used terms should be explained. Voids are the spaces between asphalt coated aggregate after molding of the Marshall specimens or after the rollers in the field. Voids are necessary for the longevity of the roadway. Too high of voids will tend to compact and ravel and if the voids are to low there is no place for the asphaltic concrete to go but to push and shove. After lay down and the finish rollers we would like to have somewhere between 6 – 8 % voids. Six to ten years down the road after traffic, we would like to have the air voids somewhere between 3 – 5% and remain for a few more years. When the roadway gets to 2% voids or less the pavement is said to be at the end of its life.

Voids in the Mineral Aggregate (VMA) are the air voids between the virgin aggregate if you could mold a specimen of just the aggregate. VMA is important for design so that there is room for the asphalt cement. VMA varies from approximately 13 – 15% and is dependent on the nominal aggregate size.

During this time it was also discussed to involve the contractor personnel in the mix design and testing process. By 1994 the mix design and field testing was the contractor responsibility and the department had the responsibility of verifying all results, thus the Quality Assurance/ Quality Control (QA/QC) program was initiated. The Department of Roads has 4 Branch laboratories (N. Platte, Grand Island, Norfolk and Omaha) with the main lab in Lincoln. All five labs were furnished the same equipment so that correlation of testing between state labs was not a problem. Also a list of equipment was made for the contractor that was needed for their testing. The contractors began buying trailers and equipping them with the necessities. Marshall machines, rice apparatus (voidless density), ovens, sieves, shakers, sample splitters, running water, air conditioning, computers, fax machines, etc. were all included in what the contractors needed to include in their labs. The cost was great for both sides but we were turning a corner and not looking back. Unfortunately our consultant made the mistake of saying that the sands of Nebraska were "unique". These sands, unlike the rest of the country, were great builders of VMA and the cost for the material was minimal. Our new mix designs, though having better mix and field specifications, ended up not being exactly the product that we wanted. Although we had a specification for crushed value on the design, it seemed like after a couple of years that more and more of our "unique" sand was showing up in our mixes. We had given contractor crushed values for their aggregates which we thought were reasonable. For example, crushed ledge rock, was given a value of 100%. Crushed gravel was given 80% crushed value and plain river gravels and sands were 0%. If a design contained 25% crushed rock and 65% crushed gravel and 10% gravel its crushed value was 77% ((25 x100%) + (65 x 80%) + (10 x 0%) =77%). If the design criteria for this mix had 60 % crushed value, it looked like a good design. Somehow though, more and more of our VMA building sands were entering the designs and our mixes ended up becoming very tender. The department ended up with designs that would rut or fail even before the job was finished. We had taken a big step with our specifications during this time even if the roads ended up not quite where we wanted them. The contractor was running their own samples with our verification. Field samples were now being controlled, not only density and binder content, but voids, VMA, minimum asphalt contents, gradations and dust to asphalt content. Even though some mix designs left a lot to be desired, some worked quite well and we had learned quite a bit that helped us get into the next phase of building better roadways.

In the late 80's the Strategic Highway Research Program (SHRP) was developing and testing new ways to build better asphalt pavements. It was called the "Superpave" program. The program consisted of new ways to test asphalt cement (now called Performance Graded Binders) and to check the asphaltic concretes properties during design and field testing. Most testing at SHRP was finished by the early 90's and the Federal Government had bought into the program and was looking for states to try the new test methods. In 1996 and 97 the Feds were offering states money to buy new Superpave equipment and build roads to the new specifications. Superpave design methods are based on Equivalent Single Axle Loads (ESAL). This is a means of equating various axle loads and configurations to the damage done by a number of 18,000 pound single axles with dual tires, on pavement of specified strength, over the design life of the pavement. Originally 7 designs were created with SP-1 being the road with the lowest ESAL and SP-7 the highest.

Testing and equipment was quite different also, especially on the binder side. Instead of the penetration and viscosities, which were now going to be a thing of the past, new equipment was purchased and new test methods were learned. The asphalt cements went from 85 -100 and AC-10 to PG 58 -28 which were climate and temperature graded binders. The numbers were based on records from the National Weather Service and several different weather stations around the United States from the last ten years. The first number (58°C) being the average high temperature of the roadway during the summer months and the last (-28°C) being the one time low during the winter. Higher grades of binder were also better suited for highways with more ESAL's such as PG 70 -28 (polymer modified) may be used on the Interstate system because of the higher tire pressures and larger trucks.

Binder testing during this time took on a whole new look. We began testing at high temperature, low temperature, before aging and after aging, checking phase angles and elastic properties.

The Dynamic Shear Rheometer (DSR) is used for reporting of phase angles and the dynamic shear of the binders. Phase angles told us whether polymer modifications are present. Dynamic shear is an indication of the binder stiffness at the upper grade temperature and also indicates the "viscous behavior" at a lower temperature, after aging.

The Rolling Thin Film Oven (RTFO) simulates the aging of an original binder after going through the field hot mix plant during production. This material can then be run through the DSR again to see how much aging occurs during production.

The Pressure Aging Vessel (PAV) takes the RTFO material through a timed process of controlled heat and oxidation. The PAV simulates the long term aging of the binder and is then run through the DSR for the purpose of Dynamic Shear (lower temperature viscous behavior) testing again.
The Bending Beam Rheometer (BBR) and Direct Tension (DT) are used to give us test data at the lower temperatures. The BBR and DT are used to determine the low temperature stiffness and tensile properties of the binder. Stiffness correlates with brittleness at low temperatures and brittle materials are more likely to crack (BBR) or fracture (DT).

The Elastic Recovery Apparatus works in conjunction with the DSR phase angle for modified binders. It indicates whether adequate polymer modification is present or not by measuring its "elastic" properties.

The changes on the mix design were not quite so drastic. In place of the Marshall which molded a 2 ½"x 4" specimen, was a Gyratory Compactor which molded a 4 ½" X 6" specimen. Instead of the slide hammer pounding the sample a certain number of times on each side, a plunger would be hydraulically inserted into the mold with 600Kps of pressure, an angle of 1.25° placed on the sample and a set number of gyrations would all be started and stopped automatically. Each time the mold rotated, a height was obtained and printed out. All the new designs were figured for N initial, N design and N maximum and density were figured at each height. From this puck a density was run and that density was N maximum or end of the life of the pavement. N design and N initial were back figured with a simple algebraic formula.

The Rice test (maximum gravity) was basically run the same way as always and with this number and the gyratory densities, air voids at each level were figured. N design should be between 3 & 5% air voids and N maximum should be somewhere around 2%.

One of the innovations that Superpave changed was the way that the asphalt content was obtained. No longer were toxic chemicals or any type of centrifuge used. Their method involved an ignition oven where temperature was kept at 538°C and when the asphaltic concrete sample was weighed and placed into the ignition oven, the weight was entered on the oven. As the asphalt was burned off, the asphalt content was printed out and automatically shut off when burn off was complete. After cooling, this burned off sample could then be washed and a gradation obtained.
Perhaps the greatest innovations that SHRP developed, was their way of finding the angularity of the fine materials. There was no more guessing or looking under a microscope to see if fine particles were crushed to the degree necessary. Their method obtained a void content and the device was very simple but effective, involving -8 /+100 material. A mason jar with no bottom was inverted and screwed to a calibrated funnel on a tripod. Below the funnel was a calibrated brass cylinder. A finger was then placed over the hole in the funnel and the sample was poured into the mason jar and leveled. The finger was removed and the sample free fell into the cylinder. The cylinder was carefully scraped off with a straightedge and weighed. After calculating, a person could tell how angular the fines were by the void content. The higher the number the more angular the fine material was. In Nebraska we were soon to find out this test was very important to the longevity of our roadways.

Other aggregate tests included the Coarse Aggregate Angularity which was a visual count of materials above the #4 sieve. Flat and Elongated which used a device at 5:1 ratio to determine the amount of flat pieces compared to normal crushed material. To many flat pieces in a roadway surface can cause early failure. The last test, Sand Equivalent shows the relative proportions of fine dust or claylike material in graded aggregate.

LATE NINETIES TO PRESENT

Our first 2 Superpave jobs were let in 1997. Since it was early in Nebraska's Superpave career and the contractors were just getting gyratory compactors, the design was ran with both gyratory compactor and Marshall hammers as a comparison. Both designs were just called SP-97. The first project, let in February, was constructed by U.S. Asphalt from Omaha was RD-50-1(1006) In Tecumseh. It was an SP-4(3/4") containing 28%-5/8" crushed rock, 32%- ¼" limestone chips, 15% limestone manufactured sand and 25%- crushed gravel. The binder used was PG 64 -22 and the percent added was 4.65% (by weight of mix).Superpave mix specifications used on this job were: Gyratory % air voids @ Ndes = 4.0 $\pm$1.0%, VMA = 13%, Void filled with Asphalt = 65 – 78 % and field Marshall air voids = 3.5 $\pm$1.0% was subject to change based on the Gyratory results. The job was only ½ mile long and was produced during early June to mid June. During the Test Strip, the voids barely reach 2.0% and VMA never got over 11.5%. Binder and aggregates were adjusted slightly to get the design into specification and production continued. The new result was fairly consistent but still had some highs and lows. The mix was quite open and in some spots was placed between curb and gutter. Superpave had gotten off to a rocky start but the bugs got worked out by the next project.

The second project, let in May, was constructed by Henningsen Construction from Atlantic, IA was EACSTPD-STPP-50-2(120) Louisville to Springfield. It was an SP-5(1/2") containing 5%- 5/8" limestone chips, 25%- ¼" limestone chips, 30%- crushed gravel, 20% limestone manufactured sand, 20%- ¾" crushed gravel. The binder used was PG 64 -22 and the percent added to the design was 4.90%. Superpave mix specifications that were used were: VMA = 14%, Voids Filled with Asphalt = 65% to 75%, Gyratory air voids @ Ndes = 4.0$\pm$1.0 and initial field Marshall air voids of 4.0$\pm$1.0% subject to change based on gyratory results. The seven miles of construction took place the end of August and finished in early September. The production Gyratory pucks at Ndes ran very close to the specifications with the voids at about 4.0% and VMA running about 14.3%. Marshall results ran slightly lower on both. This project was built along a rock quarry with very large, heavy truck traffic and seemed to perform quite well.

In 1998, seven projects were Superpave. The department went from one end of the ESAL spectrum to the other. We made two SP-1's, two SP-2's, one SP-3, one SP-4 and one SP-5 on Interstate 680 in Omaha. All of the designs contained between 17 and 25% millings with the exception of the 680 project, where no millings was used at all. The department bought Gyratories for all the branch labs and the contractors were gearing up with all the necessary Superpave equipment too. It was quite a cost to both the contractors and the department but we were going to see significant increase in the performance of our asphaltic concrete as time went on.

By 1999, thirty-six Superpave projects were let and the Marshall equipment was being used less and less. The contractors were designing mixes using the gyratory compactor and using all of Superpave volumetric and consensus properties to control the mix in the field. Three 10,000 gram batches of their design were submitted to the NDOR lab for verification along with 6 gyratory pucks prepared for moisture susceptibility. The department was verifying all mix designs and correlating well with the contractor design and field samples

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We had started controlling our 1960, 70 and 80's designs only with field density, asphalt content and gradation. In the 1990's we controlled, not only with the previous, but also Voids, VMA, minimum asphalt content and a certain percent of crushed materials for design. Superpave gave us even more control. By 1999, the department was looking at plant produced gradations, binder content, air voids, VMA,VFA, FAA, CAA, dust to asphalt and even whether the design had a tendency to strip or not. Better grades of binder were used for higher traffic roadways.

At least one QC sample was tested for each 750 ton of mix produced. That random sample was split by the contractor and half was sent to the NDOR lab for correlation. During construction, if two consecutive points were outside the Specification limits, production was stopped until the problem was fixed.

By the end of 1999, it was decided that certification of the contractors test technicians, was necessary and another consultant was hired for technician training, mix design and certification. This consultant also trained NDOR personnel in the new methods of testing and ways to help control mixes during production. Although the end result was the contractor's responsibility, through our partnering, our roadways could only become better. The more knowledge of Superpave, on both sides, could only be helpful to the performance of our roadways in the coming years.
By the year 2000, Nebraska had turned the corner and was entirely specifying Superpave for its asphalt surfacing, including rebuilds and overlays. That's not to say everything was going to go perfectly and Superpave was a fix-all.

In May of 2000, three tied project were started using an SP-2(0.5) mix design. The three tied projects were EACSTPD-43-2(106) Adams to Bennet, RD-S55G(1007) Hickman Spur and RD-S34B(1002) Firth Spur with the Adams job starting first. The project was started using a PG 58 -28 binder from Koch Material at 5.00% (by weight of mix). The roadway surface was milled and the new asphalt was to be laid in 2 lifts of 2" each. The first and second lifts went down smoothly with air voids between 3.2 to 4.0% and VMA of about 14.4 to 15.0%. FAA on the original design was 43.5 and during construction, using the burn-off, it still ran in the 42's. Just after July 4, 2000 the Firth Spur was started, using the same design. During this time period we had very hot and humid weather and things began to change. The Adams project started flushing and by the 8th of July the Firth project had been stopped to see what the problem was so it didn't continue. Cores were taken, evaluated and NDOR could find nothing out of the ordinary except that now, where the top lift had originally been about 5.00% binder, it was now between 6.50and 10.00%. After splitting the cores on the lift line, the bottom still contained about 5.00%. When looking at some places on the project, a person could take a spade and scrape off about 1/8" to ¼" of pure binder for thirty or forty feet at a time. In other spots no flushing was noted. A letter was sent to the contractor to ask what course of action he was going to take to alleviate the problem. An upgrade in PG binder was suggested and the job was switched to PG 64 -22 from Trifinery. The project resumed August 22nd with the new binder and shut down again with the same problem on the Firth job August 24th. The mix was now totally redesigned, pulling the limestone screenings and replacing with millings from the project. The project resumed September 8 and no further flushing was found on the rest of that project, nor the Hickman Spur project.

Over the next couple of years, more projects with SP-2 designs were found to be flushing. During the Bennet project several cores were taken and kept in storage. Since the department had done all the testing it could do and really found nothing, some of the cores went to Western Research Institute in Laramie, Wy. and some to the North Central Superpave Center at Purdue University in West Lafayette, IN. to see what they could find. Nobody could come up with anything conclusive as to why our SP-2's were flushing. In 2003, the department decided that the flushing possibly was result of our fine sands. Since the SP-2's FAA was only 40, the specification was changed to 43 and seemed to alleviate some of the problems with these mix designs. In 2003, a new mix was tried and later used exclusively, for all low volume roadways. It had all the properties of an SP-4 with the exception of the gyrations which were like our SP-2 at 117. It was called an SP-4 Special, tried on a few projects in 2003 and from then on has taken the place of our SP-1's,2's and 3's. During 2002 the University of Nebraska (UNL) was developing an asphalt research program in conjunction with the Department of Roads and their first project was the SP-2 flushing project. The UNL project was finished in the year 2005 and their conclusions were about like everyone else's. There was not a clear cut answer as to why the SP-2 mixes flushed.

During our Superpave tenure in Nebraska, we had been noticing on some mixes, that stripping was a problem. We had been using liquid anti-strips but the quality and variability between producers was great. We had been paying

invoice price to the contractor and they had been adding their own anti-strip at about 0.5% to percent total binder. Some contractors were using high quality liquid anti-strips and some were not. About 2002, the department was finding that some anti-strips were not compatible with the binders being used. At that time, we made it the responsibility of the binder producer to add and certify that the correct amount was added when the contractor received his binder shipment for the project.

About the same time, the department found out that the binder producers were using polyphosphoric acid to modify the upper temperature of their PG binders. They were doing this because of the cost of real polymers. The acid was a lot less expensive and the upper temperature specifications could be met using the acid. The problem was, we weren't getting the highly modified binders that we thought we were. We also had some concerns, that with the acid modification, it may react with our limestone and actually cause a stripping problem as the roadway aged. The modified binder specification was changed and producers could only incorporate a blend of base asphalt and elastomer modifiers of styrene-butadiene (SB), styrene-butadiene-styrene (SBS) or styrene-butadiene-rubber (SBR). No acid could be used.
In 2004, the department decided that liquid anti-strips were not giving us the moisture sensitivity numbers that we wanted. The industry had been using hydrated lime, as an anti-stripping agent, for quite a while. Nebraska had done some experimentation with hydrated lime and type 2 cement on a couple of earlier projects and it seemed to perform well. In late 2004, several projects were let with the option of using 1% hydrated lime in their mix designs as an anti-stripping agent and a specification was written. Originally the virgin aggregate was moistened and the hydrated lime was pug milled onto the aggregate, mixed thoroughly and dried, and then the % binder was added. By 2005, all mainline surface designs contained at least 1% hydrated lime and could be added by pug mill, lime slurry or premixed and stockpiled for use during the project.

Also in 2005, some contractors asked the department if they could verify their designs during the construction process instead of submitting verification samples to the Lincoln Lab. After some discussion it was decided that it would be tried on a few project and the mix design would be verified in the 1000 ton test strip by the NDOR Branch Lab closest to the project. By 2006 all project were handled in this way and it has seemed to work well, but as always the department is always in a learning process.

Over the years the department has come a long way. At first we were using a compression machine and controlling with density only. Then we started using Marshall equipment and controlling the projects with field density, asphalt content and gradation. The mixes were designed by the Flexible Pavement section, mixed by our laboratory and controlled and tested during production by state personnel on the project. We then learned about voids, VMA and dust to asphalt ratios. The contractor bought his own equipment, designed his own mix and helped control the field production. We still used the Marshall hammer but now during production the designs were controlled not only with density, asphalt content and gradation, but voids, VMA, dust to asphalt and we had started to have some control on crushed material. The designs definitely were far from perfect during this period but we were learning. Then along came Superpave with new design methods, equipment and more efficient ways of controlling production. Today Nebraska still uses the original Superpave designs and gyrates to Nmax but our roadway, for the most part, are now dependable and holding up quite well. We are not stuck in a paradigm but welcome new changes and ideas with open minds and arms. We know that as tire pressures and truck weights increase that more changes will be made and even better roadway will be needed. The Nebraska Dept. of Roads looks forward to what the future will hold and welcomes the challenge.

11.4 Typical RAP Percentages in Past Mixes

Date: Nov 08
Source: Koves

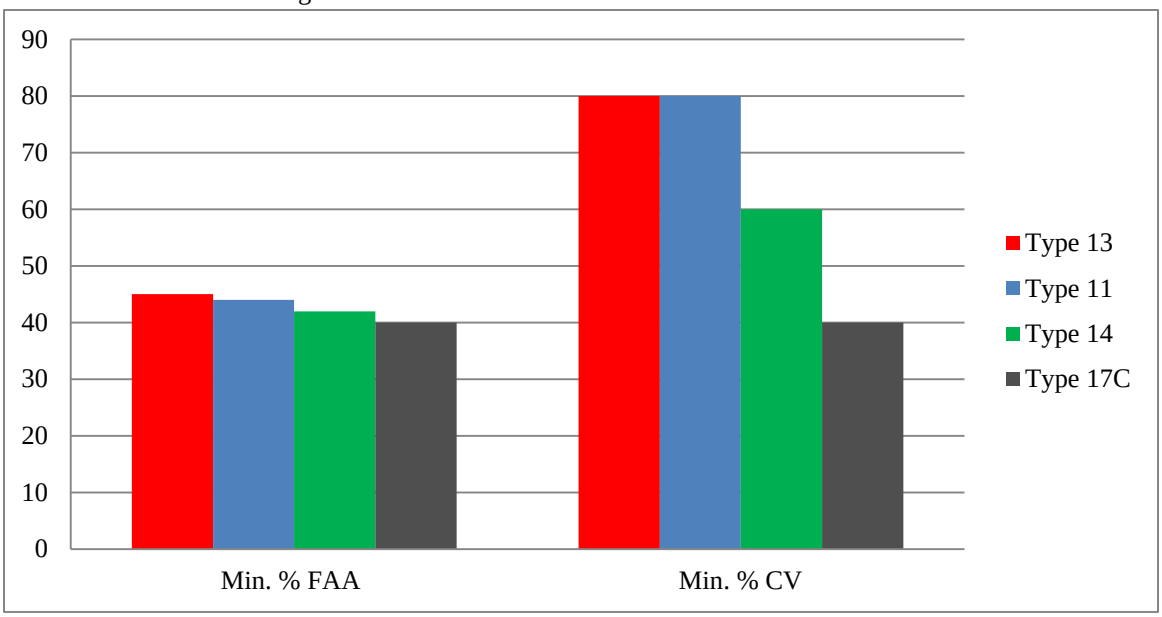
Year	Project	Type	AC Content	Recycle
1984	80-5(42)	A Sp CC	4.6%	45% Crushed Concrete
1985	80-7(75)	RCC	5.3%	40% Crushed Concrete, 50% Millings, 10% 3A
1986	80-3(96)	A Sp CC	5.3%	47% Crushed Concrete
1993	19-2(1002)	CCF	7.0%	50% Crushed Concrete
1992	12-6(1008)	RB	?	30% Millings
1993	11-2(110)	RB	4.0%	15% Millings
1993	15-2(104)	RB	4.6%	30% Millings
1983	2-3(106)	R	?	50% Millings
1983	6-3(105)	R	?	50% Millings
1984	2-4(103)	R	?	50% Millings
1984	2-6(111)	R	?	50% Millings
1984	34-4(104)	R	?	40% Millings
1985	6-3(108)	R	?	50% Millings
1990	20-3(1004)	AX	4.8%	32% Rock, 65.5% 3A, 2.5% Fly Ash
1992	15-3(109)	RAX	3.5%	25% Millings
1992	20-6(1008)	RAX	4.3%	50%
1993	14-3(1008)	RAX	4.2%	20% Millings
1993	20-4(116)	RAX Sp.	5.6%	15% Millings

11.5 Typical Crushed Values and/or FAA of Past mixes

Date: 11/12/10 (Data from 6/14/95)
Source: Varilek (Koves)

Asphalt Type	Material or Use	Crushed Value[1]	FAA
A, AX, or RAX	3A Gravel & Ledge rock	80%	-
A Special	3A Gravel & Ledge Rock	85%	-
B or RB	Mainly 2A Gravel, Some Sand	20%	-
C	3A Gravel & Sand	70%	-
MQ	Quartzite & 3A Gravel	100%	-
Q or RQ	Quartzite	100%	-
13	Interstate/Expressway Surface	80%	45%
11	Interstate/Expressway Base	80%	44%
14	Medium Volume Roadways	60%	42%
17C	Low Volume[2]	40%	40%

[1]Crushed Value *approximates* percentage of crushed material. Experience showed that although the material passed through a crusher, not all was crushed, resulting in lower actual percentages.
[2]Mix exhibited severe rutting.



Note: FAA and Crushed value are not directly related.

Chapter 12: Miscellaneous

12.1 Project Prefix Explanation

Date: 2/13
Source: Bettenhausen

SAFETY-LU		SAFETY-LU	MAP 21	MAP 21	
Prefix	**Description**	**Appr Code**	**Prefix**	**Appr Code**	**Federal Participation Rate**
IM	Interstate Maintenance: Resurfacing,	L010		M001	90%
	rehabilitation or reconstruction of the interstate			Discontinued (IM) Prefix	
	system. May not be used to add capacity.			Now use (NH)	
NH	National Highway System: Used only on	L050	NH	Discontinued (L050)	80%
	highways designated as part of the National			(Combined into M001)	(90% on the interstate if
	Highway System, including the Interstate				not used to add capacity)
BR/BH	Federal-Aid Bridge - On System: Replacement	L1C0		Discontinued (BR/BH)	80%
	(BR) or rehabilitation (BH) of bridges on the			Now use STP or NH prefix	
	federal-aid highway system.			according to the Hwy System	
BRO/BHO	Federal-Aid Bridge - Off System:	L110	BRO/BHO	M233	80%
	Replacement (BRO) or rehabilitation (BHO) of				
	off system bridges.				
STP	Any Area: Generally used on federal-aid	L240	STP	M240	80
	highways not on the NHS or interstate. Funds				
	can be used on all roads classified higher than				
	local or rural minor collector, except that certain				
	designated types of work (bridge, safety and rail				
	crossing can be used on any public road.				
HSIP	Highway Safety Improvement Program: Safety	LS30	HSIP	MS30	90%
	Improvements on any public road.				
RRZ	Rail-Highway - Hazard Elimination: Replacement	LS40	RRZ	MS40	90%
	of at grade crossings with grade				

	separation				
	structures.				
RRX	Rail-Highway - Protective Devices: Signals,	LS50	RRX	MS50	90%
	gates, etc.				
LCLC	Urbanized Areas: Population > 200,000 in	L230	LCLC	M230	80%
	the Lancaster County Lincoln City (LCLC) urban				
	area.				
MAPA	STP-Urbanized Areas: Population > 200,000 in	L230	MAPA	M230	80%
	the Omaha Metro area (MAPA).				
URB	Urban Areas: First class cities (5,000 - 200,000	L200	URB	M231	80%
	population)				
RUR	Non-Urban Areas/Counties: Allocated to counties	L250	RUR	M232	80%
	for work on rural major and minor collector routes.				
ENH	Enhancement: Use on enhancement activities	L220		Discontinued	80%
	including pedestrian/bicycle facilities; scenic/historic				
	program; landscaping/beautification; historic				
	preservation; rehab transportation structures;				
	Preserve abandoned railway corridors; remove				
	outdoor advertising; archeological planning and				
	research; mitigate water pollution of highway runoff.				
SRTS	Safe Routes to School Program: Allocation for	LU10/LU20/LU30		Discontinued	100%
	projects that promote safe walking and biking to				
	school.				
DPS/DPU	High Priority Projects: Discretionary fund for High	To Be Determined	DPS/DPU	To Be Determined	100%
	Priority Projects.				
BRD	Bridge Discretionary: Discretionary fund for bridge	To Be Determined	BRD	To Be Determined	
	construction.				
ER	Emergency Relief: Use for roads on the federal-aid	To Be Determined	ER	To Be Determined	100%/80%
	system for emergency repairs and restoration on				

	natural disaster damaged roads.				
PLH	Public Lands Highways: Use for construction on	To Be Determined	PLH	To Be Determined	100%
	roads through federal public lands.				
TAP	Transportation Alternatives Program: Replaces		TAP	M300/M301/M302/M303	80%
	funding from pre-MAP 21 programs including				
	transportation enhancements, recreational trails,				
	Safe Routes to School and several other discretionary				
	programs wrapping them into a single funding source.				

12.2 Available Working Days

Date: 2006, Reviewed 2013
Source: Brill

Month	Working Days
January	None
Febuary	None
March	None
April	15 Days
May	15 Days
June	20 Days
July	20 Days
August	20 Days
Sept	15 Days
Oct	15 Days
Nov	15 Days
Dec	None

Year Total	135 Days

12.3 Common Materials and Properties

Date: 7/27/06
Source: Varilek/ Syslo

Aggregate

- Sand - FAA ≈ 40%
- 2A Gravel – round, washed natural gravel, FAA ≈ 40%
- 3A Gravel – Crushed 2A, FAA ≈ 43-45%
- 3A Sharp Gravel – Crushed 2A, FAA ≈ 45%
- Crushed Stone CAA ≈ 95-100%
    - Limestone – NE sources, rarely used in AC due to cost of crushing, little absorption
    - Quartzite – CO sources, non-absorbent
    - Granite – CO sources,
    - Crusher Run – Aggregate (typically ledgerock but also gravel) crushed to nominal size but not washed

Fly Ash

- Class C – High Calcium (>25%), sourced in NE, currently used in soil stabilization, previously used in PCC (83-01),
- Class F – Low Calcium (<10%), sourced in TX, currently used in PCC to mitigate ASR

Cement - Classified as Type I-V

Concrete

- 47B – 30% CA (limestone), 70% FA (sand/gravel)
- 47C – 60% CA (limestone), 40% FA (sand/gravel)

Slag

- By-product of steel manufacturing
- Grade 100 – cementitious properties equal to cement
- Grade 120 – cementitious properties greater than cement

AC Modifiers

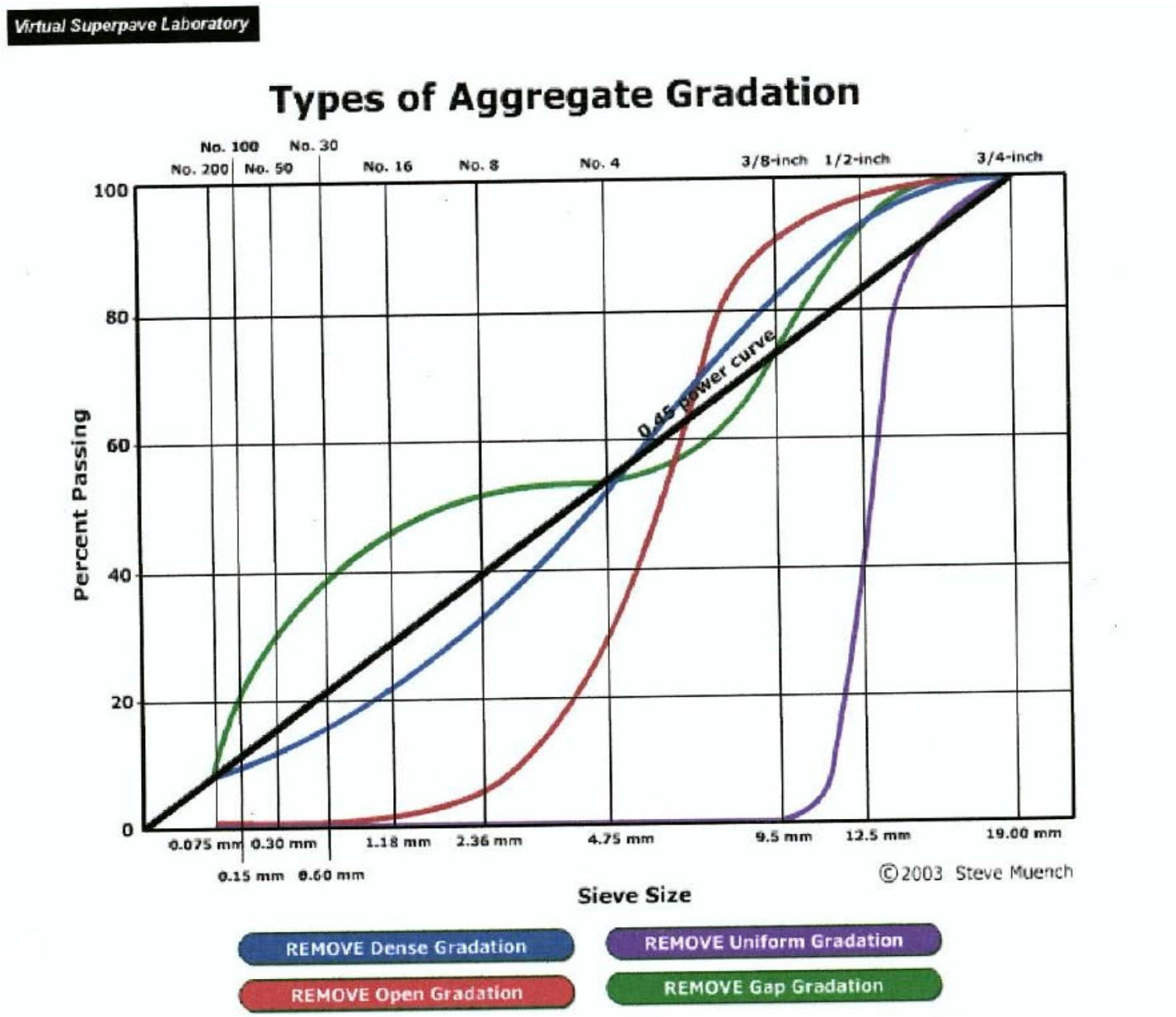
- Acid – Currently not allowed in NE
- Blown Air - Currently not allowed in NE
- Styrene Butanium Styrene (SBS) – Synthetic Polymer
- Styrene Butanium Rubber (SBR) – Synthetic Polymer
- Crumb Rubber – Ground rubber from tires

Emulsions

- Water and asphaltic oil mixture
- Allows work at lower temperature and easier mixing
- Emulsion “breaks” when water is driven off (turns from brown to black)
- Anionic (negative charge) or cationic (positive charge) used in NE
- Cutters – Can be rapid, medium or slow set (gasoline, kerosene, diesel)
    - Example CRS – Cationic, Rapid Set

12.4 Aggregate Gradation Graph

Date: Dec 06
Source: Virtual Superpave Laboratory



12.5 NCAT Asphalt Layer Coefficient

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Recalibration of the Asphalt Layer Coefficient

RESEARCH SYNOPSIS 09-03

Background

Although many highway agencies are exploring the use of new mechanistic-empirical pavement design methods, many currently still use the pavement design guide based on the AASHO Road Test in Ottawa, Illinois, from 1958 to 1960. This test established an empirical relationship between traffic loading and pavement thickness. One of the key inputs to this method is the layer coefficient for the hot mix asphalt (HMA) layers. This HMA layer coefficient has not been updated in more than 50 years despite numerous improvements in mix design methods, quality control and construction of HMA.

Objective

The primary objective of this study was to recalibrate the asphalt layer coefficient based on current paving materials and construction using data collected at the NCAT Test Track accelerated pavement testing facility (Figure 1).

Figure 1. NCAT test track

Description of Study

In the first phase of the study, a sensitivity analysis was performed to determine the influence of design inputs on the resulting HMA thickness. A total of 5,120 design iterations were conducted, as the inputs were varied. Analysis of these data showed that the layer coefficient was the most influential parameter on the resulting HMA thickness.

The second phase of the study involved recalibrating the asphalt layer coefficient using traffic and performance data from the structural sections of the 2003 and 2006 NCAT Test Track. Using the 1993 AASHTO Design Guide flexible pavement design equation, the predicted amounts of traffic in equivalent single axle loads (ESALs) were calculated to reach given levels of pavement serviceability. The predicted ESALs were compared to actual traffic on the sections. Least squares regression was performed to determine new asphalt layer coefficients for each section.

Key Findings

Figure 2 shows the computed layer coefficients for each section individually, as well as the average HMA layer coefficient of 0.54. Two test sections resulted in layer coefficients lower than the AASHTO recommended value of 0.44; however, forensic investigations showed that both sections had poor bonds between asphalt layers. No trends were observed relative to overall pavement cross-section, HMA layer thickness or binder grade.

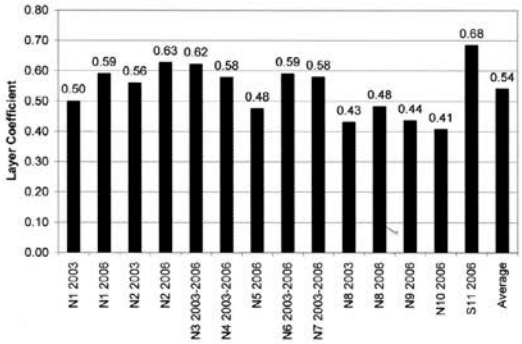


Figure 2. Computed layer coefficients for NCAT Test Track structural sections

The relationship between HMA layer coefficient and HMA modulus at 68°F is given graphically in the 1993 AASHTO Design Guide. This relationship can be modeled using a natural logarithmic function, allowing extrapolation for higher modulus values. When using the average HMA modulus value (backcalculated using falling weight deflectometer data) for the structural sections of the 2003 NCAT Test Track, this extrapolation yielded a corresponding layer coefficient of 0.543, which serves as additional validation of the 0.54 value in Figure 2.

Recommendations for Implementation

This study recommends an asphalt layer coefficient of 0.54 for flexible pavement designs using the AASHTO Design Guide. Increasing the coefficient will result in approximately 18 percent thinner HMA cross-sections. This translates directly into annual cost savings and/or more efficient use of HMA material to pave more highway mileage.

Care should be exercised when applying this coefficient in other states, as the recommended layer coefficient is based on the environmental conditions and materials used in this study.

For the Full Report, see NCAT Report 09 - 03 at www. N C AT. us

Acknowledgements and Disclaimer
This study was sponsored by the Alabama Department of Transportation. This Research Synopsis provides a brief summary of the study's final publication. This document is for general guidance and reference purposes only. NCAT, Auburn University, and the listed sponsoring agencies assume no liability for the contents or their use.
Auburn University is an equal opportunity educational institution/employer.
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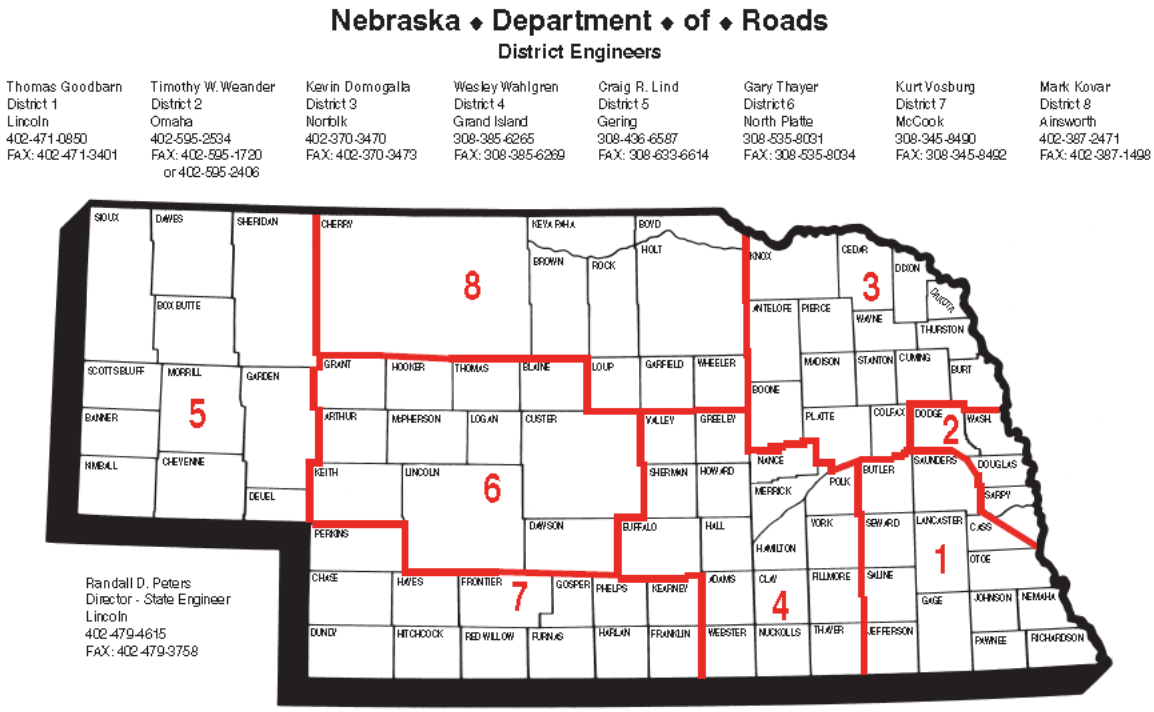
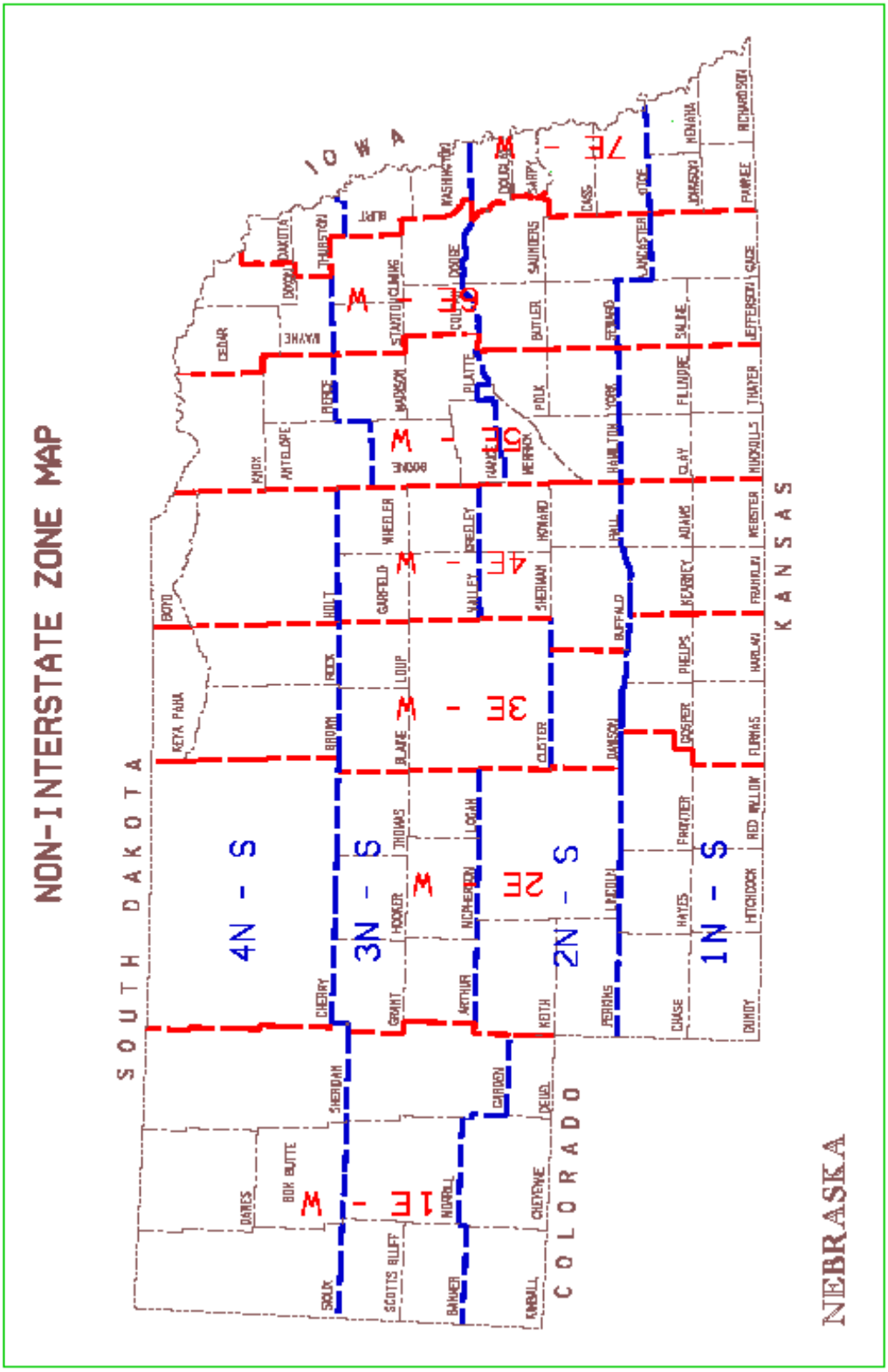
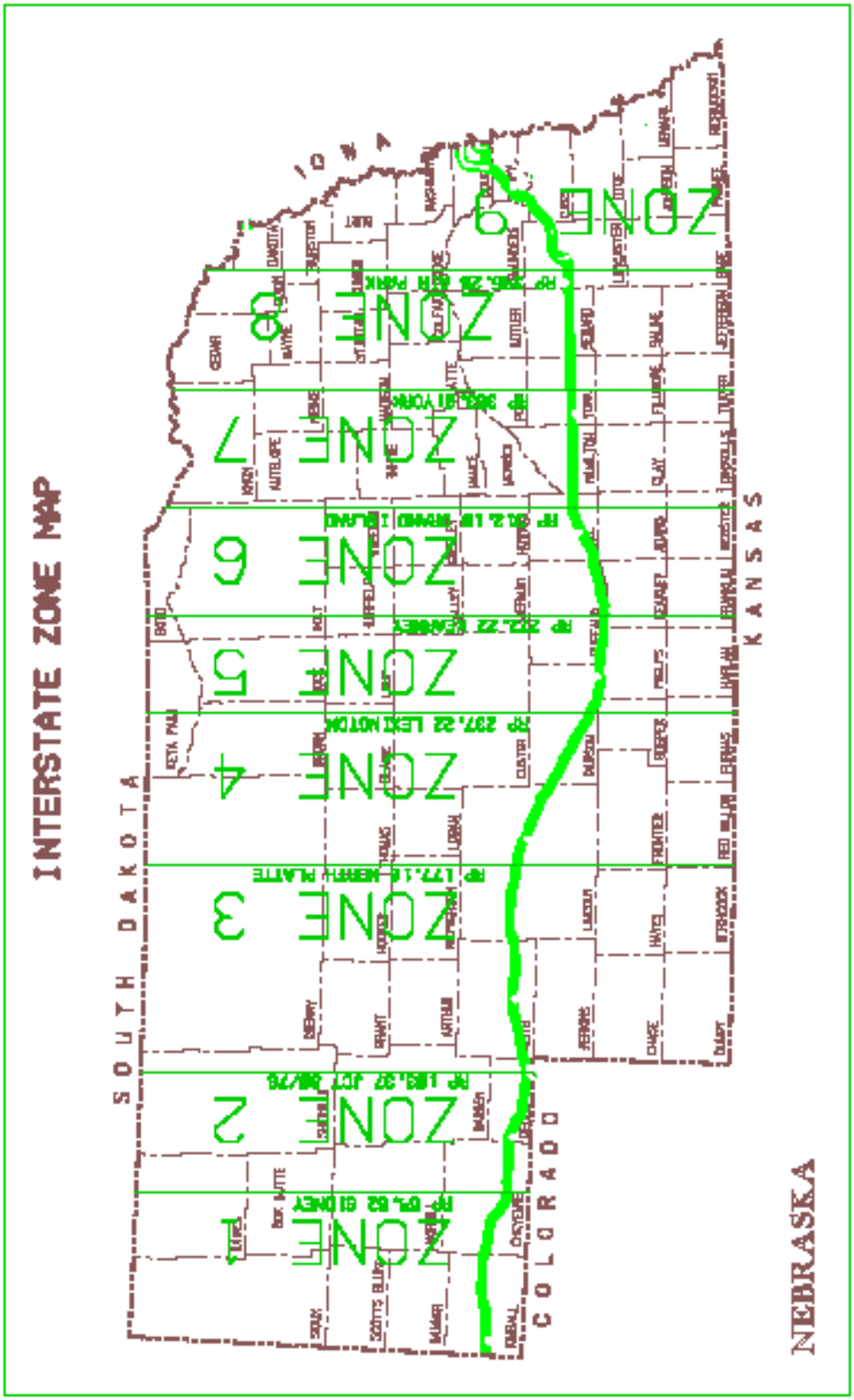
12.6 Map of NDOR Districts



12.7 Map of Zone Convention for Project Numbering




INTERSTATE ZONE MAP
SOUTH DAKOTA
COLORADO
KANSAS
NEBRASKA
IOWA
ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
ZONE 6
ZONE 7
ZONE 8
ZONE 9

12.8 28 Ft Surfaced Top - Alternate Route System

Sandhills

Two 12' wide lanes, four feet wide shoulders of which two feet are surfaced.

US-30 - RP 0.00 to RP114.31 I-80 Parallel Alternate Route System

Two 12' wide lanes, four feet wide shoulders of which two feet are surfaced.

L50A - RP 0.00 to RP 7.00 I-80 Parallel Alternate Route System

Two 12' wide lanes, four feet wide shoulders of which two feet are surfaced.

Connecting Links on the Alternate Route System between I-80 and the Parallel Alternate Route System

Two 12' wide lanes, four feet wide shoulders of which two feet are surfaced.

The links affected are those listed below. These are the links that are on the Alternate Route System and do not meet any other Need Criteria for a 28' top.

Highway Number	Length	Location
L10B	1.98	Odessa
L10C	2.5	Gibbon
L10D	3.99	Shelton
L40C	5.83	Alda
S41B	3.31	Giltner
S93A	4.39	Henderson

The approved Needs Criteria are applied to the statewide system to determine the geometric needs. These are not design standards and should not be used as such.

Approved this 21st day of January, 2010

Randall D. Peters
Deputy Director – Engineering Services

Revised January 11, 2010

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12.9 Discussion on Warrants for 28 ft Surfaced Top for a Specific Roadway Segment

Excerpt of email from Jim Knott dated 12/14/2012

When I receive these requests I review five things.

1) **The existing shoulder condition**. This evaluation is subjective and based upon a visual review from Pathweb Roadviewer. The roadway shoulders on N-71 between MM 81 and 90 appear to be in good condition with no apparent drop-offs except through some of the sharper horizontal curves.

2) **The costs to maintain the shoulders over the past five years**. This evaluation is objective and based upon a review of the maintenance costs in the Integrated Highway Inventory. This measure indicates two things. One is the amount effort the District has had to spend to maintain the shoulders over the past five years and, two, the priority the district has placed upon the shoulders on this segment of highway. Over the past fives the district has spent approximately $2,500 over a period of two years for approximately 18 miles or 36 shoulder miles for an average of $34 per shoulder mile per year. Based upon the current condition of the shoulders I would say that they do not experience much annual deterioration. The last information I have on costs indicates it costs about $50,000/mile to add the additional 4' of widening. At that rate it would take approximately 715 years to recoup the costs based upon annual shoulder maintenance costs. ☺

3) **Traffic Volumes.** This evaluation is objective and is based upon the information in the Pavement Optimization Program (POP). The warrant for 28' top is a roadway that exceeds 2,000 vehicles per day on average. Sometimes, while the roadway may not warrant a 28' top it will be close and a large volume of trucks may create a situation where a 28' top can be appropriate. The current traffic is 780 vpd and the 20 year projected traffic is 1,092 vpd with approximately 13% trucks. Since this would be a 3R project we would use a 10 year traffic which would be approximately 910 VPD. This is not very close to the warrant.

4) **Adjacent land use.** This is an objective review based upon a review of Google Earth and Pathweb Roadviewer. In general, farm equipment that serves row crops is wider and have greater impact upon the turf shoulders than equipment used in ranching and pasture maintenance. In reviewing this segment of roadway and adjacent segments there is one center pivot at the north end where row crops are being raised. The remainder is ranch land.

5) C**rash history**. This is an objective evaluation based upon a review of the crashes recorded in NECTAR. I note crashes over the past six years that could be attributed to a shoulder drop off. In general, I look for roll over or overturning crashes. This segment of roadway recorded two crashes in the past six years that were recorded as rollover crashes.

As Brandie indicated in her email, continuity is not considered in the evaluation. Since the pavement determinations vary segment to segment there is no 28' top system and the 28' top occurs randomly across the state on unwarranted roadways based upon whether a particular roadway segment required a recycling strategy or not.

Binder Label:

NDOR Pavement Design Manual