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DESIGN AND CONSTRUCTION OF NDOT TEST SECTIONS ON INTERSTATE 80

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NEVADA DOT

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16. Abstract

Four test sections were constructed on I-80 east of Reno, Nevada during the month of September, 1998. The sections are located in the travel lane of the westbound direction of I-80. Two sections were designed with the Superpave volumetric mix design method and two sections were designed using the Hveem design method. Two different binders were used: AC-20P and PG64-22. The PG64-22 binder is a neat asphalt binder similar to one used on Westrack. Each binder was used with a Superpave designed mix and a Hveem designed mix which resulted in the four sections labeled as: SPAC-20P, SPPG64-22, NVPG64-22, and NVAC-20P. All four sections are placed in series to be evaluated under similar environmental and traffic conditions. The Superpave mix designs were conducted in the University of Nevada's Pavements/Materials Laboratory while the Hveem mix designs were conducted in the NDOT's Materials Division Laboratory. Materials testing and evaluations were conducted before, during and after the construction activities. Aggregates, binders and mixtures were tested for their conformance with the Superpave and Hveem mix design specifications.

Based on the testing data it was concluded that the asphalt binders used on the test sections consistently conformed to the specified grades throughout the entire construction activities. The hot mixed asphalt plant used by Granite Co. (Lockwood Plant) was not capable of controlling the amount of bag house materials being returned into the mix. The Superpave volumetric mix design is not capable of estimating the optimum asphalt binder content based on the volumetric properties of the mix at a given asphalt binder content. The in-pace compaction data indicate that the Superpave mixtures with both the AC-20P and the PG64-22 binders experienced some tenderness and were moving under the roller. This behavior of the Superpave mixtures has resulted in two problems: a) additional roller passes were needed to achieve a constant density, and b) the bottom lift became over-compacted as the top lift was being rolled.

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INTRODUCTION

In 1998, the Nevada Department of Transportation (NDOT) initiated a research project in cooperation with the Pavements/Materials Program at the University of Nevada to assess the applicability of the Superpave mix design process to Nevada's conditions. As part of this effort, field test sections were constructed on Interstate 80 (I-80) to compare the performance of Superpave hot mixed asphalt (HMA) mixtures with the NDOT standard Hveem HMA mixtures.

The Superpave mix design process of HMA mixtures was developed as a result of the Strategic Highway Research Program (SHRP) effort on asphalt binders and mixtures between 1987 and 1992. The SHRP research recommended a new asphalt binder grading system and a new mixture design method. The combination of these two steps represents the basics for the Superpave HMA mixture design system. In other words a Superpave designed HMA mixture would have an asphalt binder selected based on the Superpave weather data and graded using the performance based binder grading system, aggregates that meet the Superpave criteria and an optimum asphalt binder content selected based on the Superpave volumetric criteria.

The binder grading system is referred to as the PG grading system, which stands for performance graded asphalt binders. The basic concept of the PG grading system is that asphalt binders should be graded based on their potential performance under the environmental and traffic conditions of the project. The potential performance of asphalt binders is evaluated in terms of their contributions to the HMA mixtures resistance to rutting, fatigue, and low temperature cracking. Rheological properties are used to assess the contribution of the asphalt binders to the performance of HMA mixtures.

The SHRP research identified the following rheological properties as being critical to the performance of asphalt binders:

$G^*/\sin(\delta)$: a property measured using the dynamic shear rheometer (DSR) to indicate the asphalt binder's resistance to tenderness and rutting. It is measured on the original binder and the short term aged binder through the rolling thin film oven (RTFO).

$G^*\sin(\delta)$: a property measured using the DSR to indicate the asphalt binder's resistance to fatigue cracking. It is measured on the long-term aged binder through the pressure aging vessel (PAV).

S: a property measured using the bending beam rheometer (BBR) to indicate the asphalt binder's resistance to low temperature cracking. It is measured on the PAV aged binder.

m: a property measured using the BBR to indicate the asphalt binder's resistance to low temperature cracking. It is measured on the PAV aged binder.

Strain: a property measured using the direct tension (DT) to indicate the asphalt binder's resistance to low temperature cracking. It is measured on the PAV aged binder.

Where:

G*: complex modulus of the asphalt binder
δ: phase angle of the asphalt binder
S: stiffness of the asphalt binder
m: slope of the creep stiffness curve
Strain: maximum tensile strain an asphalt binder can take prior to failure

Using the above measured properties, the asphalt binder is graded based on the temperatures at which the properties' limits are achieved. Figure 1 shows the the PG grading chart for asphalt binders. The final grade is given in the form of PGXX-YY, where XX represents the highest seven-days average pavement temperature under which this binder can be used while the -YY represents the lowest pavement temperature under which this binder can be used. For example a binder graded as PG64-22 represents a binder that can be used on a pavement where the highest seven-days average pavement temperature is 64^oC and the lowest pavement temperature is -22^oC.

The Superpave volumetric mix design method is based on the use of the gyratory compactor coupled with a set of aggregate and mixture's volumetric criteria. The aggregate criteria include requirements on the fractured faces, sand equivalency, flat and elongated particles, and gradation. The mix volumetric criteria include limits on the air voids (Va), voids in mineral aggregates (VMA), voids filled with asphalt (VFA) and filler to asphalt binder ratio. The aggregate properties are measured first and an acceptable aggregate blend and gradation is established.

The gyratory compactor is then used to compact HMA mixtures at trial asphalt binder contents. The volumetric criteria are established as a function of the number of gyrations as shown in Table 1 (1). The $N_{initial}$, N_{design}, and $N_{maximum}$ are selected to establish air voids levels of 11, 4, and 2 percent, respectively. The VMA and VFA criteria are a function of the nominal maximum aggregate size and traffic level, respectively as shown in Tables 2 and 3. The optimum asphalt binder content is selected based on the mixture that meets all the volumetric criteria. The optimum binder content is expressed in terms of the total weight of the mix.

NDOT has been using the Hveem mix design method to design HMA mixtures for a long time. The Hveem method uses the kneading compactor and selects the optimum asphalt binder content based on: no flushing, 4% air voids, and a minimum stability. NDOT has added the VMA requirement on the Hveem design method. The optimum binder content is expressed in terms of the dry weight of aggregates.

NDOT has developed a great historical record with excellent performing Hveem-designed HMA mixtures throughout the entire state. It should be noted here that Nevada's environmental and traffic conditions are rather unique. In the northern part of the state, the weather can be very cold in the winter with freeze-thaw cycling and very warm and dry in the summer. While in the southern part of the state, the weather is moderate in the winter and very hot in the summer. Also, traffic volumes range from the extreme low in the rural areas to the extreme high in the urban areas. The combination of these extremes presented a real challenge which NDOT combated with fundamental research and development efforts which brought the state highway system to an extremely high level of service. With this much success with the current Hveem mix design method, NDOT is approaching the implementation of the Superpave mix design system with extreme caution. As mentioned earlier, the objective of these test sections is to assess the applicability of the Superpave mix design system to Nevada's conditions.

PROJECT DESCRIPTION

As mentioned earlier, the overall objectives of the project are to compare the performance of Superpave HMA mixtures to NDOT Hveem mixtures. Specifically, the Superpave mixture used on this project was similar to one used on the Westrack project in terms of aggregate source, gradation, and binder source and grade. It should be noted here that this Superpave mixture failed very prematurely under the Westrack loading during the summer of 1997.

A total of four test sections were constructed on I-80 east of Reno, Nevada during the month of September 1998. The sections are located in the travel lane of the westbound direction of I-80 in Churchill County, Nevada, between mileposts 2.20 and 1.52. Figure 2 shows the layout of the four test sections. Each section consists of a 500-foot performance monitoring area and two sampling areas (one at the beginning and one at the end of the section). There are transition areas between consecutive sections. The original intent was to have uniform length among all sections, however, due to logistical construction problems, the overall length of the sections were not uniform. It was decided to keep the performance monitoring area at 500 feet long while adjusting the length of the sampling areas as shown in Figure 2. The following is a description of the sections nomenclature:

SPAC-20P: this section is designed using the Superpave mix design system with a binder grade of AC-20P.

SPPG64-22: this section is designed using the Superpave mix design system with a binder grade of PG64-22.

NVPG64-22: this section is designed using the NDOT Hveem mix design method with a binder grade of PG64-22.

NVAC-20P: this section is designed using the NDOT Hveem mix design method with a binder grade of AC-20P.

The constructed layer consisted of milling the top 2 inches of the existing HMA mix (8 inches) and placing 4 inches of new HMA mixture. The new mix was placed in two lifts. The base consists of a 9 in. aggregate base. In order to be consistent with the Westrack experiment, the overlay did not receive an open graded surface mix on sections SPAC-20P and SPPG64-22. The contractor for the project was Granite Construction.

The following traffic data apply to the location of the test sections:

One direction ADT:	3,342
Truck factor:	1.61
Percent trucks:	39%
Daily one direction ESALs:	2,096
20 years average growth rate:	3.5%
20 years design ESALs:	19,500,000

AGGREGATES

All four sections were constructed using the same aggregate source located in Lockwood, Nevada, owned by Granite Construction Company. The Superpave and Hveem mixtures had different aggregate gradations. The aggregates were produced into six different stockpiles:1"-1/2", 3/4", ½", 3/8", rock dust, and bank sand. The Superpave mixtures used only the 3/4", ½", 3/8", and rock dust stockpiles while the Hveem mixtures used all stockpiles except the 3/4". Table 4 summarizes the gradation of the various stockpiles. Lime was added to the mix at 1.5 % by dry weight of aggregate and marinated for 48 hours.

Properties of Stockpiles Aggregates

In addition to the gradation, the following properties were measured on aggregates from the individual stockpiles:

Specific gravity and absorption of coarse aggregate
Specific gravity and absorption of fine aggregates
Angularity of coarse aggregate
Angularity of fine aggregate
Sand equivalent
Flat and elongated particles

Table 5 summarizes the properties of the stockpiles aggregates. It should be noted that all these properties are either required by the Superpave volumetric mix or the NDOT Hveem mix design methods. All of the measured properties were checked against the appropriate criteria.

Properties of Blend Aggregates

Superpave Mixtures

The blend for the Superpave mixtures was as follows:

3/4" stockpile:	24%
½" stockpile:	15.5%
3/8" stockpile:	26%
Rock dust:	33%
Lime:	1.5%

The following properties were measured on the blend aggregates:

Specific gravity and absorption of coarse aggregates.
Specific gravity and absorption of fine aggregates.

Table 6 summarizes the properties of the blend aggregates. Table 7 summarizes the gradation of the blend and Figure 3 shows the aggregate gradation for the Superpave mixtures.

Hveem Mixtures

The Hveem mix design conducted by NDOT Materials Division used a five-stockpile blend. A bank sand stockpile was used in addition to the four stockpiles used in the Superpave Mixtures. The blend for the Hveem mixtures was as follows:

1"- 1/2" stockpile:	27.5%
½" stockpile:	20%
3/8" stockpile:	9%
Rock dust:	32%
Bank sand:	10%
Lime:	1.5%

The following properties were measured on the blend aggregates:

Specific gravity and absorption of coarse aggregates.
Specific gravity and absorption of fine aggregates.

Table 6 summarizes the properties of the blend aggregates. Table 7 summarizes the gradation of the blend, and Figure 4 shows the aggregate gradation for the Hveem mixtures.

ASPHALT BINDER

Two types of asphalt binders were used: AC-20P and PG64-22. As indicated earlier, two test sections were constructed using each binder. This provided a total of four test sections as shown in Figure 2. The AC-20P binder was supplied by the Telfer Sheldon Co. and is a typical polymer-modified binder that is commonly used by NDOT. The PG64-22 is an unmodified asphalt binder supplied by Idaho Asphalt Co. This specific PG64-22 binder from Idaho Asphalt Co. was selected to exactly match the binder used on the Westrack project since one of the objectives is to compare the performance of the I-80 sections with those on the Westrack project.

The AC-20P and PG64-22 binders were both graded using the Superpave binder grading system. Tables 8 and 9 summarize the properties of the AC-20P and PG64-22 binders, respectively. Table 10 summarizes the conventional properties of the AC-20P binder tested by the Nevada DOT Materials Division. The data in Tables 8, 9, and 10 indicate that the AC-20P binder is graded as PG58-22, the PG64-22 binder satisfies the requirements of this grade, and the AC-20P binder passes the NDOT grade requirements.

MIX DESIGNS

The mix designs for the four test sections were completed during August, 1998. The Pavements/Materials Program conducted the mix designs for the Superpave sections while NDOT Materials Division conducted the mix designs for the Hveem sections.

Superpave Sections

The Superpave sections included the SPAC-20P and the SPPG64-22. The mix designs for these two sections were conducted using the Superpave volumetric mix design system. The mix design temperature was selected to be 38^{o}C and the design ESALs were selected at 4 million. Using this combination of temperature and design ESALs, the number of gyrations was identified as follows:

$N_{initial} = 8$ $N_{design} = 96$ $N_{maximum} = 152$

Tables 11 and 12 summarize the mix design data for the SPAC-20P and SPPG64-22 sections, respectively. The data in these tables show all the mixtures' properties required by the Superpave volumetric mix design system. Using the data in Tables 11 and 12 along with the aggregate and binder properties, the mix design recommendations are presented in Tables 13 and 14 for the SPAC-20P and SPPG64-22 sections, respectively. It can be seen from the mix design data in Tables 13 and 14 that the recommended mix designs satisfy all the Superpave criteria except for the criterion on the filler to effective asphalt binder ratio. This criterion was allowed to be violated in order to be consistent with the HMA mixture used on the Westrack project. The recommended optimum asphalt binder content was 5.80% by total weight of mix for both sections.

When reviewing the mix design data presented in Tables 11 through 14, the following notes would apply:

- Target blend was selected to match the 1997 rehabilitation section of Westrack.
- The selected blend uses -0.5% baghouse fines to adjust gradation.
- The mixtures were marinated for 48 hours with 1.5% lime.
- The mixtures were ran at 4.7, 5.2, 5.7, and 6.2% binder contents by total weight of mix.

Hveem Sections

The Hveem sections included the NVPG64-22 and NVAC-20P. The mix designs for the two sections were conducted using the NDOT Hveem mix design procedure. As indicated earlier, the Hveem sections used the same asphalt binders as the Superpave sections. Tables 15 and 16 summarize the mix data as generated by NDOT's Materials Division. In addition to the 4% air voids and the minimum stability requirements, NDOT specifications include limits on VMA, dry tensile strength and the percent retained tensile strength after moisture conditioning. Tables 17 and 18 present the mix design recommendations for the NVPG64-22 and NVAC-20P sections, respectively. The recommended optimum asphalt binder contents were 4.50 and 4.25% by dry weight of aggregates for the NVPG64-22 and NVAVC-20P sections, respectively.

CONSTRUCTION ACTIVITIES

The construction of the test sections began on September 22, 1999. In addition to the construction crew and NDOT resident engineer, personnel from NDOT's Materials Division and UNR's Pavements/Materials Program were present on the site. The objective was to let the construction of the test sections follow the normal construction activities of the entire project as closely as possible. In other words, the intention was not to build unique test sections but to construct normal sections with unique mixtures. Therefore, no special precautions or modification of construction activities were imposed. The major concern was to make sure that the appropriate mixtures were delivered and placed in the appropriate sections.

During the construction of the eastbound pavement, a coating problem was identified in the mixture. It required adjusting the flights inside the drum to lengthen the mixing time and provide better coating of the large aggregates. The coating problem was resolved prior to the start of the test sections construction.

The construction of the test sections went very smooth. The only major concern was to ensure that mixtures types coincide well between top and bottom lifts and within the appropriate section. There was no problem of loaded trucks waiting to dump on the windrow. One truck load of the SP PG64-22 was placed at the end of the SP AC-20P section which forced the change in the section length to adjust for the locations.

SAMPLING AND TESTING DURING CONSTRUCTION

During the construction of the test sections, several types of samples were obtained. Some of the sampled materials were tested immediately during construction while other materials were saved for future testing and evaluation. The following tests were conducted on materials sampled during construction:

- Asphalt binder properties.
- Asphalt binder content.
- Aggregate gradation.

- Volumetric properties.
- In-Place Compaction.
- In-Place Air Voids.

Asphalt Binder Properties

Asphalt binder samples were obtained and tested for grade verification. Some of the testing was conducted by the NDOT Materials Division and some testing was conducted in the Pavements/Materials Laboratory. The NDOT testing consisted of measuring the absolute viscosity at 60^{o}C for the AC-20P binder and the G*/Sind at 64^{o}C for the PG64-22 binder. Tables 19 and 20 summarize the binders properties measured by NDOT during the construction of the test sections. The data in Tables 19 and 20 indicate that all the sampled binders met the NDOT specification for the intended grade.

The testing conducted at the Pavements/Materials Laboratory consisted of conducting the full Superpave PG grading process on the sampled binders. Tables 21 through 25 summarize the Superpave PG grading of two samples from each binder type. The data in these tables show that both samples of the PG64-22 binder met the grade requirements and both of the AC-20P binders met the requirements of a PG58-22 grade. This data is consistent with the data generated on the binders tested during the mix design process.

Asphalt Binder Content

Construction testing of asphalt binder content included both the ignition and the reflux methods. The NDOT Materials Division conducted the ignition testing while the Pavements/Materials Laboratory conducted the reflux testing. Samples were obtained from both the bottom and top lifts. Table 25 summarizes the asphalt binder content data measured on mixtures from the bottom and top lifts of the test lanes. The data in Table 25 show that the two methods are within 0.20% in all cases.

Aggregate Gradation

Aggregate gradation analyses were completed on samples obtained from the ignition and reflux tests. The return of the bag house materials was a critical issue during the construction of the test sections. Based on the sieve analysis of the various stockpiles and the mix design data, it was decided that a partial return of the baghouse materials would be the ideal situation. However, Granite Construction Co. indicated that a partial return was not an option. Therefore, the two options were either returning all of the baghouse materials or none. The bottom lifts of the test sections were constructed with the option of returning all of the baghouse materials. Tables 26 and 27 summarize the aggregate gradations of the bottom lift mixtures. The data showed that the percent passing #200 is well above the target value.

Based on the test results of the bottom lift, it was decided to waste all the baghouse materials during the construction of the top lift. Tables 28 and 29 summarize the aggregate gradations of the top lift mixtures. The data showed that the percent passing #200 is close to the target values. The air-voids in the compacted mix are highly influenced by the amount of materials passing #200. Air-void measurements on cores showed that the bottom lift experienced significantly lower air voids than the top lift.

Volumetric Properties

This effort consisted of using the Superpave Gyratory compactor to conduct quality control testing of the Superpave mixtures. Field mixtures were compacted in the Gyratory compactor and their volumetric properties were obtained. As part of the Superpave calculations, the estimated binder content to achieve 4% air voids at N_{design} can be calculated using the actual binder content of the mix. The Superpave calculations were used along with the binder contents measured using the reflux and ignition test methods. The estimated optimum binder contents are summarized in Table 30. It can be seen that none of the estimated optimum binder contents match the determined binder contents. In other words, none of the field samples achieved 4% air voids when compacted at N_{design}. However, in the case of the top lift of the SPAC-20P section, the estimated optimum binder content is within 0.1% of the determined binder content. In four out of six cases, the Superpave volumetrics indicated that the mixture is under-asphalted. For the SPPG64-22 section, the Superpave volumetrics indicated that the mixtures are under-asphalted in all the cases.

There were some attempts to use this data in controlling the binder content in the field but the scatter of the data made it a very difficult task. For example, during the construction of the bottom lift of the SPPG64-22 section, the Superpave volumetrics recommended that the optimum binder content should be changed from 5.80 to 6.00, however, when the binder content was changed to 6.00 in the top lift of the same section, the Superpave volumetrics recommended an optimum binder of 6.40. It should be noted that in addition to changing the binder content from 5.80 to 6.00, the baghouse materials were wasted also during the construction of the top lift. Wasting the baghouse materials would impact the optimum binder content in two conflicting ways: there will be a need for some additional binder to fill the voids and less binder content to coat the fine aggregates. Therefore, the net effect should result in almost no impact on the optimum binder content. To the contrary, the Superpave volumetrics recommended an increase of 0.4% in the optimum binder content. This issue still represents a great discrepancy within the Superpave mix design system that should be resolved prior to the full implementation of this system.

In-Place Compaction

In-place compaction of the test sections was completed through a steel roller. The in-place density of the HMA mixtures as a function of the number of roller passes was measured using a nuclear density gauge. Figure 5 shows the change in the in-place density as a function of the number of roller passes for the SPAC-20P, SPPG64-22, and NVPG64-22 sections. The in-place density data for the NVAC-20P were not available. The data presented in Figure 5 show that both of the Superpave sections experienced some tenderness during compaction. This data indicate that the Superpave mixes were moving under the roller and required a higher number of roller passes to achieve a constant density. Even after a higher number of roller passes, the Superpave sections achieved a lower maximum density than the Nevada sections.

In-Place Air-Voids

The in-place air-voids in the bottom and top lifts of the test sections were measured on cores obtained immediately after construction. Table 31 summarizes the air-voids data as measured in the FHWA laboratories at Turner Fairbanks, on cores obtained from the test sections. The air voids data clearly show that Superpave mixtures experience more compaction than the NDOT Hveem mixtures especially the bottom lift, which continues to compact after the placement of the top lift. The calculated average air voids for the entire section show that the Superpave sections have average air voids below the NDOT recommended range of 6-8%. When evaluating this data in connection with the compaction data, it can be concluded that the Superpave mixtures experienced some movements under the roller which required more roller passes during compaction of the individual lifts and resulted in significant reduction in the air voids of the bottom lift when the top lift was being compacted.

SUMMARY AND CONCLUSIONS

This report documents the construction activities of the NDOT test sections placed on I-80 westbound east of Reno, Nevada. The project consisted of placing four test sections: two sections designed with the Superpave volumetric mix design method and two sections designed using the Hveem design method. Two different binders were used: AC-20P and PG64-22. The PG64-22 binder is a neat asphalt binder similar to one used on Westrack. A large amount of testing was conducted by NDOT and UNR personnel during the construction of the test sections to assess the quality of the HMA mixtures and evaluate the Superpave volumetric mix design principles. Based on the analysis of the construction test data, the following conclusions can be made:

- The asphalt binders used on the test sections consistently conformed to the specified grade throughout the entire construction activities.
- The hot mixed asphalt plant used by Granite Co. (Lockwood Plant) was not capable of controlling the amount of baghouse materials being returned into the mix. The only two options were either 0% or 100% return. This limitation of the plant caused some problems in controlling the gradations of the produced HMA mixtures to meet the mix design gradations.
- As part of the Superpave volumetric mix design, the design engineer should be able to estimate the optimum asphalt binder content based on the volumetric properties of the mix at a given asphalt binder content. Based on the data measured on the two Superpave sections constructed on this project, this feature of the Superpave volumetric mix design does not work. The data showed that the Superpave analysis keeps on oscillating between higher and lower asphalt binder

contents and never reaches the appropriate recommendation.

- The in-place compaction data indicate that the Superpave mixtures with both the AC-20P and the PG64-22 binders experienced some tenderness and were moving under the roller. This behavior of the Superpave mixtures has resulted in two problems: a) additional roller passes were needed to achieve a constant density, and b) the bottom lift became over-compacted as the top lift was being rolled.

Additional laboratory testing is currently being conducted on laboratory prepared mixtures and field prepared mixtures to assess the resistance of the mixtures to failure modes of rutting, low temperature cracking, fatigue, and moisture damage. The construction and post-construction laboratory testing will be coupled with the field performance of the test sections to assess the applicability of the Superpave volumetric mix design method under Nevada's conditions.

Table 1 Superpave Design Gyratory Compactive Efforts.

Design ESALs (millions)	Average Design High Air Temperature (C)											
	<39			39-40			41-42			43-44		
	$N_{initial}$	Ndesign	Nmax	Ninitial	Ndesign	Nmax	Ninitial	Ndesign	Nmax	Ninitial	Ndesign	Nmax
< 0.3	7	68	104	7	74	114	7	78	121	7	82	127
0.3 – 1	7	76	117	7	83	129	7	88	138	8	93	146
1 – 3	7	86	134	8	95	150	8	100	158	8	105	167
3 – 10	8	96	152	8	106	169	8	113	181	9	119	192
10 – 30	8	109	174	9	121	195	9	128	208	9	135	220
30 - 100	9	126	204	9	139	228	9	146	240	10	153	253
> 100	9	143	235	10	158	262	10	165	275	10	172	288

Table 2 Superpave VMA Criteria.

Nominal Maximum Aggregate Size (mm)	Minimum VMA, percent
9.5	15.0
12.5	14.0
19.0	13.0
25.0	12.0
37.5	11.0

Table 3 Superpave VFA Criteria.

Traffic, million ESALs	Design VFA, percent
< 0.3	70 - 80
< 1	65 - 78
< 3	65 - 78
< 10	65 - 75
< 30	65 -75
< 100	65 -75
> 100	65 - 75

Table 4 Gradations of the Stockpile Aggregates.

Sieve Size	3/4" Stockpile	½" Stockpile	3/8" Stockpile	Rock Dust	1"-½" Stockpile	Bank Sand
1"	100.0	100.0	100.0	100.0	100.0	100.0
3/4"	98.9	100.0	100.0	100.0	57.9	100.0
1/2"	36.0	99.7	100.0	100.0	12.8	100.0
3/8"	7.7	52.4	99.7	100.0	4.1	100.0
#4	1.2	1.1	26.1	98.2	0.5	99.3
#8	0.8	0.9	2.8	69.9	0.4	96.4
#16	0.7	0.8	1.6	45.4	0.4	79.6
#30	0.6	0.7	1.3	31.2	0.3	59.6
#50	0.6	0.7	1.2	23.4	0.3	35.4
#100	0.5	0.6	1.1	18.4	0.3	8.6
#200	0.5	0.6	0.9	14.8	0.3	1.9

Table 5 Properties of the Stockpile Aggregates.

Property	3/4" Stockpile	½" Stockpile	3/8" Stockpile	Rock Dust
Bulk Sp. Gr. (Dry)	2.615	2.614	2.607	2.514
Bulk Sp. Gr. (SSD)	2.676	2.673	2.667	2.613
Apparent Sp. Gr.	2.785	2.776	2.773	2.789
Absorption (%)	2.332	2.226	2.301	2.913
Fract. faces (%)	100	100	100	NA
Uncomp. Voids (%)	NA	NA	NA	46.2
Sand Equivalent	NA	NA	NA	72
Flat and elongated (%)	0.0	0.0	0.0	NA

Table 6 Properties of the Blend Aggregates.

Property	Superpave Mixtures		Hveem Mixtures	
	- #4	**+ #4**	**- #4**	**+ #4**
Bulk Sp. Gr. (Dry)	2.454	2.632	2.531	2.628
Bulk Sp. Gr. (SSD)	2.579	2.690	2.622	2.683
Apparent Sp. Gr.	2.804	2.795	2.784	2.780
Absorption (%)	5.088	2.224	3.584	2.077

Table 7 Gradations of the Blend Aggregates for the Superpave and Hveem Mixtures.

Sieve Size	Superpave Mixtures					Hveem Mixtures		
	Blend w/ lime	**Blend w/o lime**	**Control Points**		**Restricted Zone**	**Blend w/ lime**	**Blend w/o lime**	**NDOT Spec.**
			Upper	**Lower**				
1"	100.0	100.0	100			100.0	100.0	100
3/4"	99.6	99.6	100	90		88.4	88.2	88-95
1/2"	84.1	83.9				76.0	75.6	70-85
3/8"	70.1	69.6				63.3	62.8	60-78
#4	40.7	39.8	49	23	34.6	45.3	44.5	43-60
#8	24.9	23.8			22.3-28.3	33.5	32.5	
#10							29.9	30-44
#16	16.4	15.1			16.7-20.7	25.3	24.2	
#30	11.7	10.4			13.7	19.2	18.0	
#40							14.4	12-22
#50	9.0	7.7				12.0	10.7	
#100	7.2	5.9				7.7	6.5	
#200	5.9	4.8	8	2		5.9	4.8	3-8

Table 8 Superpave Binder Grading of the AC-20P Refinery Sample.

PG Grade Sheet

Contract Number	2880	SUPERPAVE PG Grade
AC Sample Number	Refinery Sample #1	
Source of Sample	Telfer Sheldon	
Asphalt Type	AC-20P	PG 58-22
Mass Loss, %	0.385	
Brookfield Vis., Pas	0.416	
Flash Pt., °C	282	
Limiting Temp. Tmax, °C	58.9	
Limiting Temp. Tint, °C	18.7	
Limiting Temp. Tmin, °C	-15.0	

DSR-Original						DSR-RTFOT					
Temp, °C	Plate Diam., mm	Strain, %	G*, KPa	Phase angle δ	G*/sinδ kPa	Temp, °C	Plate Diam., mm	Strain, %	G*, KPa	Phase angle δ	G*/sinδ kPa
58	25	12	1.687	69.99	1.795	58	25	10	2.405	74.54	2.495
64	25	12	0.944	66.26	1.032	64	25	10	1.241	73.88	1.292
70	25	12	0.587	59.86	0.679	70	25	10	0.688	71.49	0.725
76	25	12	0.416	50.75	0.538	76	25	10	0.405	66.75	0.441

DSR-PAV						BBR-PAV			DT-PAV		
Temp, °C	Plate Diam., mm	Strain, %	G*, Mpa	Phase angle δ	G*sinδ Mpa	Temp, °C	S(t), MPa	m	Temp, °C	Avg. Failure Strain, %	Avg. Failure Stress, Pa
16	8	1	9.433	54.24	7.655	-12	200.1	0.400	-12	1.97	5.29
19	8	1	5.737	58.30	4.881		198.0	0.388			
22	8	1	3.242	62.58	2.878	-18	450.2	0.286	-18	0.67	5.29
25	8	1	1.759	66.39	1.612						

1- Original: Tmax 65.6 °C
Temperature at which G*/sinδ= 1.0 KPa

2- RTFOT: Tmax 58.9 °C
Temperature at which G*/sinδ= 2.2 KPa

3- DSR-PAV: Tint 18.7 °C
Temperature at which G*/sinδ= 5.0 MPa

4- BBR-PAV: Tmin
Temperature at which S(t)= 300.0 MPa -15.0 °C
Temperature at which m= 0.3 -17.2 °C

5- DTT-PAV: Tmin
Temperature at which %Strain= 1.0 % -15.8 °C

Table 9 Superpave Binder Grading of the PG64-22 Refinery Sample.

PG Grade Sheet

Contract Number	2880	SUPERPAVE PG Grade
AC Sample Number	Refinery Sample #1	
Source of Sample	Idaho Asphalt	
Asphalt Type	PG64-22	PG 64-22
Mass Loss, %	0.135	
Brookfield Vis., Pas	0.375	
Flash Pt., °C	340+	
Limiting Temp. Tmax, °C	65.8	
Limiting Temp. Tint, °C	20.1	
Limiting Temp. Tmin, °C	-16.0	

DSR-Original						DSR-RTFOT					
Temp, °C	Plate Diam., mm	Strain, %	G*, KPa	Phase angle δ	G*/sinδ kPa	Temp, °C	Plate Diam., mm	Strain, %	G*, KPa	Phase angle δ	G*/sinδ kPa
58	25	12	2.609	85.80	2.616	58	25	10	5.876	82.01	5.934
64	25	12	1.225	87.10	1.227	64	25	10	2.667	84.03	2.682
70	25	12	0.607	88.15	0.607	70	25	10	1.265	86.38	1.268
76	25	12	0.316	87.46	0.317	76	25	10	0.636	87.38	0.636

DSR-PAV						BBR-PAV			DT-PAV		
Temp, °C	Plate Diam., mm	Strain, %	G*, Mpa	Phase angle δ	G*sinδ Mpa	Temp, °C	S(t), MPa	m	Temp, °C	Avg. Failure Strain, %	Avg. Failure Stress, Pa
19	8	1	9.412	42.09	6.309	-12	171.6	0.341	-12	1.72	4.05
22	8	1	6.494	44.46	4.548		161.3	0.337			
25	8	1	4.191	47.05	3.068	-18	341.3	0.278	-18	0.32	2.24
28	8	1	2.709	49.74	2.067		362.7	0.282			

1- Original: Tmax 65.9 °C
Temperature at which G*/sinδ= 1.0 KPa

2- RTFOT: Tmax 65.8 °C
Temperature at which G*/sinδ= 2.2 KPa

3- DSR-PAV: Tint 21.0 °C
Temperature at which G*/sinδ= 5.0 MPa

4- BBR-PAV: Tmin
Temperature at which S(t)= 300.0 MPa -16.7 °C
Temperature at which m= 0.3 -16.0 °C

5- DTT-PAV: Tmin
Temperature at which %Strain= 1.0 % -13.9 °C

Table 10 Conventional Properties of the AC-20P Binder.

Tests Performed	Property	NDOT Specification
Viscosity 60°C, 300mm Hg, Pa..s, Original	210+	Minimum 210
Viscosity, 60°C, 300 mm Hg, Pa..s, Residue	300+	Minimum 300
Viscosity, 135°C, mm2/s, Original	530	475 - 3000
Flash point, C.O.C., °C	240+	Minimum 232
Original ductility, 4°C, cm, (5cm/min)	55+	Minimum 50
Residue ductility, 4°C, cm (5cm/min)	30+	Minimum 25
Toughness, N.m	15.59	Minimum 12.43
Tenacity, N.m	12.88	Minimum 8.47
Loss on heating, %	0.283	Maximum 0.5

Table 11 Superpave Mix Design Data for the SPAC-20P Section.

%AC	G_{mm}	G_{sb}	Sample#	G_{mb}	$\%G_{mm}$ @N_{ini}	$\%G_{mm}$ @N_{des}	$\%G_{mm}$ @N_{max}	% Air	VMA	VFA
4.7	2.461	2.554	1	2.340	84.9	93.9	95.1	6.1	13.8	55.7
			2	2.335	85.0	93.7	94.9	6.3	14.0	54.9
			3	2.353	85.5	94.4	95.6	5.6	13.3	57.9
			Mean	2.343	85.1	94.0	95.2	6.0	13.7	53.9
			St. Dev.	0.009	0.3	0.4	0.4	0.4	0.3	1.6
			C.V.	0.397	0.4	0.4	0.4	6.0	2.4	3.0

%AC	G_{mm}	G_{sb}	Sample#	G_{mb}	$\%G_{mm}$ @N_{ini}	$\%G_{mm}$ @N_{des}	$\%G_{mm}$ @N_{max}	% Air	VMA	VFA
5.2	2.442	2.554	1	2.349	85.8	94.9	96.2	5.1	14.0	63.5
			2	2.327	85.1	94.0	95.3	6.0	14.8	59.4
			3	2.356	86.4	95.3	96.5	4.7	13.6	65.5
			4	2.325	85.6	94.0	95.2	6.0	14.8	59.4
			5	2.346	86.5	94.8	96.0	5.2	14.1	63.0
			Mean	2.341	85.9	94.6	95.8	5.4	14.3	62.1
			St. Dev.	0.014	0.6	0.6	0.6	0.6	0.5	2.7
			C.V.	0.591	0.7	0.6	0.6	10.7	3.7	4.3

%AC	G_{mm}	G_{sb}	Sample#	G_{mb}	$\%G_{mm}$ @N_{ini}	$\%G_{mm}$ @N_{des}	$\%G_{mm}$ @N_{max}	% Air	VMA	VFA
5.7	2.424	2.554	1	2.326	85.9	94.7	96.0	5.3	15.2	65.2
			2	2.334	86.3	95.0	96.3	5.0	15.0	66.6
			3	2.344	86.8	95.4	96.7	4.6	14.6	68.5
			4	2.368	87.9	96.5	97.7	3.5	13.6	74.3
			5	2.348	87.2	95.6	96.9	4.4	14.4	69.5
			Mean	2.344	86.8	95.4	96.7	4.6	14.6	68.7
			St. Dev.	0.016	0.8	0.7	0.6	0.7	0.6	3.5
			C.V.	0.680	0.9	0.7	0.7	15.1	4.2	5.1

%AC	G_{mm}	G_{sb}	Sample#	G_{mb}	$\%G_{mm}$ @N_{ini}	$\%G_{mm}$ @N_{des}	$\%G_{mm}$ @N_{max}	% Air	VMA	VFA
6.2	2.406	2.554	1	2.353	87.4	96.4	97.8	3.6	14.8	75.7
			2	2.381	88.5	97.6	99.0	2.4	13.8	82.6
			3	2.360	87.7	96.8	98.1	3.2	14.5	77.9
			4	2.361	88.8	97.0	98.1	3.0	14.3	79.0
			5	2.360	88.7	96.9	98.1	3.1	14.4	78.4
			Mean	2.363	88.2	96.9	98.2	3.1	14.3	78.7
			St. Dev.	0.011	0.6	0.4	0.5	0.4	0.4	2.5
			C.V.	0.447	0.7	0.4	0.5	14.2	2.7	3.2

Table 12 Superpave Mix Design Data for the SPPG64-22 Section.

%AC	G_{mm}	G_{sb}	Sample#	G_{mb}	%G_{mm} @N_{ini}	%G_{mm} @N_{des}	%G_{mm} @N_{max}	% Air	VMA	VFA
4.7	2.469	2.554	1	2.325	83.9	92.9	94.2	7.1	14.4	50.7
			2	2.359	84.3	94.1	95.5	5.9	13.3	55.7
			3	2.346	84.5	93.8	95.0	6.2	13.6	54.4
			Mean	2.343	84.2	93.6	94.9	6.4	13.8	53.6
			St. Dev.	0.017	0.3	0.6	0.7	0.6	0.6	2.8
			C.V.	0.732	0.4	0.7	0.7	9.8	4.2	4.8

%AC	G_{mm}	G_{sb}	Sample#	G_{mb}	%G_{mm} @N_{ini}	%G_{mm} @N_{des}	%G_{mm} @N_{max}	% Air	VMA	VFA
5.2	2.451	2.554	1	2.331	84.8	93.7	95.1	6.3	14.8	57.3
			2	2.331	85.1	93.9	95.1	6.1	14.6	58.1
			3	2.366	85.5	95.0	96.5	5.0	13.6	63.2
			4	2.346	86.3	94.5	95.7	5.5	14.0	60.8
			5	2.334	85.3	94.0	95.2	6.0	14.5	58.6
			Mean	2.342	85.4	94.2	95.5	5.8	14.3	59.5
			St. Dev.	0.015	0.6	0.5	0.6	0.5	0.5	2.4
			C.V.	0.640	0.7	0.6	0.6	9.1	3.4	4.0

%AC	G_{mm}	G_{sb}	Sample#	G_{mb}	%G_{mm} @N_{ini}	%G_{mm} @N_{des}	%G_{mm} @N_{max}	% Air	VMA	VFA
5.7	2.443	2.554	1	2.375	87.0	96.3	97.6	3.7	13.5	72.6
			2	2.344	86.3	95.1	96.4	4.9	14.8	66.4
			3	2.398	87.8	97.2	98.6	2.8	12.7	77.9
			4	2.362	87.6	95.6	97.1	4.2	13.9	69.9
			5	2.355	87.3	95.5	96.8	4.5	14.2	68.3
			Mean	2.367	87.2	96.0	97.3	4.0	13.8	70.8
			St. Dev.	0.021	0.6	0.8	0.8	0.8	0.7	4.5
			C.V.	0.877	0.7	0.8	0.9	20.2	5.3	6.3

%AC	G_{mm}	G_{sb}	Sample#	G_{mb}	%G_{mm} @N_{ini}	%G_{mm} @N_{des}	%G_{mm} @N_{max}	% Air	VMA	VFA
6.2	2.416	2.554	1	2.347	86.6	95.8	97.1	4.2	15.0	72.0
			2	2.354	87.3	96.1	97.4	3.9	14.7	73.5
			3	2.386	88.4	97.5	98.8	2.5	13.5	81.5
			4	2.359	87.7	96.3	97.7	3.7	14.6	74.6
			5	2.372	88.1	96.9	98.2	3.1	14.0	77.9
			Mean	2.364	87.6	96.5	97.8	3.5	14.4	75.8
			St. Dev.	0.016	0.7	0.7	0.7	0.7	0.6	3.8
			C.V.	0.656	0.8	0.7	0.7	19.5	4.2	5.0

Table 13 Recommended Superpave Mix Design for the SPAC-20P Section.

Binder Properties (AC-20P Required)		
Property	**Measured**	**Specification**
Flash Point, (^{o}C)	284	> 230
Mass Loss, (%)	0.38	< 1.0
Brookfield Viscoisty, (Pa*S), @ 135^{o}C	0.408	< 3.0
Original G*/(sinδ), (kPa), @ 64 ^{o}C	1.79	> 1.0
RTFOT G*/(sinδ), (kPa), @ 64 ^{o}C	2.51	> 2.2
PAV G*(sinδ), (kPa), @ 19^{o}C	2920	< 5000
Creep Stiffness, (Mpa), @ -18^{o}C	199.4	< 300
Slope (m), @ -18^{o}C	0.397	> 0.30
Direct Tension, Fail Strain % @ -18^{o}C	1.76	> 1.0
Aggregate Properties		
Property	**Measured**	**Specification**
Coarse Aggregate Angularity, (%)	100/100	> 85/80
Fine Aggregate Angularity, (%)	46.1	> 40
Flat and Elongated Particles, (%)	0	< 10
Sand Equivalent, (%)	72	> 45
Mixtures Properties		
Property	**Measured**	**Specification**
% Gmm at N_{design}	96.0	96.0
% AC (by twm)	5.8	n/a
% VMA at N_{design}	14.7	>13.0
% VFA at N_{design}	73.0	65 - 75
Filler to Effective AC Ratio at N_{design}	1.32	0.6 -1.2
% Gmm at $N_{initial}$	87.2	< 89.0
%Gmm at N_{max}	97.1	< 98.0
Retained Strength Ratio, (%)	95.5	> 80

Table 14 Recommended Superpave Mix Design for the SPPG64-22 Section.

Binder Properties (PG64-22 Required)		
Property	**Measured**	**Specification**
Flash Point, (^{o}C)	340+	> 230
Mass Loss, (%)	0.135	< 1.0
Brookfield Viscoisty, (Pa*S), @ 135^{o}C	0.375	< 3.0
Original G*/(sinδ), (kPa), @ 64 ^{o}C	1.23	> 1.0
RTFOT G*/(sinδ), (kPa), @ 64 ^{o}C	2.68	> 2.2
PAV G*(sinδ), (kPa), @ 19^{o}C	3070	< 5000
Creep Stiffness, (Mpa), @ -18^{o}C	166.5	< 300
Slope (m), @ -18^{o}C	0.339	> 0.30
Direct Tension, Fail Strain % @ -18^{o}C	1.72	> 1.0
Aggregate Properties		
Property	**Measured**	**Specification**
Coarse Aggregate Angularity, (%)	100/100	> 85/80
Fine Aggregate Angularity, (%)	46.1	> 40
Flat and Elongated Particles, (%)	0	< 10
Sand Equivalent, (%)	72	> 45
Mixtures Properties		
Property	**Measured**	**Specification**
% Gmm at N_{design}	96.0	96.0
% AC (by twm)	5.8	n/a
% VMA at N_{design}	13.9	>13.0
% VFA at N_{design}	72.0	65 - 75
Filler to Effective AC Ratio at N_{design}	1.35	0.6 -1.2
% Gmm at $N_{initial}$	87.3	< 89.0
%Gmm at N_{max}	97.5	< 98.0
Retained Strength Ratio, (%)	86.9	> 80

Table 15 Properties of the Hveem Mixtures for the NVPG64-22 Section.

Binder Content % by dwa	Hveem Stability	Air Voids (%)	VMA (%)
4.0	41	7.8	16.1
4.5	41	5.7	15.1
5.0	43	3.4	14.0
5.5	31	2.1	13.9

Table 16 Properties of the Hveem Mixtures for the NVAC-20P Section.

Binder Content % by dwa	Hveem Stability	Air Voids (%)	VMA (%)
3.5	48	7.2	15.6
4.0	47	5.7	15.3
4.5	46	4.0	14.8
5.0	38	2.1	14.1
5.5	33	0.9	14.0

Table 17 Mix Design Summary for the NVPG64-22 Section.

Property	Value	NDOT Specifications
Optimum Binder Content	4.5 %	
Air Voids	5.7 %	4 - 7 %
Stability	41	37 min.
VMA	15.1 %	12 - 22 %
Sand Equivalent	63	
+#4 Water Absorption	1.7 %	4 % max.
Fractured Faces	100 %	60% min.
Split Tensile Strength	733 kPa	450 kPa min.
% Retained Strength	87 %	70 % min.

Table 18 Mix Design Summary for the NVAC-20P Section.

Property	Value	NDOT Specifications
Optimum Binder Content	4.25 %	
Air Voids	4.9 %	4 - 7 %
Stability	43	37 min.
VMA	15.0 %	12 - 22 %
Sand Equivalent	63	
+#4 Water Absorption	1.7 %	4 % max.
Fractured Faces	100 %	60% min.
Split Tensile Strength	687 kPa	450 kPa min.
% Retained Strength	105 %	70 % min.

Table 19 NDOT Construction Testing Results for the AC-20P Binder.

Date Sampled	**Viscosity at 60°C, Specification: 210 Pa.s Min.**
9-22-98	210+
9-22-98	210+
9-23-98	210+
9-24-98	210+
9-24-98	210+
9-24-98	210+
9-24-98	210+
9-24-98	210+
9-24-98	210+
9-25-98	210+

Table 20 NDOT Construction Testing Results for the PG64-22 Binder.

Date Sampled	**G*/Sind at 64°C, Specification: 1.00 kPa min.**
9-22-98	1.33
9-22-98	1.32
9-23-98	1.29
9-28-98	1.40
9-28-98	1.43

Table 21 Superpave Binder Grading of the AC-20P Binder, Construction Sample #1.

PG Grade Sheet

Contract Number	2880	SUPERPAVE PG Grade
AC Sample Number	Construction Sample #1	
Source of Sample	Telfer Sheldon	
Asphalt Type	AC-20P	PG 58-22
Mass Loss, %	0.280	
Brookfield Vis., Pas	0.387	
Flash Pt., °C	270	
Limiting Temp. Tmax, °C	60.0	
Limiting Temp. Tint, °C	18.2	
Limiting Temp. Tmin, °C	-14.1	

DSR-Original						DSR-RTFOT					
Temp, °C	Plate Diam., mm	Strain, %	G*, KPa	Phase angle δ	G*/sinδ kPa	Temp, °C	Plate Diam., mm	Strain, %	G*, KPa	Phase angle δ	G*/sinδ kPa
52	25	12	3.358	73.91	3.495	52	25	10	5.514	75.87	5.686
58	25	12	1.707	72.71	1.788	58	25	10	2.600	75.45	2.686
64	25	12	0.917	68.24	0.987	64	25	10	1.305	74.99	1.351
70	25	12	0.570	63.66	0.636	70	25	10	0.700	73.83	0.729

DSR-PAV						BBR-PAV			DT-PAV		
Temp, °C	Plate Diam., mm	Strain, %	G*, Mpa	Phase angle δ	G*sinδ Mpa	Temp, °C	S(t), MPa	m	Temp, °C	Avg. Failure Strain, %	Avg. Failure Stress, Pa
19	8	1	5.611	51.56	4.395	-12	224.0	0.383	-12	2.06	5.63
22	8	1	3.042	56.59	2.539		225.3	0.384	-18	0.82	6.26
25	8	1	1.750	61.83	1.543	-18	495.1	0.271	-24	0.28	3.61
28	8	1	1.006	64.71	0.910		535.6	0.269			

1- Original: Tmax 64.6 °C
Temperature at which G*/sinδ= 1.0 KPa

2- RTFOT: Tmax 60.0 °C
Temperature at which G*/sinδ= 2.2 KPa

3- DSR-PAV: Tint 18.2 °C
Temperature at which G*/sinδ= 5.0 MPa

4- BBR-PAV: Tmin
Temperature at which S(t)= 300.0 MPa -14.1 °C
Temperature at which m= 0.3 -16.4 °C

5- DTT-PAV: Tmin
Temperature at which %Strain= 1.0 % -16.5 °C

Table 22 Superpave Binder Grading of the AC-20P Binder, Construction Sample #2.

PG Grade Sheet

Contract Number	2880	SUPERPAVE PG Grade
AC Sample Number	Construction Sample #2	
Source of Sample	Telfer Sheldon	
Asphalt Type	AC-20P	PG 58-22
Mass Loss, %	0.290	
Brookfield Vis., Pas	0.400	
Flash Pt., °C	272	
Limiting Temp. Tmax, °C	59.4	
Limiting Temp. Tint, °C	19.4	
Limiting Temp. Tmin, °C	-14.0	

DSR-Original						DSR-RTFOT					
Temp, °C	Plate Diam., mm	Strain, %	G*, KPa	Phase angle δ	G*/sinδ kPa	Temp, °C	Plate Diam., mm	Strain, %	G*, KPa	Phase angle δ	G*/sinδ kPa
52	25	12	3.470	73.63	3.617	52	25	10	5.128	76.29	5.278
58	25	12	1.775	72.07	1.866	58	25	10	2.451	76.39	2.522
64	25	12	0.970	69.7	1.034	64	25	10	1.251	76.06	1.289
70	25	12	0.584	65.37	0.642	70	25	10	0.669	73.88	0.696

DSR-PAV						BBR-PAV			DT-PAV		
Temp, °C	Plate Diam., mm	Strain, %	G*, Mpa	Phase angle δ	G*sinδ Mpa	Temp, °C	S(t), MPa	m	Temp, °C	Avg. Failure Strain, %	Avg. Failure Stress, Pa
19	8	1	6.343	57.20	5.332	-12	228.5	0.386	-18	0.98	7.28
22	8	1	3.660	61.94	3.230		222.9	0.383			
25	8	1	2.031	65.95	1.855	-18	525.5	0.274	-24	0.35	4.57
28	8	1	1.157	69.13	1.081		521.6	0.274			

1- Original: Tmax 64.9 °C
Temperature at which G*/sinδ= 1.0 KPa

2- RTFOT: Tmax 59.4 °C
Temperature at which G*/sinδ= 2.2 KPa

3- DSR-PAV: Tint 19.4 °C
Temperature at which G*/sinδ= 5.0 MPa

4- BBR-PAV: Tmin
Temperature at which S(t)= 300.0 MPa -14.0 °C
Temperature at which m= 0.3 -16.6 °C

5- DTT-PAV: Tmin
Temperature at which %Strain= 1.0 % -17.9 °C

Table 23 Superpave Binder Grading of the PG64-22 Binder, Construction Sample #1.

PG Grade Sheet

Contract Number	2880	SUPERPAVE PG Grade
AC Sample Number	Construction Sample #1	
Source of Sample	Idaho Asphalt	
Asphalt Type	PG64-22	PG 64-22
Mass Loss, %	0.300	
Brookfield Vis., Pas	0.287	
Flash Pt., °C	308	
Limiting Temp. Tmax, °C	66.0	
Limiting Temp. Tint, °C	20.1	
Limiting Temp. Tmin, °C	-16.1	

DSR-Original						DSR-RTFOT					
Temp, °C	Plate Diam., mm	Strain, %	G*, KPa	Phase angle δ	G*/sinδ kPa	Temp, °C	Plate Diam., mm	Strain, %	G*, KPa	Phase angle δ	G*/sinδ kPa
58	25	12	2.640	85.15	2.649	58	25	10	6.576	81.48	6.649
64	25	12	1.236	86.31	1.239	64	25	10	2.978	83.16	2.999
70	25	12	0.609	88.98	0.609	70	25	10	1.396	85.49	1.400
76	25	12	0.309	85.59	0.310	76	25	10	0.728	87.90	0.729

DSR-PAV						BBR-PAV			DT-PAV		
Temp, °C	Plate Diam., mm	Strain, %	G*, Mpa	Phase angle δ	G*sinδ Mpa	Temp, °C	S(t), MPa	m	Temp, °C	Avg. Failure Strain, %	Avg. Failure Stress, Pa
19	8	1	8.353	42.17	5.608	-12	152.4	0.329	-12	1.82	3.76
22	8	1	5.840	43.98	4.055		163.7	0.346			
25	8	1	3.933	46.95	2.874	-18	330.9	0.282	-18	0.87	4.76
28	8	1	2.636	49.73	2.011		335.4	0.281			

1- Original: Tmax	66 °C	
Temperature at which G*/sinδ=	1.0 KPa	
2- RTFOT: Tmax	66.7 °C	
Temperature at which G*/sinδ=	2.2 KPa	
3- DSR-PAV: Tint	20.1 °C	
Temperature at which G*/sinδ=	5.0 MPa	
4- BBR-PAV: Tmin		
Temperature at which S(t)=	300.0 MPa	-17.1 °C
Temperature at which m=	0.3	-16.1 °C
5- DTT-PAV: Tmin		
Temperature at which %Strain=	1.0 %	-16.9 °C

Table 24 Superpave Binder Grading of the PG64-22 Binder, Construction Sample #2.

PG Grade Sheet

Contract Number	2880	SUPERPAVE PG Grade
AC Sample Number	Construction Sample #2	
Source of Sample	Idaho Asphalt	
Asphalt Type	PG64-22	PG 64-22
Mass Loss, %	0.260	
Brookfield Vis., Pas	0.287	
Flash Pt., °C	308	
Limiting Temp. Tmax, °C	66.6	
Limiting Temp. Tint, °C	21.2	
Limiting Temp. Tmin, °C	-16.3	

DSR-Original						DSR-RTFOT					
Temp, °C	Plate Diam., mm	Strain, %	G*, KPa	Phase angle δ	G*/sinδ kPa	Temp, °C	Plate Diam., mm	Strain, %	G*, KPa	Phase angle δ	G*/sinδ kPa
58	25	12	2.807	84.89	2.818	58	25	10	6.750	81.31	6.828
64	25	12	1.296	86.54	1.298	64	25	10	3.042	83.63	3.061
70	25	12	0.661	87.44	0.662	70	25	10	1.424	84.75	1.430
76	25	12	0.335	87.58	0.335	76	25	10	0.725	87.42	0.725

DSR-PAV						BBR-PAV			DT-PAV		
Temp, °C	Plate Diam., mm	Strain, %	G*, Mpa	Phase angle δ	G*sinδ Mpa	Temp, °C	S(t), MPa	m	Temp, °C	Avg. Failure Strain, %	Avg. Failure Stress, Pa
19	8	1	9.499	42.06	6.363	-12	171.1	0.343	-12	1.96	3.98
22	8	1	6.520	44.18	4.544		156.3	0.343			
25	8	1	4.429	47.28	3.254	-18	337.1	0.282	-18	1.04	5.28
28	8	1	2.888	49.98	2.212		323.0	0.284			

1- Original: Tmax 66.6 °C
Temperature at which G*/sinδ= 1.0 KPa

2- RTFOT: Tmax 66.8 °C
Temperature at which G*/sinδ= 2.2 KPa

3- DSR-PAV: Tint 21.2 °C
Temperature at which G*/sinδ= 5.0 MPa

4- BBR-PAV: Tmin
Temperature at which S(t)= 300.0 MPa -17.2 °C
Temperature at which m= 0.3 -16.3 °C

5- DTT-PAV: Tmin
Temperature at which %Strain= 1.0 % -18.4 °C

Table 25 Asphalt Binder Content Measurements During Construction.

Section	Lift	UNR Reflux	NDOT Ignition
SPAC-20P	**Top**	6.13 6.28	6.30 6.40 6.40
	Average	6.20	6.40
	Bottom	6.16 6.02	6.00 6.20 6.00
	Average	6.10	6.10
SPPG64-22	**Top**	6.23 5.77	6.30 6.10 6.10
	Average	6.00	6.20
	Bottom	5.74 5.88	5.60 5.60 5.80
	Average	5.80	5.70

Table 26   Aggregate Gradations Based on Construction Samples from Bottom Lift of the SPAC-20P Section.

Sieve Size	**Target (original)**	**Target (all bag-house returned)**	**UNR Reflux**	**NDOT Ignition**
1"	100	100	100	100
3/4"	99.6	99.6	99.5	99.0
1/2"	84.1	84.2	86.6	87.7
3/8"	70.1	70.3	75.7	77.0
#4	40.7	41.0	44.8	46.3
#8	24.9	25.3	28.5	29.0
#16	16.4	16.8	19.1	19.0
#30	11.7	12.1	13.9	14.0
#50	9.0	9.4	10.9	11.0
#100	7.2	7.7	8.9	9.0
#200	5.9	6.4	7.4	6.8

Table 27 Aggregate Gradations Based on Construction Samples from Bottom Lift of the SPPG64-22 Section.

Sieve Size	Target (original)	Target (all bag-house returned)	UNR Reflux	NDOT Ignition
1"	100	100	100	100
¾"	99.6	99.6	99.6	99.3
½"	84.1	84.2	84.0	84.3
3/8"	70.1	70.3	70.4	72.0
#4	40.7	41.0	39.7	41.7
#8	24.9	25.3	24.6	26.0
#16	16.4	16.8	15.9	17.3
#30	11.7	12.1	11.5	13.0
#50	9.0	9.4	9.0	10.0
#100	7.2	7.7	7.5	8.0
#200	5.9	6.4	6.3	6.7

Table 28 Aggregate Gradations Based on Construction Samples from Top Lift of the SPAC-20P Section.

Sieve Size	Target (original)	UNR Reflux	NDOT Ignition
1"	100	100	100
3/4"	99.6	99.8	99.0
1/2"	84.1	85.8	87.7
3/8"	70.1	74.0	76.3
#4	40.7	44.2	45.3
#8	24.9	27.3	27.0
#16	16.4	18.0	17.0
#30	11.7	12.9	12.0
#50	9.0	9.6	8.7
#100	7.2	7.4	6.7
#200	5.9	6.0	5.1

Table 29 Aggregate Gradations Based on Construction Samples from Top Lift of the SPPG64-22 Section.

Sieve Size	Target (original)	UNR Reflux	NDOT Ignition
1"	100	100	100
¾"	99.6	99.3	99.0
½"	84.1	84.5	86.7
3/8"	70.1	72.0	72.7
#4	40.7	41.5	42.7
#8	24.9	25.6	25.7
#16	16.4	16.7	16.0
#30	11.7	11.8	11.0
#50	9.0	9.0	8.0
#100	7.2	7.1	6.0
#200	5.9	5.7	4.6

Table 30 Estimated Optimum Binder Content Using Superpave Volumetrics and Determined Binder Contents.

Section	Lift	Binder Content		Binder Content	
		Determined by Reflux	Recommended by Superpave Volumetrics	Determined by Ignition	Recommended by Superpave Volumetrics
SPAC-20P	Top	6.20	6.30	NA	NA
	Bottom	6.10	5.70	6.10	5.70
SPPG64-22	Top	6.00	6.40	NA	NA
	Bottom	5.80	6.00	5.70	5.90

Table 31 In-Place Air-Voids Based on Measurements from Cores.

Section	Top Lift				Bottom Lift				Section Average
	I	II	III	Avg	I	II	III	Avg	
SPAC-20P	5.45	4.62	6.90	5.66	1.07	1.52	3.50	2.03	3.85
SPPG64-22	5.95	5.62		5.79	1.93	2.21	1.92	2.02	3.91
NVPG64-22	5.82	6.72	6.19	6.24	5.77	6.10	6.08	5.98	6.11
NVAC-20P	6.74	6.10	5.84	6.23	6.26	6.30	6.97	6.51	6.37

PERFORMANCE GRADE	**PG 64-**			**PG 52-**							**PG 58-**					PG 64-					
	34	**40**	**46**	**10**	**16**	**22**	**28**	**34**	**40**	**46**	**16**	**22**	**28**	**34**	**40**	**10**	**16**	**22**	**28**	**34**	**40**
Average 7-day Maximum Pavement Design Temperature, °C[a]	< 46			< 52							< 58					< 64					
Minimum Pavement Design Temperature, °C[a]	>-34	>-40	>-46	>-10	>-16	>-22	>-28	>-34	>-40	>-46	>-16	>-22	>-28	>-34	>-40	>-10	>-16	>-22	>-28	>-34	>-40
ORIGINAL BINDER																					
Flash Point Temp, T48: Minimum °C	230																				
Viscosity, ASTM D4402:[b] Maximum, 3 Pa*s, Test Temp, °C	135																				
Dynamic Shear, TP5:[c] G*/sinδ, Minimum, 1.00 Kpa Test Temp @ 10 rad/s, °C	46			52							58					64					
ROLLING THIN FILM OVEN RESIDUE (T240)																					
Mass Loss, Maximum, percent	1.00																				
Dynamic Shear, TP5: G*/sinδ, Minimum, 2.20 Kpa Test Temp @ 10 rad/s, °C	46			52							58					64					
PRESSURE AGING VESSEL RESIDUE (PP1)																					
PAV Aging Temperature, °C[d]	90			90							100					100					
Dynamic Shear, TP5: G*sinδ, Maximum, 5000 Kpa Test Temp @ 10 rad/s, °C	10	7	4	25	22	19	16	13	10	7	25	22	19	16	13	31	28	25	22	19	16
Physical Hardening[e]	Report																				
Creep Stiffness, TP1:[f] S, Maximum, 300 MPa *m* -value, Minimum, 0.300 Test Temp @ 60s, °C	-24	-30	-36	0	-6	-12	-18	-24	-30	-36	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30
Direct Tension, TP3:[f] Failure Strain, Minimum, 1.0% Test Temp @ 1.0 mm/min, °C	-24	-30	-36	0	-6	-12	-18	-24	-30	-36	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30

Figure 1 Superpave PG binder grading system.

PERFORMANCE GRADE	PG 70-						PG 76-					PG 82-				
	10	16	22	28	34	40	10	16	22	28	34	10	16	22	28	34
Average 7-day Maximum Pavement Design Temperature, °C[a]	< 70						< 76					< 82				
Minimum Pavement Design Temperature, °C[a]	>-10	>-16	>-22	>-28	>-34	>-40	>-10	>-16	>-22	>-28	>-34	>-10	>-16	>-22	>-28	>-34
ORIGINAL BINDER																
Flash Point Temp, T48: Minimum °C																
Viscosity, ASTM D4402:[b] Maximum, 3 Pa*s, Test Temp, °C																
Dynamic Shear, TP5:[c] G*/sinδ, Minimum, 1.00 Kpa Test Temp @ 10 rad/s, °C	70						76					82				
ROLLING THIN FILM OVEN RESIDUE (T240)																
Mass Loss, Maximum, percent	1.00															
Dynamic Shear, TP5: G*/sinδ, Minimum, 2.20 Kpa Test Temp @ 10 rad/s, °C	70						76					82				
PRESSURE AGING VESSEL RESIDUE (PP1)																
PAV Aging Temperature, °C[d]	100 (110)						100 (110)					100 (110)				
Dynamic Shear, TP5: G*sinδ, Maximum, 5000 Kpa Test Temp @ 10 rad/s, °C	34	31	28	25	22	29	37	34	31	28	25	40	37	34	31	28
Physical Hardening[e]	Report															
Creep Stiffness, TP1:[f] S, Maximum, 300 MPa *m*-value, Minimum, 0.300 Test Temp @ 60s, °C	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	0	-6	-12	-18	-24
Direct Tension, TP3:[f] Failure Strain, Minimum, 1.0% Test Temp @ 1.0 mm/min, °C	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	0	-6	-12	-18	-24

Figure 1 Superpave PG binder grading system (cont.).

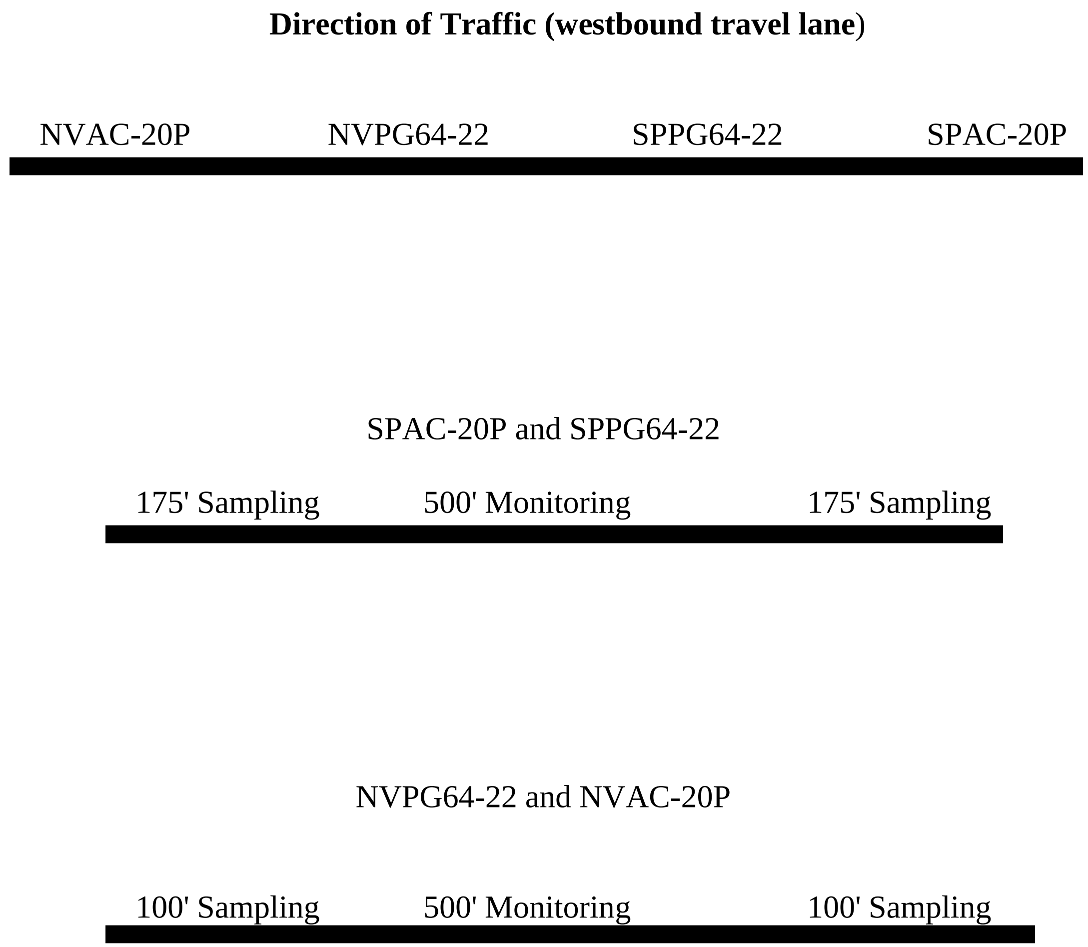

Figure 2 Layout of the test sections on I-80 westbound travel lane.

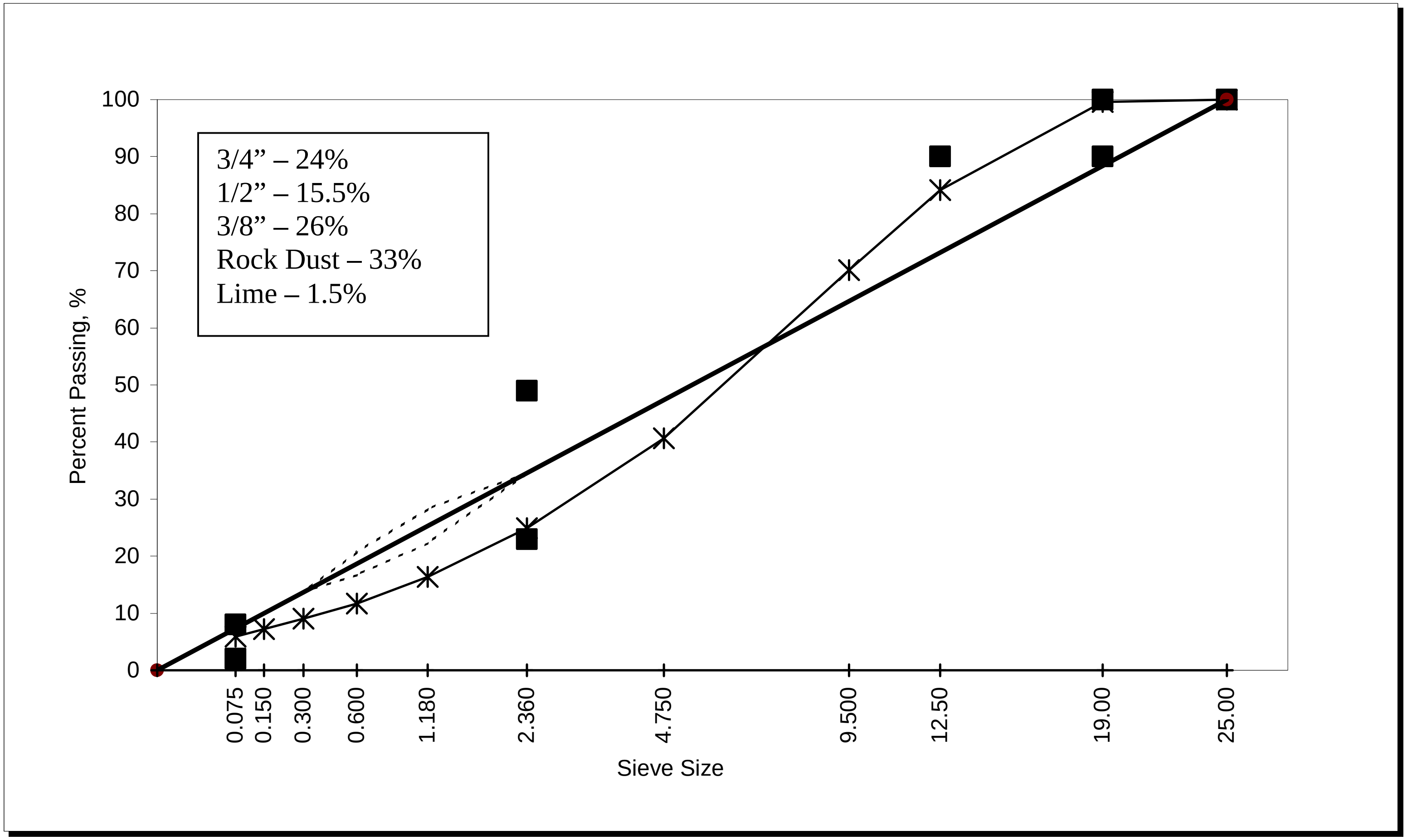

Figure 3 Aggregate gradation for the Superpave mixtures.

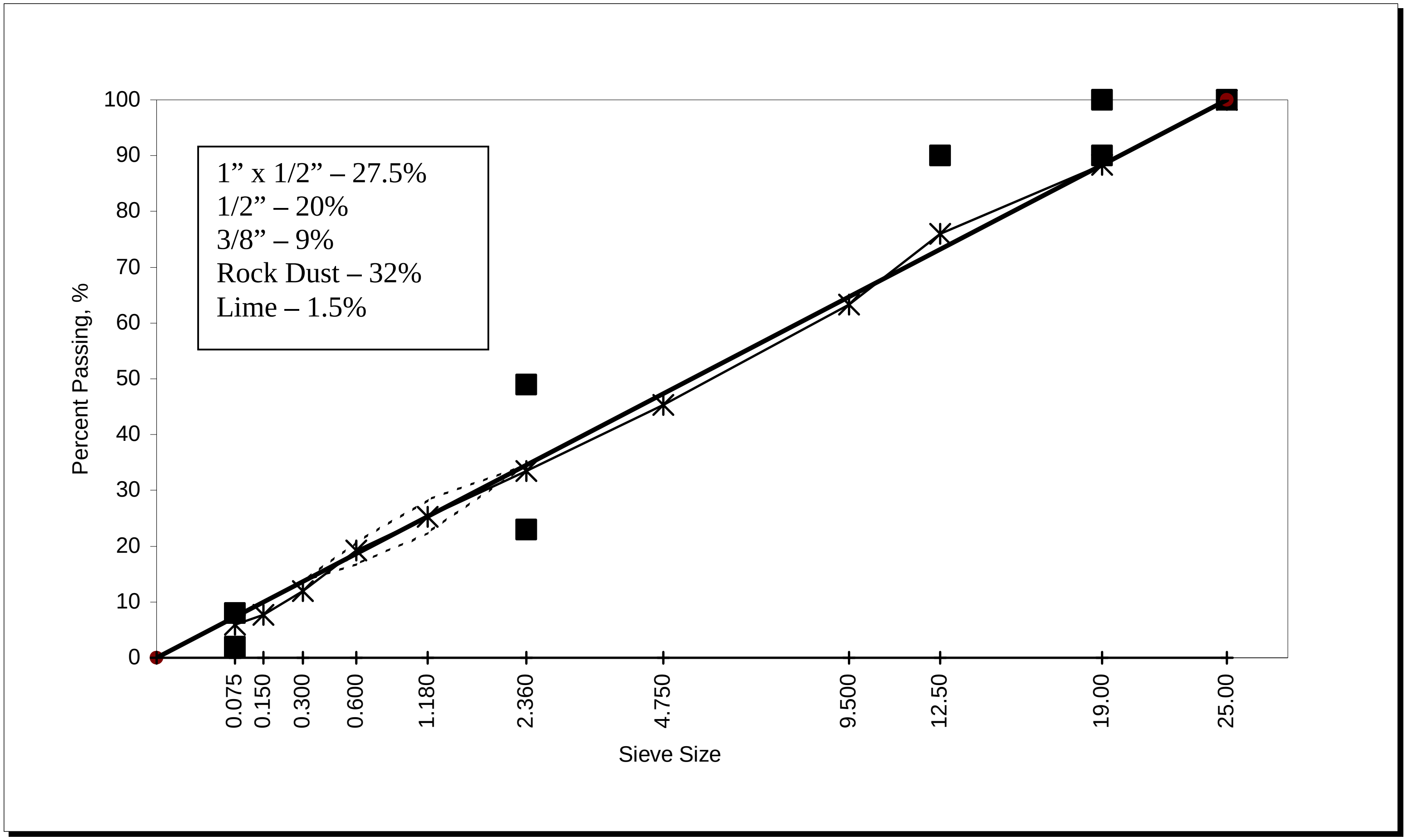

Figure 4 Aggregate gradation for the Hveem mixtures.

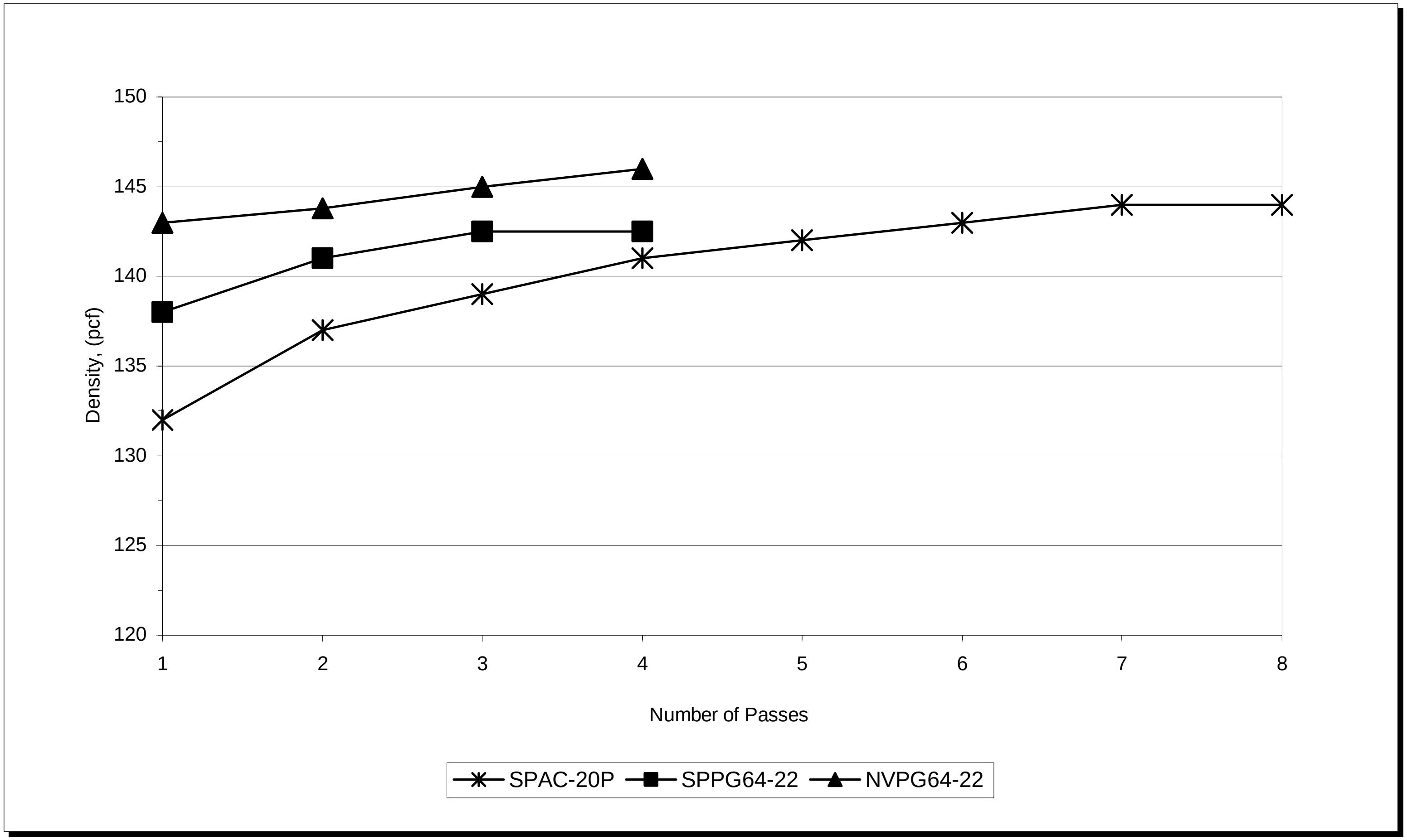

Figure 5 Density of the various HMA mixtures as a function of roller passes.

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