STATE OF SOUTH DAKOTA
DEPARTMENT OF TRANSPORTATION
PLANS FOR PROPOSED

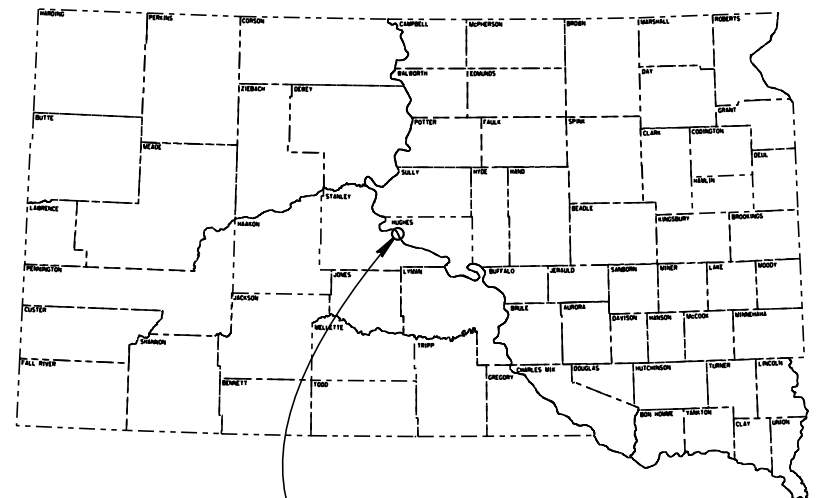411C413

HUGHES COUNTY

ASPHALT SURFACE TREATMENT
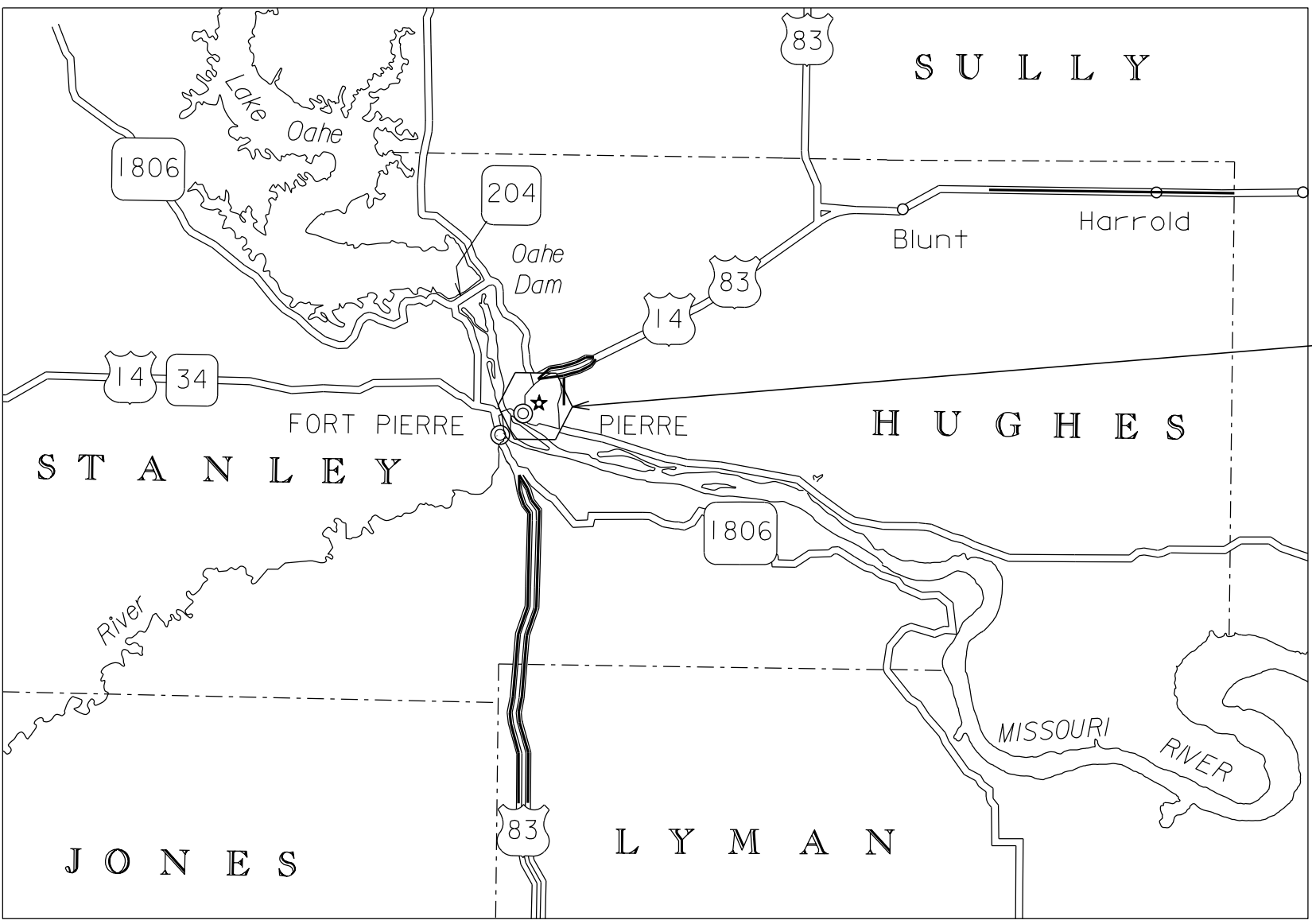PCN 13CD

PROJECT

SULLY

83

1806

204

Oahe Dam

Blunt   Harrold

83

14

SDDOT PARKING LOT (#3233)
104 S. GARFIELD AVE.
PIERRE, SD

HUGHES

14 34

FORT PIERRE   PIERRE

STANLEY

1806

River

MISSOURI   RIVER

JONES   83   LYMAN

N

ESTIMATE OF QUANTITIES

411C413 - HUGHES COUNTY PCN I3CD

Bid Item Number	Item	Quantity	Unit
009E0010	Mobilization	Lump Sum	LS
330E0300	SS-1h or CSS-1h Asphalt for Fog Seal	3.7	Ton
330E3000	Sand for Fog Seal	20.0	Ton
360E0042	CRS-2P Asphalt for Surface Treatment	20.6	Ton
360E1200	Modified Cover Aggregate	208.1	Ton

PARKING LOTS — Areas A, B, and C

BLDG A

BUILDING E

AREA C

BUILDING C

AREA A

AREA B

BUILDING B
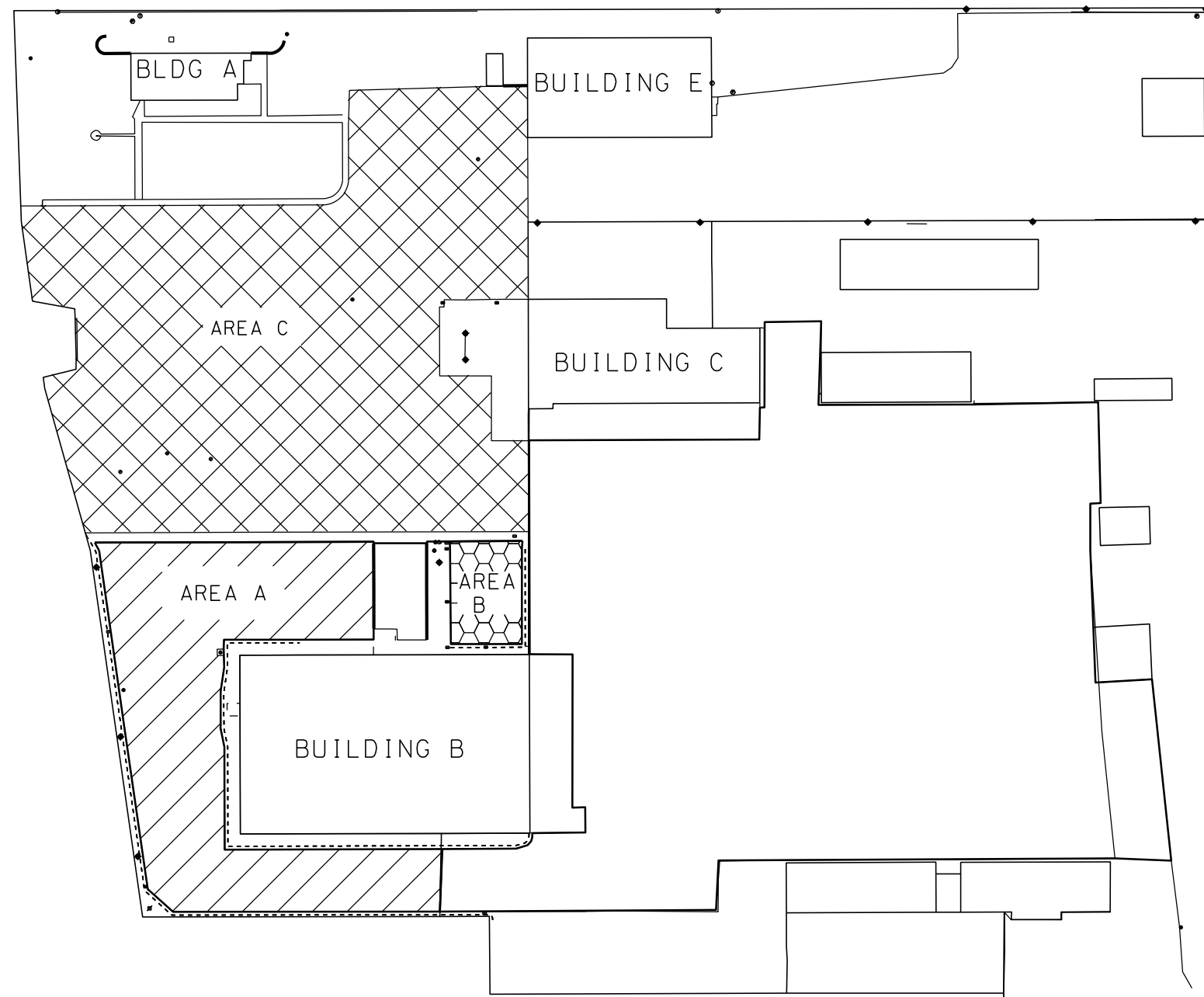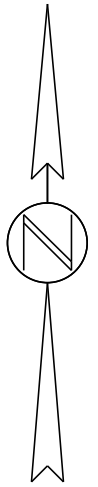
Area A = 4,690 SqYds
Area B = 534 SqYds
Area C = 12,120 SqYds

Not to Scale

SPECIFICATIONS

Standard Specifications for Roads and Bridges, 2004 Edition and Required Provisions, Supplemental Specifications and/or Special Provisions as included in the Proposal.

SEQUENCE OF OPERATIONS

The work must be done during the course of two consecutive weekends (weather permitting). No work will be allowed Monday thru Friday of any week. Weekend hours begin on Fridays at 5:00pm and end on Sundays at 8:00pm.

The surface treatment work shall be sequenced such that access to the fuel pump island is maintained at all times.

ENGINEER NOTIFICATION

The Contractor is required to notify the Area Engineer at least 10 days prior to beginning asphalt surface treatment operations.

BUILDINGS, SIDEWALKS, VALLEY GUTTER, AND FUEL ISLAND CONCRETE

Asphalt surface treatment and fog seal treatment shall not be placed on any building, sidewalk, valley gutter, or fuel island concrete. Any emulsion or cover aggregate found to be on any of these items shall be removed by the Contractor as directed by the Engineer at no cost to the state.

Cover aggregate material shall not be broomed into any drop inlets.

CRS-2P ASPHALT FOR SURFACE TREATMENT

Application of the asphalt surface treatment shall be applied to the areas specified in the plans. The Contractor will have to consider the shapes and areas to receive the surface treatment to ensure coverage over the total area specified. Gaps between surface treatment passes will not be allowed. NOTE: The fog seal shall be applied to cover the total area specified by the plans.

MODIFIED COVER AGGREGATE

Aggregate for Modified Cover Aggregate shall conform to the following gradation requirements:

Passing a 3/8 Inch Sieve	100%
Passing a No. 4 Sieve	0-75%
Passing a No. 8 Sieve	0-30%
Passing a No. 40 Sieve	0-6%
Passing a No. 200 Sieve	0-1.5%

NOTE: A tighter requirement for the percent passing the 200 Sieve has been specified. Aggregate may be crushed or uncrushed. All other requirements of the Standard Specifications for Type 1B shall apply.

After the aggregate stockpile has been produced, the Contractor shall submit an aggregate sample to the asphalt supplier a minimum of 14 days prior to starting the project to allow time to evaluate the compatibility and design of the surface treatment. A copy of the test results shall be submitted to the Engineer and Bituminous Engineer for approval prior to starting the asphalt surface treatment work.

Quality tests on the Cover Aggregate for abrasion and soundness are required by specification. The Contractor shall notify the Pierre Area Office prior to sampling and a representative from the Area Office shall witness all sampling of aggregates to be submitted to the Central Testing Laboratory for quality testing. Satisfactory test results for the Cover Aggregate shall be obtained prior to its use on the project.

NOTE: Due to the lack of traffic in the DOT yard, rollers shall increase the number of complete roller coverages from four to eight. As per the Standard Specification, a complete coverage is defined as rolling full width in one direction. The cost for this work shall be incidental to other contract bid items.

BROOMING

As per the Standard Specifications, loose material remaining on the surface shall be lightly broomed off during the cool morning period the day following application or as directed by the Engineer. NOTE: All brooming to remove the excess aggregate shall be done with a pickup broom. The excess aggregate shall become the property of the DOT and stockpiled at an approved location in the DOT yard. The cost for this work shall be incidental to other contract bid items.

FOG SEAL

The fog seal shall be placed following the completion of the chip seal. Prior to the application of the fog seal the Contractor will be required to broom the chip seal. The final brooming shall be accomplished no earlier than 5:00pm on the Friday following the application of the asphalt surface treatment. Brooming shall be done with a pickup broom. The excess aggregate shall become the property of the DOT and stockpiled at an approved location in the DOT yard. A CSS-1h or SS-1h emulsion shall be used for the fog seal application. A water-to-emulsion rate of 1:1 should be used for the binder application.

Blotting Sand for Fog Seal shall conform to the Standard Specifications Section 879.1.B.

Prior to hauling, Blotting Sand shall be screened to minimize segregation, eliminate oversize and effectively breakup or discard material bonded into chunks.

SIGNING

If signing is found to be necessary, applicable signing shall be provided by DOT. Contact Keith Johnson at 605-280-4660.

PERMANENT PAVEMENT MARKING PAINT

The DOT Traffic Crew will mark all of the existing parking lot stripes with tabs to sufficiently allow for locating and repainting of these stripes after completion of the work. The DOT Traffic Crew will permanently repaint the new parking lot stripes after final brooming operations.

EXISTING PAVEMENT CONDITIONS AND TRAFFIC VOLUMES

The existing pavement conditions for each area are listed in the table below for information only. The descriptions correspond to the McLeod procedure for seal coat design.

PARKING AREA	EXISTING PAVEMENT CONDITION
A	Badly Pocked, Porous, and Oxidized
B	Badly Pocked, Porous, and Oxidized
C	Slightly Pocked, Porous, and Oxidized

The traffic volumes vary from high volumes at the entrance to nearly zero in other areas.

COMMITMENT H: WASTE DISPOSAL SITE

The Contractor shall furnish a site(s) for the disposal of construction and/or demolition debris generated by this project.

Action Taken/Required:

Construction and/or demolition debris may not be disposed of within the State ROW.

The waste disposal site(s) shall be managed and reclaimed in accordance with the following from the General Permit for Highway, Road, and Railway Construction/Demolition Debris Disposal Under the South Dakota Waste Management Program issued by the Department of Environment and Natural Resources.

The waste disposal site(s) shall not be located in a wetland, within 200 feet of surface water, or in an area that adversely affects wildlife, recreation, aesthetic value of an area, or any threatened or endangered species, as approved by the Project Engineer.

If the waste disposal site(s) is located such that it is within view of any ROW, the following additional requirements shall apply:

1. Construction and/or demolition debris consisting of concrete, asphalt concrete, or other similar materials shall be buried in a trench completely separate from wood debris. The final cover over the construction and/or demolition debris shall consist of a minimum of 1 foot of soil capable of supporting vegetation. Waste disposal sites provided outside of the State ROW shall be seeded in accordance with Natural Resources Conservation Service recommendations. The seeding recommendations may be obtained through the appropriate County NRCS Office. The Contractor shall control the access to waste disposal sites not within the State ROW through the use of fences, gates, and placement of a sign or signs at the entrance to the site stating "No Dumping Allowed".

2. Concrete and asphalt concrete debris may be stockpiled within view of the ROW for a period of time not to exceed the duration of the project. Prior to project completion, the waste shall be removed from view of the ROW or buried and the waste disposal site reclaimed as noted above.

The above requirements will not apply to waste disposal sites that are covered by an individual solid waste permit as specified in SDCL 34A-6-58, SDCL 34A-6-1.13, and ARSD 74:27:10:06.

Failure to comply with the requirements stated above may result in civil penalties in accordance with South Dakota Solid Waste Law, SDCL 34A-6-1.31.

All costs associated with furnishing waste disposal site(s), disposing of waste, maintaining control of access (fence, gates, and signs), and reclamation of the waste disposal site(s) shall be incidental to the various contract items.

COMMITMENT I: HISTORICAL PRESERVATION OFFICE CLEARANCES

The SDDOT has obtained concurrence with the State Historical Preservation Office (SHPO or THPO) for all work included within the project limits and all designated option borrow sites provided within the plans.

Action Taken/Required:

All earth disturbing activities not designated within the plans require review of cultural resources impacts. This work includes, but is not limited to: staging areas, borrow sites, waste disposal sites, and all material processing sites.

The Contractor shall arrange and pay for a cultural resource survey and/or records search. The Contractor has the option to contact the state Archaeological Research Center (ARC) at 605-394-1936 or another qualified archaeologist, to obtain either a records search or a cultural resources survey. A record search might be sufficient for review; however, a cultural resources survey may need to be conducted by a qualified archaeologist.

The Contractor shall provide ARC with the following: a topographical map or aerial view on which the site is clearly outlined, site dimensions, project number, and PCN. If applicable, provide evidence that the site has been previously disturbed by farming, mining, or construction activities with a landowner statement that artifacts have not been found on the site.

The Contractor shall submit the records search or cultural resources survey report and if the location of the site is within the current geographical or historic boundaries of any South Dakota reservation to SDDOT Environmental Engineer, 700 East Broadway Avenue, Pierre, SD 57501-2586 (605-773-3180). SDDOT will submit the information to the appropriate SHPO/THPO. Allow **30 Days** from the date this information is submitted to the Environmental Engineer for SHPO/THPO review.

If evidence for cultural resources is uncovered during project construction activities, then such activities shall cease and the Project Engineer shall be immediately notified. The Project Engineer will contact the SDDOT Environmental Engineer in order to determine an appropriate course of action.

SHPO/THPO review does not relieve the Contractor of the responsibility for obtaining any additional permits and clearances for staging areas, borrow sites, waste disposal sites, or material processing sites that affect wetlands, threatened and endangered species, or waterways. The Contractor shall provide the required permits and clearances to the Project Engineer at the preconstruction meeting.

RATES OF MATERIALS

The Estimate of Quantities is based on the following rates over the areas shown.

411C413 PCN I3CD   (SD D.O.T. PARKING LOTS A, B, & C)

The Estimate of Quantities is based on the following quantities of material.

Asphalt for Surface Treatment CRS2P at the rate of 0.28 gallon per square yard.

Cover Aggregate Modified at the rate of 24 pounds per square yard.

Asphalt for Fog Seal CSS-1h or SS-1h at the rate of 0.05 gallons per square yard.

The area of the parking lot sites to be sealed has been estimated to be 17,344 square yards.

ASPHALT FOR SURFACE TREATMENT MIX DESIGN

After the aggregate stockpiles have been produced, the Contractor shall submit samples of the aggregates to the asphalt supplier, prior to construction, to determine a mix design and verify compatibility of the aggregate and asphalt.

The asphalt surface treatment will be designed in accordance with the Modified McLeod Design Procedure found in Volume II of Appendix C of the Preventive Maintenance Surface Treatments Report. The asphalt surface treatment design will be prepared by qualified personnel experienced in asphalt surface treatment design.

The surface design will be based on the traffic volume(s) and pavement conditions contained in the plans. The final application rate for the asphalt binder and cover aggregate will be determined after the source of the material is known and field adjustments are made. The design will include the following information:

1) Aggregate gradation.
2) Bulk specific gravity of the aggregate.
3) Loose unit weight of the aggregate.
4) Asphalt type and rate of application.
5) Aggregate rate of application.

In addition to the above data, the Contractor will submit with the design of the asphalt surface treatment a sample of each aggregate and emulsion for use by the Engineer for verifying the test results. The design may be verified by the Department.

The mix design shall be submitted to the Engineer at least one week prior to the start of construction.

Appendix C Volume II. Guidelines for Design of Chip Seals are reproduced below:

Volume II. Guidelines for Design of Chip Seals

Introduction

This volume presents the guidelines for the design of chip seals. The guidelines first cover some general information regarding the aggregate chips and the asphalt emulsion. The guidelines then address the specific material properties that are used in the recommended design procedure. Finally, the design equations for the aggregate and emulsion application rates are presented. An example design problem, illustrating the design procedure in a step-by-step manner, is also presented.

Aggregate Chips

Aggregate Type

Three aggregate types—quartzite, limestone and natural aggregates— are commonly used throughout the state. Quartzite is more common in the eastern part of the state, whereas limestone is more common in the western part of the state. Natural aggregates are found in the central as well as the northeast portion of the state. Other aggregate types, such as river gravel and granite, have been used for chip seals but are not common.

The selection of the aggregate type should be based on the availability and cost of aggregates in the area. The performance of chip seals with specific aggregate types should also be considered in the selection. On specialized applications, such as for high-volume roadways, additional considerations may need to be taken into account. For example, crushed aggregate can provide improved retention and durability characteristics.

ASPHALT FOR SURFACE TREATMENT MIX DESIGN (CONTINUED)

Aggregate Shape

The ideal shape for aggregate chips is cubical and angular, as opposed to flat and rounded. Flat particles tend to orient on their flattest side under traffic loadings and can become completely covered with emulsion and create a bleeding problem. In addition, these completely embedded chips prevent proper embedment of chips that lie on top of the embedded chips, resulting in continued chip loss. With cubical aggregates, the chip height is essentially the same regardless of its orientation, resulting in more uniform chip embedment.

Angular or crushed aggregate particles are preferred over rounded particles. Rounded aggregates are more susceptible to rolling and displacement under traffic, especially in locations of stopping or turning traffic. Angular particles tend to lock together and provide better long-term retention and stability.

Aggregate Gradation

The aggregate gradation plays a key role in the design, construction and performance of chip seals. The gradation requirements shown in this Design Procedure are for information only and Modified Cover Aggregate is specified in the plans. The ideal gradation comprises the following characteristics:

- The aggregate chips should be similarly sized. A one-size aggregate provides a more uniform thickness and a more consistent and proper embedment of the chips, which improves the retention and performance of the chip seal. Similarly sized chips also help improve the surface friction and drainage capabilities of the chip seal.

- The aggregate bands should not be too wide. Allowing a wide range of aggregate retained on a particular sieve will result in widely varying gradations and differing performance. A tight gradation band ensures consistency and uniformity of the chip seal.

- The gradation should limit the amount of fines (material passing the 0.075 mm [No. 200] sieve). Fine materials create dust and can be a safety hazard for passing vehicles. Furthermore, fine materials absorb emulsion and can affect the bonding characteristics and performance of the chip seal.

To better account for these ideal properties, the aggregate gradations in Table II-1 are recommended for all roadways. The maximum aggregate size is 9.52 mm (⅜ in). The gradation also forces the majority of the aggregate to a small range to create a more uniform chip seal. The gradation also addresses the amount of fines by limiting the material passing the 0.075 mm (No. 200) sieve to one percent. The recommended gradation for sections using a second choke stone layer is also provided in the table.

Table II-1. Recommended aggregate gradations for chip seal designs.

Sieve Size	Percent Passing	
	Aggregate Chips	Choke Stone
12.7 mm (½ in)	100	100
9.52 mm (⅜ in)	90 – 100	100
6.35 mm (¼ in)	40 – 70	100
4.75 mm (No. 4)	0 – 15	85 – 100
2.36 mm (No. 8)	0 – 5	10 – 40
1.18 mm (No. 16)	–	0 – 10
0.300 mm (No. 50)	–	0 – 5
0.075 mm (No. 200)	0 – 1	0 – 1

ASPHALT FOR SURFACE TREATMENT MIX DESIGN (CONTINUED)

Flat and Elongated Particles (Flakiness Index)

Like small particles, flat and elongated particles can become completely embedded in the emulsion and thus prevent larger aggregate particles from achieving proper embedment. The flakiness index – determined in accordance with the Central Federal Lands Highway Division (CFLHD) DFT-508, *Standard Method of Determining the Flakiness Index and Average Least Dimension of Aggregates* – should be performed to limit the amount of flat and elongated particles. The Flakiness Index is a measure of the percentage, by weight, of flat particles. For most applications, the Flakiness Index should be limited to 30 percent (i.e., the weight of flat and elongated particles should not exceed 30 percent of the total aggregate weight). For special applications such as high-volume roadways, the limit should be tightened to 20 or 25 percent.

Asphalt Emulsion

Emulsification is a process in which two otherwise incompatible materials are blended together. In the case of asphalt emulsion, the two incompatible materials are asphalt and water. An asphalt emulsion consists of asphalt particles dispersed in water, which is stabilized using a chemical solution (also know as an emulsifier). Upon application, the water and asphalt separate, a process referred to as "breaking" of the emulsion. The water then evaporates leaving the asphalt as the bonding agent.

Emulsion Classification

Asphalt emulsions are classified into three categories – anionic, cationic and nonionic – referring to the electrical charge of the emulsifier surrounding the asphalt particles. Anionic emulsions have a negative electrical charge surrounding the asphalt particles, and cationic emulsions have a positive charge.

Because opposite electrical charges attract, anionic emulsions should be used with aggregates that have a positive charge (such as limestone and natural aggregates). Likewise, cationic emulsions should be used with aggregates that have a negative charge (such as quartzite).

Emulsions are further identified based on how quickly they revert back to asphalt cement. The following terms are used to classify the emulsion grades:

- Rapid-setting (RS)
- Medium-setting (MS)
- Slow-setting (SS)
- Quick-setting (QS)

The grades indicate the speed at which the emulsion will become unstable and "break" coming into contact with the aggregate. An RS emulsion breaks very quickly and has little or no ability to mix with an aggregate. An MS emulsion will mix with coarse aggregate but not fine aggregate. SS and QS emulsions are designed to mix with fine aggregates.

High-float emulsions (designated as HF) allow a thicker film of asphalt material on the aggregate, which enhances the bonding and retention. They are designated as such because they pass the Float Test (ASTM D139 or AASHTO T50). High-float emulsions are recommended for use with dusty aggregates (greater than 2 percent fines).

Numbers are used in the classification to indicate the relative viscosity of the emulsion. Lower numbers indicate a lower viscosity or more fluid material (i.e., an MS-2 is more viscous than an MS-1). Letters are also sometimes used following the designation: "h" indicates a harder base asphalt, "s" indicates a softer base asphalt and "p" indicates a polymer-modified asphalt.

ASPHALT FOR SURFACE TREATMENT MIX DESIGN (CONTINUED)

Table II-2 shows the classifications for asphalt emulsion. Standard specifications are available for anionic asphalt emulsions (ASTM D977 or AASHTO M140) and for cationic asphalt emulsions (ASTM D2397 or AASHTO M208).

Table II-2. Classifications of asphalt emulsions.

Anionic Asphalt Emulsions	Cationic Asphalt Emulsions
RS-1	CRS-1
RS-2	CRS-2
HFRS-2	–
MS-1	–
MS-2	CMS-2
MS-2h	CMS-2h
HFMS-1	–
HFMS-2	–
HFMS-2h	–
HFMS-2s	–
SS-1	CSS-1
SS-1h	CSS-1h

Chip Seal Design

Chip seals should be designed so that the proposed materials are of sufficient quality and have the desired properties to provide the expected performance. Proper design also ensures that the proper application rates are being used. The design procedure presented herein is a modified version of the McLeod design procedure (McLeod 1969) and is currently being used by the Minnesota Department of Transportation (Janisch and Gaillard 1998).

The procedure is based on two basic principles:

- The aggregate application rate is designed to provide a chip seal that is one stone thick (i.e., there should be a single layer of uniformly sized chips) with minimal excess.

- The voids in the aggregate are designed to be 70 percent filled with asphalt cement for good performance (i.e., the chips should be 70 percent embedded).

Emulsion Properties

Residual Asphalt Content

A portion of an asphalt emulsion consists of water, which evaporates as the binder breaks. The amount of asphalt cement that remains after breaking is referred to as the residual asphalt content. It is important to consider the residual asphalt content because it represents the amount of material that is available for bonding to the aggregate. In general, the residual asphalt content is about 65 to 70 percent (i.e., 65 to 70 percent of an asphalt emulsion consists of asphalt cement).

As mentioned, the objective of this design procedure is to achieve 70 percent embedment of the average-sized aggregate. To accomplish this, the emulsion must be at the top of the average-sized aggregate before curing. If only 70 percent of the aggregate is covered initially, the asphalt height will be about 30 percent too low after curing.

ASPHALT FOR SURFACE TREATMENT MIX DESIGN (CONTINUED)

Aggregate Properties

Median Particle Size

The median particle size is the theoretical size through which 50 percent of the material passes. It is determined from the gradation chart using the following sieve sizes: 25.0 mm (1 in), 19.0 mm (¾ in), 12.5 mm (½ in), 9.5 mm (⅜ in), 6.3 mm (¼ in), 4.75 mm (No. 4), 2.36 mm (No. 8), 1.18 mm (No. 16), 0.300 mm (No. 50) and 0.075 mm (No. 200).

Flakiness Index

The Flakiness Index is a measure of the percentage, by weight, of flat particles. It is determined by testing a sample of aggregate particles for their ability to fit through a slotted plate. The test is conducted in accordance with the Central Federal Lands Highway Division (CFLHD) DFT-508, *Standard Method of Determining the Flakiness Index and Average Least Dimension of Aggregates.* The weight of the material passing the slots is divided by the total weight of the aggregate sample to determine the percent of flat particles or Flakiness Index.

Average Least Dimension

The average least dimension represents a reduction of the median particle size after accounting for the amount of flat particles. It represents the chip seal thickness in the wheel path after traffic has reoriented the chips on their flattest side. It is determined from the median particle size and flakiness index using the following equation:

$$H = \frac{M}{1.139285 + 0.011506\,FI} \qquad \text{(Eq. II-1)}$$

where:

H = Average Least dimension, in.
M = Median particle size, in.
FI = Flakiness index, percent.

Loose Unit Weight

The loose unit weight is required in order to determine the voids in the aggregate in a loose condition. The voids represent the available space for the asphalt binder after placement and rolling. The loose unit weight is a function of the gradation, shape and specific gravity of the aggregate. It should be determined in accordance with ASTM C29.

Bulk Specific Gravity

Bulk specific gravity represents the weight of aggregate as compared to the weight of water. Different aggregate types have different unit weights or specific gravities. This factor affects the application rate of the aggregate chips because a heavier aggregate will require more weight of chips (or a higher application rate) than a lighter aggregate to cover the same area. Bulk specific gravities for aggregates typically range from 2.40 to 3.00. Natural aggregates are generally about 2.40 and quartzite and limestone aggregates are generally around 2.60.

ASPHALT FOR SURFACE TREATMENT MIX DESIGN (CONTINUED)

Voids in Loose Aggregate

The voids in the loose aggregate represent the voids after the aggregate chips are placed on the pavement. It is based on the loose unit weight and can be determined using the following equation:

$$V = 1 - \frac{W}{62.4G} \qquad \text{(Eq. II-2)}$$

where:

V = Voids in the loose aggregate.
W = Loose unit weight of the aggregate chips, lb/ft^3.
G = Bulk specific gravity of the aggregate.

For one-sized chips, this factor will typically be around 50 percent. Rolling will reduce the amount of voids, typically to around 30 percent. Traffic will further reduce the amount of voids to around 20 percent.

Aggregate Absorption

Aggregates, especially porous aggregates, will absorb a portion of the asphalt emulsion. This will affect the amount of asphalt binder that is available for bonding with the aggregate chips. To ensure that enough binder remains, this factor must be taken into account when designing the emulsion application rate. An absorption correction factor of 0.09 l/m^2 (0.02 gal/yd^2) is recommended for aggregates with absorption greater than 1.5 percent. Quartzite is generally not too absorptive and will not require an adjustment. Some limestone and natural aggregates, however, may require an adjustment to the emulsion application rate.

Other Design Properties

Traffic Volume

The traffic volume will influence the amount of asphalt binder that is required to provide sufficient embedment of the aggregate chips. All other factors equal, roadways with higher traffic volumes will require less asphalt binder. This may appear to be the opposite of what is typically expected. However, consider that traffic causes a reorientation of the chips until they eventually lie on their flattest side.

More traffic thus results in a greater probability that the chips will be laying on their flattest side and will result in a thinner chip seal. Less traffic will result in a thicker chip seal and will thus require more asphalt binder to achieve sufficient embedment. Table II-3 provides the recommended traffic correction factor to be used in determining the emulsion application rate. Failure to account for this factor will result in bleeding in the wheel paths.

Table II-3. Recommended traffic correction factor.

Traffic (ADT)	Traffic Factor
< 100	0.85
100 – 500	0.75
500 – 1000	0.70
1000 – 2000	0.65
> 2000	0.60

ASPHALT FOR SURFACE TREATMENT MIX DESIGN (CONTINUED)

Traffic Whip-Off

A portion of the aggregate chips will get thrown off the roadway before final curing and embedment under traffic has occurred. This is accounted for in the procedure using a traffic whip-off factor. The factor is based on the traffic volume and traffic speed of the roadway. Low-volume, residential streets will have about a 5 percent loss, whereas the loss on high-volume, high-speed roadways will be around 10 percent. The factor can be computed using the following equation:

$$E = 1 + \frac{P}{100} \qquad \text{(Eq. II-3)}$$

where:

   E = Traffic whip-off factor.
   P = Expected loss of aggregate chips, percent.

Thus, an expected loss of 10 percent results in a traffic whip-off factor of 1.10.

Existing Pavement Condition

The surface condition of the existing pavement will greatly influence the amount of asphalt emulsion that is required. A dry, porous pavement will absorb a tremendous amount of asphalt binder and thus affect the emulsion application rate. Conversely, a new pavement (or a pavement with bleeding on the surface) will absorb much less binder. The varying condition is accounted for in the design procedure by the surface correction factor. The recommended value, based on the pavement surface texture, is provided in Table II-4.

The same application rate cannot be used for all roadways with varying conditions. Similarly, the surface condition should be monitored during placement, and the application rate adjusted as needed to address areas of differing condition.

Table II-4. Recommended surface correction factors.

Existing Pavement Surface Texture	Surface Correction Factor, gal/yd^2
Black, flushed asphalt	-0.01 to -0.06
Smooth, non-porous	0.00
Slightly porous and oxidized	+0.03
Slightly pocked, porous and oxidized	+0.06
Badly pocked, porous and oxidized	+0.09

Design Equations

Once the inputs are determined, the application rates can be calculated using the McLeod design equations. The equations for aggregate and emulsion application rates are presented below.

ASPHALT FOR SURFACE TREATMENT MIX DESIGN (CONTINUED)

Aggregate Application Rate

The following equation is used to determine the aggregate application rate:

$$C = 46.8(1 - 0.4V) \times H \times G \times E \qquad \text{(Eq. II-4)}$$

where:

   C = Chip application rate, lbs/yd^2.
   V = Voids in loose aggregate.
   H = Average Least dimension, in.
   G = Bulk specific gravity.
   E = Traffic whip-off factor.

Emulsion Application Rate

The emulsion application rate is determined using the following equation:

$$B = \frac{2.244 \times H \times T \times V + S + A}{R} \qquad \text{(Eq. II-5)}$$

where:

   B = Binder application rate, gal/yd^2.
   H = Average Least dimension, in.
   T = Traffic correction factor.
   V = Voids in loose aggregate.
   S = Surface correction factor.
   A = Aggregate absorption factor, gal/yd^2.
   R = Residual asphalt content of binder.

Minnesota performs an additional calculation of the emulsion application rate to account for snowplow damage (Janisch and Gaillard 1998). The emulsion application rate is recalculated using the median particle size instead of the average least dimension. This new emulsion rate provides the required rate if the chips are not reoriented, and thus is more representative of the rate required outside the wheel path. The average of the two rates is then used as the starting point in the field. Minnesota has found that if this additional calculation is not performed, insufficient binder is applied in non-traffic areas, and snow plows shave off the chips (Janisch and Gaillard 1998).

Example Design Problem

A 68 kg (150 lb) sample of quartzite aggregate has been submitted for design. The roadway has traffic levels of 2,125 vehicles per day. The pavement surface is slightly pocked, porous and oxidized. A CRS-2 emulsion with a residual asphalt content of 66.5 percent will be used as the binder. Determine the emulsion and aggregate application rates for this project.

Step 1. Determine the aggregate gradation, bulk specific gravity and percent absorption.

Laboratory testing of the aggregate revealed the gradation as shown in Table II-5. Testing in accordance with AASHTO T 84-94 indicates a bulk specific gravity of the aggregate of 2.61. The aggregate absorption based on AASHTO T 84-94 is 0.55 percent, so no correction is needed.

ASPHALT FOR SURFACE TREATMENT MIX DESIGN (CONTINUED)

Table II-5. Gradation results for design project.

Sieve Size	Percent Passing
12.7 mm (½ in)	100
9.52 mm (⅜ in)	95
6.35 mm (¼ in)	62
4.75 mm (No. 4)	12
2.36 mm (No. 8)	3.2
0.075 mm (No. 200)	1.3

Step 2. Determine the mean particle size.

The median particle size (M) is determined by plotting the gradation results and reading off the size at which 50 percent of the particles pass. The median particle size represents the theoretical size at which half the stones are larger and half are smaller. For the given gradation, the median particle size is determined to be 5.8 mm (0.23 in).

Step 3. Determine the flakiness index.

To determine the flakiness index, the aggregate particles are fitted through slots. The results of this testing is shown in Table II-6.

Table II-6. Results of flakiness index test.

Size Fraction	Weight Retained on Slot, grams	Weight Passing Slot, grams
12.5 to 9.5 mm (½ to ⅜ in)	54.2	12.3
9.5 to 6.3 mm (⅜ to ¼ in)	123.3	43.5
6.3 to 4.75 mm (¼ in to No. 4)	184.4	89.5
Total	361.9	145.3

Using these results, the flakiness index (FI) is determined as follows:

$$FI = \frac{Weight\ of\ Flat\ Chips}{Weight\ of\ Sample} = \frac{145.3}{361.9 + 145.3} = 0.286 = 28.6\ percent$$

Step 4. Determine the average least dimension.

The average least dimension (H) is the expected thickness of the chip seal after the chips have been reoriented on their flattest side from traffic. It is determined using Equation II-2 as follows:

$$H = \frac{M}{1.139285 + 0.011506\,FI} = \frac{0.23\ in}{1.139285 + (0.011506 \times 28.6)} = 0.157\ in$$

Step 5. Determine the loose weight of the aggregate.

A metal cylinder with a volume of 0.014 m³ (0.50 ft³) was loosely filled with aggregate and weighed. This process was repeated three times, the results of which are shown in Table II-7.

ASPHALT FOR SURFACE TREATMENT MIX DESIGN (CONTINUED)

Table II-7. Results of loose unit weight testing.

Test Number	Weight of Aggregate, kg (lbs)
1	20.57 (45.25)
2	20.60 (45.32)
3	20.59 (45.29)
Average	20.59 (45.29)

The loose unit weight (W) is then determined as follows:

$$W = \frac{Weight\ of\ Aggregate}{Weight\ of\ Cylinder} = \frac{45.29\ lbs}{0.50\ ft^3} = 90.58\ lbs/ft^3$$

Step 6. Determine the voids in the loose aggregate.

The voids in the loose aggregate (V) is determined using Equation II-2 as follows:

$$V = 1 - \frac{W}{62.4\,G} = 1 - \frac{90.58\ lbs/ft^3}{62.4\ lbs/ft^3 \times 2.61} = 0.44$$

Step 7. Determine the aggregate application rate.

With the inputs determined above, Equation II-4 is used to determine the aggregate application rate (C):

$$C = 46.8(1 - (0.4V)) \times H \times G \times E$$
$$= 46.8(1 - (0.4 \times 0.44)) \times 0.157 \times 2.61 \times 1.10 = 17.3\ lbs/yd^2$$

Step 8. Determine the emulsion application rate.

The emulsion application rate is determined using Equation II-5. The calculation is performed twice – once for the wheel path areas (using the average least dimension) and again for the non-wheel path areas (using the median particle size). These calculations are shown below:

$$B = \frac{2.244 \times H \times T \times V + S + A}{R}$$
$$= \frac{2.244 \times 0.157 \times 0.60 \times 0.44 + 0.06 + 0.00}{0.665} = 0.23\ gal.yd^2$$

$$B = \frac{2.244 \times M \times T \times V + S + A}{R}$$
$$= \frac{2.244 \times 0.23 \times 0.60 \times 0.44 + 0.06 + 0.00}{0.665} = 0.30\ gal.yd^2$$

The average of the two results (0.27 gal/yd²) is used as the starting point in the field.