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DESIGN and CONSTRUCTION of NDOT 2001-2003 SUPERPAVE TEST SECTIONS

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16. Abstract

Based on the field performance of several Superpave mixtures throughout the state of Nevada during the 1990's, NDOT decided to modify the Superpave volumetric mix design method and construct two test sections side-by-side with the conventional NDOT Hveem mixtures. The modifications of the Superpave volumetric mix design included: a) eliminate the restricted zone requirement on aggregate gradation, b) include a minimum requirement on Hveem stability, c) verify potential performance in rutting with the APA, and d) include a minimum dry tensile strength of 65 psi and a retained tensile strength ratio of 70%.

Using the modified Superpave volumetric mix design, NDOT constructed three test sections: two on I-80 in the northern part of the state in 2001 and 2003 and one on I-15 in the southern part of the state in 2002. Each test section was built as part of a Hveem designed project which will allow for the direct comparison of the performance of mixtures designed with the modified Superpave and NDOT Hveem methods.

This report summarizes the mix designs data and construction activities of the Superpave and Hveem sections within each project. Samples were obtained during the construction of the test sections. Additional laboratory testing is currently being conducted on laboratory prepared mixtures and field prepared mixtures to assess the resistance of the mixtures to the 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 modified Superpave volumetric mix design method under Nevada's conditions.

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EXECUTIVE SUMMARY

Based on the field performance of several Superpave mixtures throughout the state of Nevada during the 1990's, NDOT decided to modify the Superpave volumetric mix design method and construct two test sections side-by-side with the conventional NDOT Hveem mixtures. The modifications of the Superpave volumetric mix design included: a) eliminate the restricted zone requirement on aggregate gradation, b) include a minimum requirement on Hveem stability, c) verify potential performance in rutting with the APA, and d) include a minimum dry tensile strength of 65 psi and a retained tensile strength ratio of 70%.

Using the modified Superpave volumetric mix design, NDOT constructed three test sections: two on I-80 in the northern part of the state in 2001 and 2003 and one on I-15 in the southern part of the state in 2002. Each test section was built as part of a Hveem designed project which will allow for the direct comparison of the performance of mixtures designed with the modified Superpave and NDOT Hveem methods.

This report summarizes the mix designs data and construction activities of the Superpave and Hveem sections within each project. Samples were obtained during the construction of the test sections. Additional laboratory testing is currently being conducted on laboratory prepared mixtures and field prepared mixtures to assess the resistance of the mixtures to the 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 modified Superpave volumetric mix design method under Nevada's conditions.

TABLE OF CONTENT

INTRODUCTION

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.

Using the measured rheological properties, the asphalt binder is graded based on the temperatures at which the properties limits are achieved. Figure 1 shows 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 single-day 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 anticipated highest seven-days average pavement temperature is 64°C and the lowest single-day pavement temperature is -22°C.

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 gyratory compactor is used to compact HMA mixtures at trial asphalt binder contents for specified number of gyrations (Table 1) (1). 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 volumetric criteria are established as a function of the number of gyrations as shown in Table 2 (2). The aggregate criteria include requirements on the fractured faces, sand equivalent, flat and elongated particles, and gradation as shown in Tables 3 and 4 (2). The aggregate properties are measured first and an acceptable aggregate blend and gradation is established. 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; pavement temperatures reaching both extremes coupled with severe winter freeze-thaw cycling in the northern part of the state. 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.

NDOT's PREVIOUS EXPERIENCE WITH SUPERPAVE MIXTURES

With good success with the current Hveem mix design method, NDOT is approaching the implementation of the Superpave mix design system with extreme caution. The following represents a brief summary of NDOT's previous experience with Superpave mixtures.

- In 1996 a Superpave test section was constructed on SR 278 in Eureka County, Nevada under contract number 2751. The Superpave designed mixture was a ½" nominal maximum aggregate size with a PG64-28 binder at an optimum binder content of 6.3%. After three years of service, the section started showing some intermittent transverse cracking on isolated areas and after five years of service, the section showed extensive transverse, longitudinal, and block cracking throughout.

- In 1997 a Superpave test section was constructed on US 93 in White Pine County, Nevada under contract number 2827. The Superpave designed mixture was a 3/4" nominal maximum aggregate size with a PG64-34 binder at an optimum binder content of 5.6%. After four years of service, the section showed longitudinal and transverse cracking throughout.

- In 1998 two Superpave sections were constructed on I 80 in Churchill County, Nevada under contract number 2880: SP AC-20P and SP PG 64-22. The SP AC-20P mixture was a 3/4" nominal maximum aggregate size with an AC-20P binder at an optimum binder content of 5.8%. The SP PG64-22 mixture was a 3/4" nominal maximum aggregate size with a PG64-22 binder at an optimum binder content of 5.8%. After three years of service the SP AC-20P section experienced an average rut depth of 0.31" and the SP PG64-22 section experienced an average rut depth of 0.60" with severe flushing in the wheelpath.

Based on the above documented experiences with Superpave mixtures, NDOT decided to re-evaluate the Superpave volumetric mix design procedure with the following modifications:

- Eliminate the Restricted Zone requirement on aggregate gradation.
- Include a minimum requirement on Hveem stability.
- Verify potential performance using the Asphalt Pavement Analyzer (APA).
- Include a minimum dry tensile strength of 65 psi on Hveem compacted samples at optimum.
- Include a minimum tensile strength ratio of 70% on Hveem compacted samples at optimum.

Between 2001 and 2003, NDOT implemented the above modifications on three test sections that are summarized in this report.

TEST SECTION ON CONTRACT 3064

The overall objective of this section is to compare the performance of a modified Superpave HMA mixture with a NDOT Hveem mixture. One Superpave test section was constructed as part of NDOT Hveem designed project on I-80 in Churchill County, east of Reno, Nevada on October 3, 2001. The entire project spans from milepost 2.20 to milepost 12.88 (2.232 to 12.832 CUM MP) in both the eastbound and westbound directions. The Superpave section is located between mileposts 5.81 and 6.78 (5.837 to 6.980 CUM MP) of the travel lane in the westbound direction. Therefore, the entire project will represent the NDOT Hveem mixture while the one-mile test section will represent the Superpave mixture.

The constructed layer consisted of milling the top 1" of the existing HMA mix (7") and placing a 2.5" of new dense graded HMA mixture and a 3/4" open graded mixture. The supporting layers consist of 6" of the remaining old HMA and 10" aggregate base. The contractor for the project was Frehner Construction.

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

One direction ADT:	3,520
Truck factor:	1.44
Percent trucks:	30%
Daily one direction ESALs:	1,521
20 years average growth rate:	2.1%
20 years design ESALs:	13,600,000

Aggregates

Both sections (Hveem and Superpave) were constructed using the same aggregate source located east of Reno, Nevada, owned by Frehner Construction Company. The Superpave and Hveem mixtures had different aggregate gradations. The aggregates were produced into four stockpiles: 1", 3/4", crusher fines, and natural fines. Table 5 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.

Superpave Mixture

The blend for the Superpave mixture was as follows:

1" stockpile:	25%
3/4" stockpile:	30%
Crusher Fines:	30%
Natural Fines:	15%
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 2 shows the aggregate gradation for the Superpave mixture.

Hveem Mixture

The Hveem mix design conducted by NDOT Materials Division used a four stockpile blend. The blend for the Hveem mixtures was a follows:

1" stockpile:	18%
3/4" stockpile:	24%
Crusher Fines:	48%
Natural Fines:	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 2 shows the aggregate gradation for the Hveem mixture.

Asphalt Binder

A single asphalt binder was used for both mixtures: AC-20P. The AC-20P binder was supplied by the Telfer Sheldon Co. and is a typical polymer-modified binder that is commonly used by NDOT. Table 8 summarizes the properties of the refinery sample and Table 9 summarizes the properties of the AC-20P binder graded using the Superpave PG grading system. The AC-20P used in this project graded as PG58-28 under both the AASHTO M320 and MP1a specifications.

Mix Designs

The mix designs for the two mixtures were completed during Summer, 2001. The NDOT Materials Division conducted the mix design for the Hveem section and the Pavements/Materials Program conducted the mix design for the Superpave section.

Superpave Section

The mix design was conducted using the Superpave volumetric mix design system with the modifications presented earlier. Using the 20 years design ESALs of 12.2 millions, the number of gyrations were identified as follows:

$N_{initial} = 8$ $N_{design} = 100$ $N_{maximum} = 160$

The data in Table 10 show all the mixtures properties required by the Superpave volumetric mix design system. Using the data in Table 10 along with the Hveem stability, tensile strength value and ratio, and APA properties, the final mix design recommendations are presented in Table 11. It can be seen from the mix design data in Table 11 that the recommended mix design satisfies all the Superpave criteria plus the NDOT modifications. The recommended optimum asphalt binder content was 4.25% by total weight of mix and 4.44% by dry weight of aggregate.

Hveem Section

The mix design was conducted using the NDOT Hveem mix design procedure. Table 12 summarizes 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. Table 13 presents the mix design recommendations. The recommended optimum asphalt binder content was 4.75% by dry weight of aggregates and 4.5% by total weight of mix.

Construction Activities

The construction of the entire project began on September 8, 2001 and the construction of the Superpave test section occurred on October 3, 2001. In addition to the construction crew and NDOT resident engineer, personnel from NDOT's Materials Division and UNR's Pavements/Materials Program were present during the construction of the Superpave section. The objective was to let the construction of the test section follow the normal construction activities of the entire project as closely as possible. In other words, the intention was not to build a unique test section but to construct a normal section with a unique mixture. Therefore, no special precautions or modification of construction activities were imposed. The construction of the test section went very smooth.

Sampling and Testing

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.

Asphalt Binder Properties

Asphalt binder samples were obtained and tested for grade verification. The testing was conducted by the NDOT Materials Division which consisted of measuring the absolute viscosity at 60°C for the AC-20P binder. Table 14 summarizes the binders properties measured by NDOT during the construction of the Superpave test section. The data in Table 14 indicate that all the sampled binders met the NDOT specification for the intended grade.

Asphalt Binder Content and Aggregate Gradation

The ignition oven method was used to assess the gradation and asphalt binder content of the field samples. Table 15 summarizes the binder contents and aggregate gradations measured on the mix samples obtained during construction.

In-Place Air-voids

The in-place air-voids of the test sections were determined using the in-place density as measured by the nuclear density gauges and the measured maximum theoretical specific gravity. Table 16 summarizes the in-place air-voids for the Hveem and Superpave sections. The air-voids data showed that a very uniform section was constructed.

TEST SECTION ON CONTRACT 3071

The overall objective of this section is to compare the performance of a modified Superpave HMA mixture with a NDOT Hveem mixture. One Superpave test section was constructed as part of NDOT Hveem designed project on I-15 in Clark County, Nevada on October 23, 2002. The entire project spans from milepost 0.00 to milepost 16.34 (2.232 to 12.832 CUM MP) in both the northbound and southbound directions. The Superpave section is located between mileposts 2.00 and 3.00 (2.00 to 3.00 CUM MP) of the travel lane in the northbound direction. Therefore, the entire project will represent the NDOT Hveem mixture while the one mile test section will represent the Superpave mixture.

The constructed layer consisted of milling the top 2.0" of the existing HMA mix (5 in.) and placing a 5.0" of new dense graded HMA mixture and a 3/4" open graded mixture. The supporting layers consist of 2.75" of the remaining old HMA and a 6.0" aggregate base. The contractor for the project was Las Vegas Paving Corporation.

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

One direction ADT:	19,800
Truck factor:	1.293
Percent trucks:	18%
Daily one direction ESALs:	4,610
20 years average growth rate:	3.0%
20 years design ESALs:	45,200,000

Aggregates

Both sections (Hveem and Superpave) were constructed using the same aggregate source from the Sloan Pit owned by Las Vegas Paving. The Superpave and Hveem mixtures had different aggregate gradations. The aggregates were produced into four stockpiles ¾", ½", crusher fines, and concrete fines. Table 17 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.

Superpave Mixture

The blend for the Superpave mixture was as follows:

¾" stockpile:	12%
½" stockpile:	50%
Crusher Fines:	28%
Concrete Fines:	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 18 summarizes the properties of the blend aggregates. Table 19 summarizes the gradation of the blend and Figure 3 shows the aggregate gradation for the Superpave mixture.

Hveem Mixture

The Hveem mix design conducted by NDOT Materials Division used a four stockpile blend. The blend for the Hveem mixtures was a follows:

¾" stockpile:	8%
½" stockpile:	44%
Crusher Fines:	25%
Concrete Fines:	23%
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 18 summarizes the properties of the blend aggregates. Table 19 summarizes the gradation of the blend and Figure 3 shows the aggregate gradation for the Hveem mixture.

Asphalt Binder

A single asphalt binder was used for both mixtures: PG76-22NV. The PG76-22NV binder was supplied by the Ergon Co. and is a polymer-modified binder. Table 20 summarizes the NDOT specification for the PG76-22NV binder and Table 21 summarizes the properties of the PG76-22NV binder graded using the Superpave PG grading system.

Mix Designs

The mix designs for the two mixtures were completed during Summer, 2002. The NDOT Materials Division conducted the mix design for the Hveem section and the Pavements/Materials Program conducted the mix design for the Superpave section.

Superpave Section

The mix design was conducted using the Superpave volumetric mix design system with the modifications presented earlier. Using the 20 years design ESALs of 45.2 millions, the number of gyrations were identified as follows:

$N_{initial} = 9$ $N_{design} = 125$ $N_{maximum} = 205$

The data in Table 22 show all the mixtures properties required by the Superpave volumetric mix design system. Using the data in Table 22 along with the Hveem stability, tensile strength value and ratio, and APA properties, the final mix design recommendations are presented in Table 23. It can be seen from the mix design data in Table 23 that the recommended mix design satisfies all the Superpave criteria plus the NDOT modifications. The recommended optimum asphalt binder content was 4.00% by total weight of mix and 4.20% by dry weight of aggregate.

Hveem Section

The mix design was conducted using the NDOT Hveem mix design procedure. Table 24 summarizes 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. Table 25 presents the mix design recommendations. The recommended optimum asphalt binder content was 4.30% by dry weight of aggregates and 4.12% by total weight of mix.

Construction Activities

The construction of the entire project began in August 2001 and the construction of the

Superpave test section occurred on October 23, 2002. In addition to the construction crew and NDOT resident engineer, personnel from NDOT's Materials Division and UNR's Pavements/Materials Program were present during the construction of the Superpave section. The objective was to let the construction of the test section follow the normal construction activities of the entire project as closely as possible. In other words, the intention was not to build a unique test section but to construct a normal section with a unique mixture. Therefore, no special precautions or modification of construction activities were imposed. The construction of the test section went very smooth.

Sampling and Testing

During the construction of the test sections, several types of samples were obtained. Only couple asphalt binder samples were tested during construction while other materials were saved for future testing and evaluation. The rotational viscosity at 135°C and $G^*/\sin(\delta)$ at 76°C were measured on the original binder for verification purposes. The tested binder had a rotational viscosity of 1.42 Pa.s and an average $G^*/\sin(\delta)$ of 1.54 kPa. The project ranges for the rotational viscosity and $G^*/\sin(\delta)$ were 1.36-2.11 Pa.s and 1.38-1.96 kPa, respectively.

TEST SECTION ON CONTRACT 3140

The overall objective of this section is to compare the performance of a modified Superpave HMA mixture with a NDOT Hveem mixture. One Superpave test section was constructed as part of NDOT Hveem designed project on I-80 in Elko County, Nevada on September 5, 2003. The entire project spans from milepost 310.00 milepost 330.00 (EL 32.00 to EL43.95 CUM MP) in both the eastbound and westbound directions. The Superpave section is located between mileposts 311.00 and 310.00 (373+03 to 320+23 CUM MP) of the travel lane in the west bound direction. Therefore, the entire project will represent the NDOT Hveem mixture while the one-mile test section will represent the Superpave mixture.

The constructed layer consisted of milling the top 1" of the existing HMA mix (5") and placing a 2.5" of new dense graded HMA mixture and a 3/4" open graded mixture. The supporting layers consist of 4" of the remaining old HMA and 6" aggregate base. The contractor for the project was Road & Highway Builders Construction Company.

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

One direction ADT:	4000
Truck factor:	1.44
Percent trucks:	30%
Daily one direction ESALs:	635,700
20 years average growth rate:	2%
20 years design ESALs:	15,450,000

Aggregates

Both sections (Hveem and Superpave) were constructed using the same aggregate source from Howell pit located east of Reno, Nevada, owned by Road & Highway Builders Construction Company. The Superpave and Hveem mixtures had different aggregate gradations. The aggregates were produced into four stockpiles: 3/4", 3/8", crusher fines, and natural fines. Table 26 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.

Superpave Mixture

The blend for the Superpave mixture was as follows:

3/4" stockpile:	30%
3/8" stockpile:	39%
Crusher Fines:	21%
Natural Fines:	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 27 summarizes the properties of the blend aggregates. Table 28 summarizes the gradation of the blend and Figure 4 shows the aggregate gradation for the Superpave mixture.

Hveem Mixture

The Hveem mix design conducted by NDOT Materials Division used a four stockpile blend. The blend for the Hveem mixtures was a follows:

3/4" stockpile:	40%
3/8" stockpile:	12%
Crusher Fines:	38%
Natural Fines:	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 27 summarizes the properties of the blend aggregates. Table 28 summarizes the gradation of the blend and Figure 4 shows the aggregate gradation for the Hveem mixture.

Asphalt Binder

A single asphalt binder was used for both mixtures: AC-20P. The AC-20P binder was supplied by the Idaho Asphalt Co. and is a typical polymer-modified binder that is commonly used by NDOT. Table 29 summarizes the properties of the refinery sample and Table 30 summarizes the properties of the AC-20P binder graded using the Superpave PG grading system. The AC-20P used in this project graded as PG64-28 under AASHTO M320 and PG64-22 under MP1a specifications.

Mix Designs

The mix designs for the two mixtures were completed during summer, 2003. The NDOT Materials Division conducted the mix design for the Hveem section and the Pavements/Materials Program conducted the mix design for the Superpave section.

Superpave Section

The mix design was conducted using the Superpave volumetric mix design system with the modifications presented earlier. Using the 20 years design ESAL's of 15.450 millions, the number of gyrations were identified as follows:

$N_{initial} = 8$ $N_{design} = 100$ $N_{maximum} = 160$

The data in Table 31 show all the mixtures properties required by the Superpave volumetric mix design system. Using the data in Table 31 along with the Hveem stability, tensile strength value and ratio, and APA properties, the final mix design recommendations are presented in Table 32. It can be seen from the mix design data in Table 32 that the recommended mix design satisfies all the Superpave criteria plus the NDOT modifications. The recommended optimum asphalt binder content was 5.4% by total weight of mix and 5.7% by dry weight of aggregate.

Hveem Section

The mix design was conducted using the NDOT Hveem mix design procedure. Table 33 summarizes 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. Table 34 presents the mix design recommendations. The recommended optimum asphalt binder content was 6.0% by dry weight of aggregates and 5.7% by total weight of mix.

Construction Activities

The construction of the entire project began on December 2002 and the construction of the Superpave test section occurred on September 5, 2003. In addition to the construction crew and NDOT resident engineer, personnel from NDOT's Materials Division and UNR's Pavements/Materials Program were present during the construction of the Superpave section. The objective was to let the construction of the test section follow the normal construction activities of the entire project as closely as possible. In other words, the intention was not to build a unique test section but to construct a normal section with a unique mixture. Therefore, no special precautions or modification of construction activities were imposed. The construction of the test section went very smooth.

Sampling and Testing

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.

Asphalt Binder Properties

Asphalt binder samples were obtained and tested for grade verification. The testing was conducted by the NDOT Materials Division, which consisted of measuring the absolute viscosity at 60°C for the AC-20P binder. Table 35 summarizes the binders properties measured by NDOT during the construction of the Superpave test section. The data in Table 35 indicate that all the sampled binders met the NDOT specification for the intended grade.

Asphalt Binder Content and Aggregate Gradation

The ignition oven method was used to assess the gradation and asphalt binder content of the field samples. Table 36 summarizes the binder contents and aggregate gradations measured on the mix samples obtained during construction.

In-Place Air-voids

The in-place air-voids of the test sections were determined using the in-place density as measured by the nuclear density gauges and the measured maximum theoretical specific gravity. Table 37 summarizes the in-place air-voids for the Hveem and Superpave sections.

SUMMARY AND CONCLUSIONS

This report documents the construction activities of NDOT Superpave test sections placed on I-80 east of Reno and on I-15 in Las Vegas. One Superpave test section was constructed within each project. The projects on contracts 3064 and 3140 (I-80) used an AC-20P binder in both the Hveem and the Superpave mixtures. The project on contract 3071 (I-15) used a PG76-22NV binder in both the Hveem and the Superpave mixtures.

Additional laboratory testing is currently being conducted on laboratory prepared mixtures and field prepared mixtures to assess the resistance of the mixtures to the 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 modified Superpave volumetric mix design method under Nevada's conditions.

REFERENCES

1. "PP28: Practice for Superpave Volumetric Design of Hot-Mix Asphalt (HMA)," AASHTO Specifications, 2002.

2. "MP2: Specifications for Superpave Volumetric Mix Design," AASHTO Specifications, 2002.

Table 1. Superpave Design gyratory compaction efforts.

Design ESALs (million)	Compaction Paramters		
	$N_{initial}$	N_{design}	N_{max}
< 0.3	6	50	75
0.3 to < 3	7	75	115
3 to < 30	8	100	160
≥ 30	9	125	205

Table 2. Superpave volumetric mixture design requirements.

Design ESALs (million)	Required Density (% of theoretical maximum specific gravity)			Voids in Mineral Aggregate, VMA Percent, minimum					Voids Filled with Asphalt, VFA, %, Minimum	Dust-to-Binder Ratio
				Nominal maximum aggregate size, mm						
	$N_{initial}$	N_{design}	N_{max}	37.5	25.0	19.0	12.5	9.5		
<0.3	≤ 91.5								70 - 80	
0.3 to < 3	≤ 90.5								65 - 78	
3 to < 10		96.0	≤ 98.0	11.0	12.0	13.0	14.0	15.0		0.6 - 1.2
10 to < 30	≤ 89.0								65-75	
≥ 30										

Table 3. Superpave aggregate consensus property requirements.

Design ESALs (million)	Fractured Faces, CA, %, min.		Uncompacted voids, FA, %, min.		Sand Equivalent %, min.	Flat & Elong., %, min.
	≤ 100 mm	> 100 mm	≤ 100 mm	> 100 mm		
< 0.3	55/-	-/-	-	-	40	-
0.3 to 3	75/-	50/-	40	40	40	10
3 to < 10	85/80[2]	60/-	45	40	45	
10 to < 30	95/90	80/75	45	40	45	
≥ 30	100/100	100/100	45	45	50	

(2) 85/80 denotes that 85 percent of the coarse aggregate has one fractured face and 80 percent has two or more fractured faces.

Table 4. Superpave aggregate gradation control points.

Sieve Size (mm)	Nominal maximum aggregate size - control point (percent passing)									
	37.5 mm		25.0 mm		19.0 mm		12.5 mm		9.5 mm	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
50.0	100									
37.5	90	100	100							
25.0		90	90	100	100					
19.0					90	100	100			
12.5							90	100	100	
9.5									90	100
4.75										90
2.36	15	41	19	45	23	49	28	58	32	67
0.075	0	6	1	7	2	8	2	10	2	10

Table 5. Gradations of the stockpile aggregates on 3064.

Sieve Size	1" Stockpile	3/4" Stockpile	Crusher Fines Stockpile	Natural Fines Stockpile
1"	100.0	100.0	100.0	100.0
3/4"	60.7	100.0	100.0	100.0
1/2"	1.1	73.3	100.0	100.0
3/8"	0.8	37.4	100.0	100.0
#4	0.6	1.8	90.5	95.8
#8	0.5	0.7	61.0	79.2
#10	0.5	0.7	53.5	74.0
#16	0.4	0.7	39.2	58.2
#30	0.4	0.7	27.1	38.8
#40	0.4	0.7	22.9	30.7
#50	0.4	0.7	19.4	24.3
#100	0.4	0.6	14.8	16.2
#200	0.4	0.5	12.1	12.5

Table 6. Properties of the blend aggregates on 3064.

Property	Superpave Mixtures		Hveem Mixtures	
	- #4	+ #4	- #4	+ #4
Bulk Sp. Gr. (SSD)	2.763	2.684	2.51	2.65
Apparent Sp. Gr.		2.747		2.774
Absorption (%)		1.4		1.1

Table 7. Gradations of the blend aggregates for the Superpave and Hveem mixtures on 3064.

Sieve Size	Superpave Mixtures			Hveem Mixtures	
	Blend	Control Points		Blend	NDOT Spec.
		Upper	Lower		
1"	100.0	100		100.0	100
3/4"	90.2	100	90	92.9	88 - 95
1/2"	67.3	90		75.8	70 - 85
3/8"	56.4			67.1	60 - 78
#4	42.2			53.6	43 - 60
#8	30.5	49	23	37.5	
#10	27.5			33.3	30 - 44
#16	20.8			24.9	
#30	14.3			17.1	
#40	11.8			14.3	12 - 22
#50	9.8			12.0	
#100	7.2			8.9	
#200	5.8	8	2	7.3	3 - 8

Table 8. Conventional properties of the refinery sample of the AC-20P binder on 3064.

Tests Performed	Property	NDOT Specification
Original Viscosity @ 60°C, 300mm Hg, Pa..s,	210+	Minimum 210
Residue Viscosity @ 60°C, 300 mm Hg, Pa..s,	300.0+	Minimum 300
Original Kinematic Viscosity @135°C, mm^2/s	495	475 - 3000
Residue Kinematic Viscosity @ 135°C, mm^2/s	515	
Original Penetration @ 25°C, 100g, 5 sec, dmm	148	
Residue Penetration @ 25°C, 100g, 5 sec, dmm	117	
Original Penetration @ 4°C, 200g, 60 sec, dmm	59	
Residue Penetration @ 4°C, 200g, 60 sec, dmm	41	
Flash point, C.O.C., °C	320	Minimum 232
Original Ductility @ 4°C, (5cm/min), cm	55+	Minimum 50
Residue Ductility @ 4°C, (5cm/min), cm	63	Minimum 25
Loss on heating, %	0.271	Maximum 0.5
Toughness, N.m	15.82	Minimum 12.43
Tenacity, N.m	14.35	Minimum 8.47
Specific Gravity	1.002	
Sieve Test	Pass	Pass

Table 9. Superpave PG grade of the refinery sample of the AC-20P binder on 3064.

PG Grade Sheet

		SUPERPAVE PG-Grade M320	SUPERPAVE PG-Grade MP1a
Contract Number	3064		
AC Sample Number	1		
Asphalt Type	AC-20P		
Mass Loss,%	0.376	PG 58-28	PG 58-28
Brookfield Vis., Pas	0.352		
Flash Pt.,°C			
Limiting Temp. for Tmax,°C	58.5		
Limiting Temp. for Tint,°C	15.2		
Limiting Temp. for Tmin,°C		-20.2	
Tcrit,°C			-30.0

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	2.762	73.93	2.874	52	25	10	4.372	75.32	4.520
58	25	12	1.435	72.87	1.502	58	25	10	2.242	75.25	2.318
64	25	12	0.800	70.43	0.849	64	25	10	1.157	74.75	1.199
70	25	12	0.491	65.28	0.540	70	25	10	0.652	72.75	0.682

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, MPa
13	8	1	9.603	47.20	7.045	-12	69.2	0.465	-12	5.22	2.69
16	8	1	5.539	52.91	4.418	-18	164.5	0.364	-18	1.43	3.62
19	8	1	3.413	57.10	2.865	-24	355.0	0.287	-24	0.25	1.33
22	8	1	2.048	60.86	1.788						
25	8	1	1.203	64.94	1.090						

Table 10. Properties of the Superpave mixtures on 3064.

%AC	G_{mm}	G_{sb}	Sample #	G_{mb}	$\%G_{mm}@N_{ini}$	$\%G_{mm}@N_{des}$	% Air	VMA	VFA
3.5	2.561	2.697	1	2.402	85.30	93.82	6.18	14.03	55.92
			2	2.407	85.83	94.01	5.99	13.85	56.75
			Mean	2.405	85.57	93.91	6.09	13.94	66.33
			St. Dev.	0.003	0.37	0.14	0.14	0.13	0.59
			C.V.	0.145	0.44	0.15	2.24	0.90	1.04

%AC	G_{mm}	G_{sb}	Sample #	G_{mb}	$\%G_{mm}@N_{ini}$	$\%G_{mm}@N_{des}$	% Air	VMA	VFA
4.0	2.541	2.697	1	2.416	87.50	95.09	4.91	13.99	64.90
			2	2.428	87.05	95.57	4.43	13.56	67.32
			Mean	2.422	87.28	95.33	4.67	13.77	66.11
			St. Dev.	0.009	0.32	0.34	0.34	0.31	1.71
			C.V.	0.356	0.37	0.36	7.27	2.23	2.59

%AC	G_{mm}	G_{sb}	Sample #	G_{mb}	$\%G_{mm}@N_{ini}$	$\%G_{mm}@N_{des}$	% Air	VMA	VFA
4.5	2.521	2.697	1	2.442	88.38	96.88	3.12	13.50	76.9
			2	2.447	88.58	97.08	2.92	13.32	78.1
			Mean	2.445	88.48	96.98	3.02	13.41	77.5
			St. Dev.	0.004	0.14	0.14	0.14	0.13	0.85
			C.V.	0.146	0.16	0.15	4.71	0.94	1.09

%AC	G_{mm}	G_{sb}	Sample #	G_{mb}	$\%G_{mm}@N_{ini}$	$\%G_{mm}@N_{des}$	% Air	VMA	VFA
5.0	2.502	2.697	1	2.457	89.74	98.23	1.77	13.43	86.8
			2	2.454	88.98	98.09	1.91	13.55	85.9
			Mean	2.456	89.36	98.16	1.84	13.49	86.4
			St. Dev.	0.002	0.53	0.10	0.10	0.09	0.65
			C.V.	0.101	0.60	0.10	5.41	0.65	0.75

%AC	G_{mm}	G_{sb}	Sample #	G_{mb}	$\%G_{mm}@N_{ini}$	$\%G_{mm}@N_{des}$	% Air	VMA	VFA
5.5	2.482	2.697	1	2.436	89.16	98.12	1.88	14.64	87.2
			2	2.445	90.14	98.51	1.49	14.30	89.6
			Mean	2.441	89.65	98.31	1.69	14.47	88.4
			St. Dev.	0.007	0.70	0.27	0.27	0.24	1.69
			C.V.	0.277	0.78	0.28	16.12	1.63	1.91

Table 11.Mix design for the Superpave section on 3064.

Mix Property	Result	Criteria
Optimum Binder Content %	4.25 twm, 4.44 dwa	
Air-voids @ N_{design} = 100, %	4.0	4.0
VMA, %	13.4	13.0 % min.
VFA, %	71.0	65 - 75 %
Dust Proportion, $P_{0.075}/P_{be}$	1.42	0.8-1.6
%Gmm @ Nini = 8	87.0	< 89%
% Gmm @ Nmax = 160	97.2	< 98%
Film Thickness, microns	8.07	
Hveem Stability on 4" samples	53	37 min.
Dry Tensile Strength on 4" Hveem samples, psi	70	65 min.
Wet Tensile Strength on 4" Hveem samples, psi	54	
Tensile Strength Ratio, %	77	70 min.
APA Rut Depth after 8,000 cycles @ 60°C, mm	2.8	8mm, max.

Table 12. Properties of the Hveem mixtures on 3064.

Binder Content % by dwa	Hveem Stability	Air-voids (%)
3.5	43	9.9
4.0	41	7.4
4.5	38	6.5
5.0	39	4.4
5.5	36	2.8
6.0	32	2.1

Table 13. Mix design for the Hveem section on 3064.

Property	Value	NDOT Specifications
Optimum Binder Content	4.75 % dwa	
Air-voids, %	5.1 %	4 - 7 %
Stability	39	37 min.
VMA, %	15.8 %	12 - 22 %
Sand Equivalent, %	47	
+#4 Water Absorption	1.1 %	4 % max.
SS Soundness Coarse, %	5	12 % max.
SS Soundness Fines, %	5	15 % max.
L.A. Abrasion, %	19	37 % max.
Fractured Faces	100 %	80% min.
Original Tensile Strength, psi	76 psi	65 psi min.
% Retained Strength	81 %	70 % min.

Table 14. Properties of field samples of the AC-20P sampled during construction of the Superpave section on 3064.

Sample Number	Viscosity at 60°C, Specification: 210 Pa.s Min.
1	254
2	249
3	423
4	210+
5	644
6	263

Table 15. Aggregate gradations and binder contents of construction samples from the Superpave section on 3064.

Value	Sieve size								Binder content (%)
	1"	1/2"	3/4"	3/8"	#4	#10	#40	#200	
Avg	100.0	94.5	77.5	67.8	55.4	32.8	13.2	6.2	4.7
Min	100.0	91.0	72.0	60.0	47.0	25.0	12.0	5.0	4.3
Max	100.0	98.0	83.0	74.0	62.0	37.0	14.0	7.0	5.3
STD	0.00	1.63	2.77	2.88	3.10	2.23	0.59	0.48	0.21

Table 16. In-place air-voids on 3064.

Value	Entire project (%)	Superpave section (%)
Avg	8.0	7.6
Min	6.0	7.0
Max	10.0	9.0

Table 17. Gradations of the stockpile aggregates on 3071.

Sieve Size	3/4" Stockpile	1/2" Stockpile	Crusher Fines Stockpile	Concrete Fines Stockpile
1"	100.0	100.0	100.0	100.0
¾"	16.7	98.7	100.0	100.0
½"	2.7	64.1	100.0	100.0
3/8"	2.5	38.7	99.5	100.0
#4	2.3	4.3	93.1	100.0
#8	2.2	3.1	63.5	95.2
#10	2.2	3.0	56.9	88.4
#16	2.1	2.9	42.9	66.7
#30	2.0	2.8	30.7	43.0
#40	1.9	2.7	26.2	33.0
#50	1.8	2.6	22.0	23.6
#100	1.6	2.4	16.1	9.2
#200	1.3	2.0	12.7	5.4

Table 18. Properties of the blend aggregates on 3071.

Property	Superpave Mixtures		Hveem Mixtures	
	- #4	+ #4	- #4	+ #4
Bulk Sp. Gr.	2.813	2.741	2.71	2.72
Apparent Sp. Gr.		2.796		2.75
Absorption (%)		0.72		0.8

Table 19. Gradations of the blend aggregates for the Superpave and Hveem mixtures on 3071.

Sieve Size	Superpave Mixtures			Hveem Mixtures	
	Blend	Control Points		Blend	NDOT Spec.
		Upper	Lower		
1"	100.0	100		100.0	100
3/4"	90.0	100	90	91.2	88 – 95
1/2"	70.4	90		71.0	70 – 85
3/8"	57.5			61.2	60 – 78
#4	38.5			48.8	43 – 60
#8	29.1	49	23	39.9	
#10	26.5			36.7	30 – 44
#16	20.4			28.9	
#30	14.5			20.9	
#40	12.2			17.6	12 – 22
#50	10.0			14.1	
#100	6.8			8.4	
#200	5.3	8	2	5.8	3 - 8

Table 20. NDOT Specification for the PG76-22NV binder.

Test	Test Method	Requirement
Tests on Original Binder		
Flash Point, °C	Nev. T716	230 Min.
Viscosity @ 135 °C, Pa.s	AASHTO T316	1.60-3.00
Dynamic Shear, G*/sinδ, Test Temp 76 °C@10rad/s, kPa	AASHTO T315	1.40 Min.
Ductility @ 4 °C, 5 cm/min, cm	Nev. T746	20 Min.
Sieve	Nev. T730	Pass
Polymer Content, % by mass	(a)	3.0 Min.
Tests on Residue from R.T.F.O, Nev. T728		
Mass Loss, %	Nev. T728	0.50 Max.
Dynamic Shear, G*/sinδ, Test Temp 76 °C@10rad/s, kPa	AASHTO T315	2.20 Min.
Ductility @ 4 °C, 5 cm/min, cm	Nev. T746	10 Min.
Tests on Residue from Pressure Aging Vessel, AASHTO R28 @ 110 oC		
Dynamic Shear, G*sinδ, Test Temp 31 °C@10rad/s, kPa	AASHTO T315	5000 Max.
Creep Stiffness, S, Test Temp –12 °C @60 sec, MPa	AASHTO T313 (b)	300 Max.
Creep Slope, m-value, Test Temp – 12 °C @60 sec	AASHTO T313 (b)	0.300 Min.
Direct Tension, Failure Strain, Test Temp –12 °C @ 1.0 mm/min, %	AASHTO T314 (b)	1.00 Min.

(a) Certificates of compliance provided for the material shall certify that the minimum polymer content is present.

(b) The m-value requirement and the direct tension failure strain requirement must be satisfied in all cases. If the creep stiffness is between 300 and 600 MPa, the direct tension failure strain requirement may be used in lieu of the creep stiffness requirement.

Table 21. Superpave PG grade of the refinery sample of the PG76-22NV binder on 3071.

PG Grade Sheet

Contract Number	3071	SUPERPAVE PG-Grade M320	SUPERPAVE PG-Grade MP1a	
AC Sample Number	1			
Asphalt Type	PG76-22NV			
Mass Loss, %	0.239	PG 76-22	PG 76-22	
Brookfield Vis., Pas	2.700			
Flash Pt., °C				
Limiting Temp. for Tmax, °C	80.0			
Limiting Temp. for Tint, °C	22.0			
Limiting Temp. for Tmin, °C		-16.3		
Tcrit, °C			-23.4	

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
70	25	12	1.796	49.31	2.368	64	25	10	4.703	51.14	6.040
76	25	12	1.273	49.00	1.687	70	25	10	3.116	50.68	4.027
82	25	12	0.897	48.84	1.191	76	25	10	2.146	50.37	2.787
88	25	12	0.663	51.41	0.848	82	25	10	1.495	51.03	1.923

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, MPa
22	8	1	4.908	50.46	3.785	-12	68.6	0.343	-12	3.345	1.30
25	8	1	2.501	51.59	1.960	-18	136.0	0.282	-18	0.855	1.19
28	8	1	1.420	50.46	1.095	-24	317.5	0.243	-24	0.285	0.76
31	8	1	0.801	51.59	0.628						

Table 22. Properties of the Superpave mixtures on 3071.

%AC	Gmm	Gsb	Sample #	Gmb	$\%Gmm@N_{ini}$	$\%Gmm@N_{des}$	%AV	VMA	VFA
3.0	2.630	2.768	1	2.423	83.7	92.1	7.9	15.1	48.0
			2	2.440	84.2	92.8	7.2	14.5	50.3
			Mean	2.432	83.9	92.5	7.5	14.8	49.1
			St. Dev.	0.01	0.32	0.11	0.11	0.10	0.40
			C.V.	0.49	0.38	0.12	1.47	0.69	0.81

%AC	Gmm	Gsb	Sample #	Gmb	$\%Gmm@N_{ini}$	$\%Gmm@N_{des}$	%AV	VMA	VFA
3.5	2.608	2.768	1	2.470	87.1	94.7	5.3	13.9	61.8
			2	2.460	85.5	94.3	5.7	14.2	60.1
			Mean	2.465	86.3	94.5	5.5	14.1	61.0
			St. Dev.	0.01	0.32	0.11	0.11	0.10	0.40
			C.V.	0.29	0.37	0.12	2.01	0.73	0.65

%AC	Gmm	Gsb	Sample #	Gmb	$\%Gmm@N_{ini}$	$\%Gmm@N_{des}$	%AV	VMA	VFA
4.0	2.587	2.768	1	2.493	88.6	96.4	3.6	13.5	73.1
			2	2.487	88.4	96.1	3.9	13.8	71.8
			Mean	2.490	88.5	96.2	3.8	13.7	72.5
			St. Dev.	0.00	0.32	0.11	0.11	0.10	0.40
			C.V.	0.17	0.36	0.11	2.94	0.75	0.55

%AC	Gmm	Gsb	Sample #	Gmb	$\%Gmm@N_{ini}$	$\%Gmm@N_{des}$	%AV	VMA	VFA
4.5	2.567	2.768	1	2.502	91.3	97.5	2.5	13.7	81.6
			2	2.515	91.2	98.0	2.0	13.2	84.8
			Mean	2.509	91.2	97.7	2.3	13.5	83.2
			St. Dev.	0.01	0.32	0.11	0.11	0.10	0.40
			C.V.	0.37	0.35	0.11	4.88	0.76	0.48

%AC	Gmm	Gsb	Sample #	Gmb	$\%Gmm@N_{ini}$	$\%Gmm@N_{des}$	%AV	VMA	VFA
5.0	2.546	2.768	1	2.518	94.9	98.9	1.1	13.6	91.8
			2	2.510	90.7	98.6	1.4	13.9	89.7
			Mean	2.514	92.8	98.7	1.3	13.7	90.8
			St. Dev.	0.01	0.32	0.11	0.11	0.10	0.40
			C.V.	0.23	0.34	0.11	8.72	0.75	0.44

Table 23. Mix design for the Superpave section on 3071.

Mix Property	Result	Criteria
Optimum Binder Content %	4.00 twm, 4.20 dwa	
Air-voids @ N_{design} = 125, %	4.0	4.0
VMA, %	13.6	13.0 % min.
VFA, %	71.5	65 - 75 %
Dust Proportion, $P_{0.075}/P_{be}$	1.30	0.8-1.6
%Gmm @ Nini = 9	88.7	< 89%
% Gmm @ Nmax = 205	96.6	< 98%
Film Thickness, microns	8.37	
Hveem Stability on 4" samples	40	37 min.
Dry Tensile Strength on 4" Hveem samples, psi	122	65 min.
Wet Tensile Strength on 4" Hveem samples, psi	109	
Tensile Strength Ratio, %	89	70 min.
APA Rut Depth after 8,000 cycles @60°C, mm	1.8	8 mm, max.

Table 24. Properties of the Hveem mixtures on 3071.

Binder Content % by dwa	Hveem Stability	Air-voids (%)
3.5	49	7.7
4.0	49	6.1
4.5	48	4.8
5.0	44	3.9
5.5	35	2.7

Table 25. Mix design for the Hveem section on 3071.

Property	Value	NDOT Specifications
Optimum Binder Content	4.30 % dwa	
Air-voids, %	5.5%	4 - 7 %
Stability	49	37 min.
VMA, %	13.8 %	12 - 22 %
Sand Equivalent, %	62	
+#4 Water Absorption	0.8 %	4 % max.
SS Soundness Coarse, %	1	12 % max.
SS Soundness Fines, %	3	15 % max.
L.A. Abrasion, %	23	37 % max.
Fractured Faces	100 %	80% min.
Original Tensile Strength, psi	120 psi	65 psi min.
% Retained Strength	85 %	70 % min.

Table 26. Gradations of the stockpile aggregates on 3140.

Sieve Size	3/4" Stockpile	3/8" Stockpile	Crusher Fines Stockpile	Natural Fines Stockpile
1"	100.0	100.0	100.0	100.0
3/4"	85.0	100.0	100.0	100.0
1/2"	35.2	100.0	100.0	98.9
3/8"	10.8	96.5	100.0	97.8
#4	2.0	32.5	99.6	77.9
#8	0.9	3.4	80.9	58.1
#10	0.8	2.6	73.9	53.1
#16	0.8	2.2	54.6	39.5
#30	0.7	2.1	37.1	24.4
#40	0.7	2.0	30.1	18.9
#50	0.7	1.9	24.0	14.7
#100	0.7	1.7	14.6	10.5
#200	0.6	1.5	9.8	9.0

Table 27. Properties of the blend aggregates on 3140.

Property	Superpave Mixtures		Hveem Mixtures	
	- #4	+ #4	- #4	+ #4
Bulk Sp. Gr. (SSD)	2.584	2.519	2.678	2.652
Apparent Sp. Gr.		2.607		2.774
Absorption (%)		1.3		1.7

Table 28. Gradations of the blend aggregates for the Superpave and Hveem mixtures on 3140.

Sieve Size	Superpave Mixtures			Hveem Mixtures	
	Blend	Control Points		Blend	NDOT Spec.
		Upper	Lower		
1"	100.0	100		100.0	100
3/4"	95.5	100	90	93.7	88 - 95
1/2"	80.5	90		77.6	70 - 85
3/8"	71.7			61.6	60 - 78
#4	42.0			48.4	43 - 60
#8	24.4	49	23	34.2	
#10	22.1			30.8	30 - 44
#16	16.5			23.0	
#30	11.3			16.1	
#40	9.2			13.3	12 - 22
#50	7.5			10.7	
#100	5.0			6.8	
#200	3.7	8	2	4.8	3 - 8

Table 29. Conventional properties of the refinery sample of the AC-20P binder on 3140.

Tests Performed	Property	NDOT Specification
Original Viscosity @ 60°C, 300mm Hg, Pa..s,	377.7	Minimum 210
Residue Viscosity @ 60°C, 300 mm Hg, Pa..s,	300+	Minimum 300
Original Kinematic Viscosity @135°C, mm^2/s	753	475 - 3000
Residue Kinematic Viscosity @ 135°C, mm^2/s	1054	
Original Penetration @ 25°C, 100g, 5 sec, dmm	129	
Residue Penetration @ 25°C, 100g, 5 sec, dmm	75	
Original Penetration @ 4°C, 200g, 60 sec, dmm	56	
Residue Penetration @ 4°C, 200g, 60 sec, dmm	40	
Flash point, C.O.C., °C	284.4	Minimum 232
Original Ductility @ 4°C, (5cm/min), cm	80	Minimum 50
Residue Ductility @ 4°C, (5cm/min), cm	41	Minimum 25
Loss on heating, %	0.355	Maximum 0.5
Toughness, N.m	17.62	Minimum 12.43
Tenacity, N.m	15.59	Minimum 8.47
Specific Gravity	1.016	
Sieve Test	Pass	Pass

Table 30. Superpave PG grade of the refinery sample of the AC-20P binder on 3140.

PG Grade Sheet

Contract Number	3140	SUPERPAVE PG-Grade M320	SUPERPAVE PG-Grade MP1a
AC Sample Number	1		
Asphalt Type	AC-20P		
Mass Loss, %	0.404	PG 64-28	PG 64-22
Brookfield Vis., Pas	0.776		
Flash Pt., °C			
Limiting Temp. for Tmax, °C	66.1		
Limiting Temp. for Tint, °C	13.9		
Limiting Temp. for Tmin, °C		-21.0	
Tcrit, °C			-26.5

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	3.878	66.40	4.232	52	25	10	8.024	64.59	8.883
58	25	12	2.173	66.67	2.367	58	25	10	4.320	65.55	4.746
64	25	12	1.283	67.30	1.390	64	25	10	2.449	65.28	2.696
70	25	12	0.795	68.27	0.856	70	25	10	1.438	65.99	1.574

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, MPa
13	8	1	7.742	45.85	5.554	-12	40.5	0.456	-12	3.60	1.44
16	8	1	5.223	48.44	3.908	-18	109.0	0.371	-18	1.30	1.30
19	8	1	3.314	51.18	2.582	-24	329.5	0.296	-24	0.73	3.01
22	8	1	2.327	53.36	1.867						

Table 31. Properties of the Superpave mixtures on 3140.

%AC	G_{mm}	G_{sb}	Sample #	G_{mb}	$\%G_{mm}@N_{ini}$	$\%G_{mm}@N_{des}$	% Air	VMA	VFA
4.0	2.453	2.546	1	2.187	81.70	89.18	10.82	17.53	38.28
			2	2.171	81.03	88.54	11.46	18.12	36.75
			Mean	2.179	81.37	88.86	11.14	17.82	37.52
			St. Dev.	0.011	0.47	0.46	0.46	0.42	1.08
			C.V.	0.515	0.58	0.52	4.11	2.37	2.89

%AC	G_{mm}	G_{sb}	Sample #	G_{mb}	$\%G_{mm}@N_{ini}$	$\%G_{mm}@N_{des}$	% Air	VMA	VFA
4.5	2.435	2.546	1	2.241	83.88	92.03	7.97	15.96	50.05
			2	2.221	83.11	91.24	8.76	16.68	47.47
			Mean	2.231	83.49	91.63	8.37	16.32	48.76
			St. Dev.	0.014	0.55	0.56	0.56	0.51	1.83
			C.V.	0.612	0.66	0.61	6.70	3.14	3.75

%AC	G_{mm}	G_{sb}	Sample #	G_{mb}	$\%G_{mm}@N_{ini}$	$\%G_{mm}@N_{des}$	% Air	VMA	VFA
5.0	2.417	2.564	1	2.264	84.84	93.67	6.33	15.52	59.2
			2	2.280	85.76	94.32	5.68	14.94	62.0
			Mean	2.272	85.30	94.00	6.00	15.23	60.6
			St. Dev.	0.011	0.65	0.46	0.46	0.41	1.94
			C.V.	0.488	0.76	0.49	7.63	2.71	3.20

%AC	G_{mm}	G_{sb}	Sample #	G_{mb}	$\%G_{mm}@N_{ini}$	$\%G_{mm}@N_{des}$	% Air	VMA	VFA
5.5	2.400	2.546	1	2.310	87.34	96.25	3.75	14.28	73.7
			2	2.307	87.54	96.12	3.88	14.39	73.1
			Mean	2.308	87.44	96.19	3.81	14.33	73.4
			St. Dev.	0.002	0.14	0.09	0.09	0.08	0.47
			C.V.	0.092	0.17	0.09	2.32	0.55	0.64

%AC	G_{mm}	G_{sb}	Sample #	G_{mb}	$\%G_{mm}@N_{ini}$	$\%G_{mm}@N_{des}$	% Air	VMA	VFA
6.0	2.382	2.546	1	2.330	88.50	97.81	2.19	13.97	84.3
			2	2.334	88.77	97.98	2.02	13.81	85.4
			Mean	2.332	88.64	97.9	2.10	13.89	84.9
			St. Dev.	0.003	0.19	0.13	0.13	0.11	0.78
			C.V.	0.128	0.22	0.13	5.95	0.79	0.92

Table 32. Mix design for the Superpave section on 3140.

Mix Property	Result	Criteria
Optimum Binder Content %	5.4 twm, 5.7 dwa	
Air-voids @ N_{design} = 100, %	4.0	4.0
VMA, %	14.5	13.0 % min.
VFA, %	71.0	65 - 75 %
Dust Proportion, $P_{0.075}/P_{be}$	0.80	0.8-1.6
%Gmm @ Nini = 8	87.0	< 89%
% Gmm @ Nmax = 160	97.2	< 98%
Film Thickness, microns	12.82	
Hveem Stability on 4" samples	40	37 min.
Dry Tensile Strength on 4" Hveem samples, psi	74	65 min.
Wet Tensile Strength on 4" Hveem samples, psi	62	
Tensile Strength Ratio, %	84	70 min.
APA Rut Depth after 8,000 cycles @ 60°C, mm	1.3	8mm, max.

Table 33. Properties of the Hveem mixtures on 3140.

Binder Content % by dwa	Hveem Stability	Air-voids (%)
4.5	42	8.9
5.0	42	7.7
5.5	41	6.5
6.0	41	4.9
6.5	41	4.0
7.0	40	3.2

Table 34. Mix design for the Hveem section on 3140.

Property	Value	NDOT Specifications
Optimum Binder Content	6.0 % dwa	
Air-voids, %	4.9 %	4 - 7 %
Stability	41	37 min.
VMA, %	17.6 %	12 - 22 %
Sand Equivalent, %	71	
+#4 Water Absorption	1.4 %	5 % max.
SS Soundness Coarse, %	5	12 % max.
SS Soundness Fines, %	6	15 % max.
L.A. Abrasion, %	25.3	37 % max.
Fractured Faces	100 %	80% min.
Original Tensile Strength, psi	76.6 psi	65 psi min.
% Retained Strength	83 %	70 % min.

Table 35. Properties of field samples of the AC-20P sampled during construction of the Superpave section on 3140.

Sample Number	Viscosity at 60°C, Specification: 210 Pa.s Min.
1	603.2
2	583.4
3	210.0+
4	210.0+
5	210.0+
6	210.0+

Table 36. Aggregate gradations and binder contents of construction samples from the Superpave section on 3140.

Value	Sieve size								Binder content (%)
	1"	3/4"	1/2"	3/8"	#4	#10	#40	#200	
Avg	100	93.2	79.1	69.8	39.8	24.5	10.1	3.8	5.72
Min	100	92.5	78.2	69.0	38.4	23.2	9.8	3.7	5.56
Max	100	94.2	80.2	71.1	41.2	25.4	10.3	3.9	5.90
STD	0.00	0.87	1.01	1.14	1.40	1.14	0.26	0.12	0.17

Table 37. In-place air-voids on 3140.

Value	Entire project (%)	Superpave section (%)
Avg	8.5	9.3
Min	5.0	6.0
Max	12.0	14.0

PERFORMANCE GRADE		PG 46			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
Avg 7-day Max. Pav. Temp., C		<46			<52							<58					<64					
Min. Pav. Design Temp, C		>-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, T48, Min. °C		230																				
Viscosity, T316, Max. 3 Pa.s, Test Temp., °C		135																				
Dynamic Shear, T315, G*/sinδ, Min. 1.00 kPa, Test Temp. @ 10 rad/s, °C		46			52							58					64					
ROLLING THIN FILM OVEN RESIDUE (T240)																						
Mass Loss, max., Percent		1.00																				
Dynamic Shear, T315, G*/sinδ, Min. 2.20 kPa, Test Temp. @ 10 rad/s, °C		46			52							58					64					
PRESSURE AGING VESSEL RESIDUE (PP1)																						
PAV Aging Temp, °C		90			90							100					100					
Dynamic Shear, T315, G*sinδ, Max. 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		Report																				
M320	Creep Stiffness, T313: S, Max. 300 Mpa, m-value, Min. 0.300, Test Temp. @ 60 s, °C	-24	-30	-36	0	-6	-12	-18	-24	-30	-36	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30
	Direct Tension, T314, failure Strain, Min. 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
MP1a	Critical Low Cracking Temp, PP42: Determine critical cracking temp as described in PP42, Test Temp, °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 Performance Grade Asphalt Binder Specification M320 & MP1a.

PERFORMANCE GRADE		PG 70						PG 76					PG 82				
		10	16	22	28	34	40	10	16	22	28	34	10	16	22	28	34
Avg 7-day Max. Pav. Temp., C		<70						<76					<82				
Min. Pav. Design Temp, C		>-10	>-16	>-22	>-28	>-34	>-40	>-10	>-16	>-22	>-28	>-34	>-10	>-16	>-22	>-28	>-34
ORIGINAL BINDER																	
Flash Point, T48, Min. °C		230															
Viscosity, T316, Max. 3 Pa.s, Test Temp., °C		135															
Dynamic Shear, T315, G*/sinδ, Min. 1.00 kPa, Test Temp. @ 10 rad/s, °C		70						76					82				
ROLLING THIN FILM OVEN RESIDUE (T240)																	
Mass Loss, max., Percent		1.00															
Dynamic Shear, T315, G*/sinδ, Min. 2.20 kPa, Test Temp. @ 10 rad/s, °C		70						76					82				
PRESSURE AGING VESSEL RESIDUE (PP1)																	
PAV Aging Temp, °C		100(110)						100(110)					100(110)				
Dynamic Shear, T315, G*sinδ, Max. 5000 kPa, Test Temp. @ 10 rad/s, °C		34	31	28	25	22	19	37	34	31	28	25	40	37	34	31	28
Physical Hardening																	
M320	Creep Stiffness, T313: S, Max. 300 Mpa, m-value, Min. 0.300, Test Temp. @ 60 s, °C	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	0	-6	-12	-18	-24
	Direct Tension, T314, failure Strain, Min. 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
MP1a	Critical Low Cracking Temp, PP42: Determine critical cracking temp as described in PP42, Test Temp, °C	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	0	-6	-12	-18	-24

Figure 1. Superpave Performance Grade Asphalt Binder Specification M320 & MP1a (Cont.)

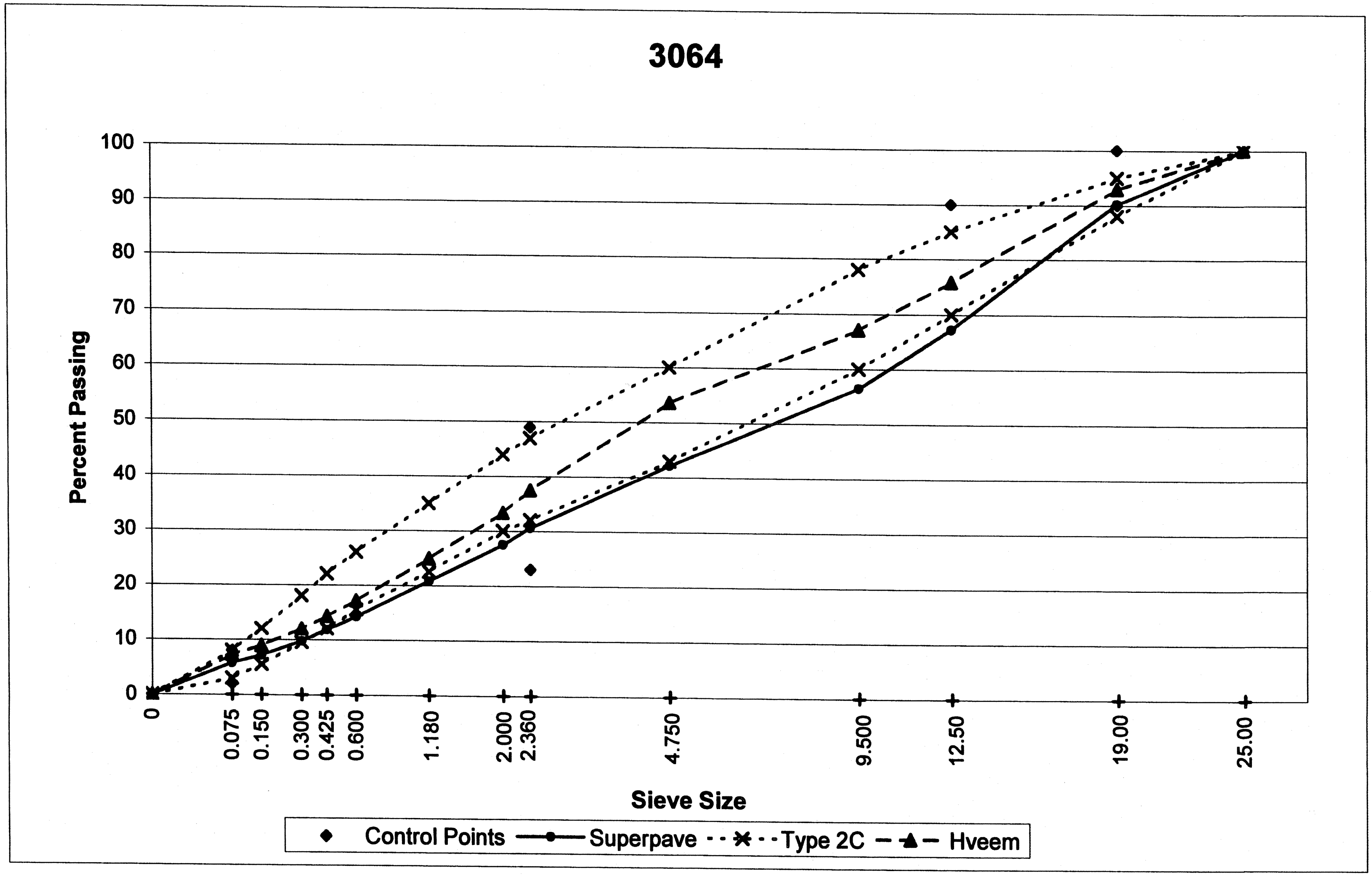

Figure 2. Aggregate gradation curves for the Superpave and Hveem sections on 3064.

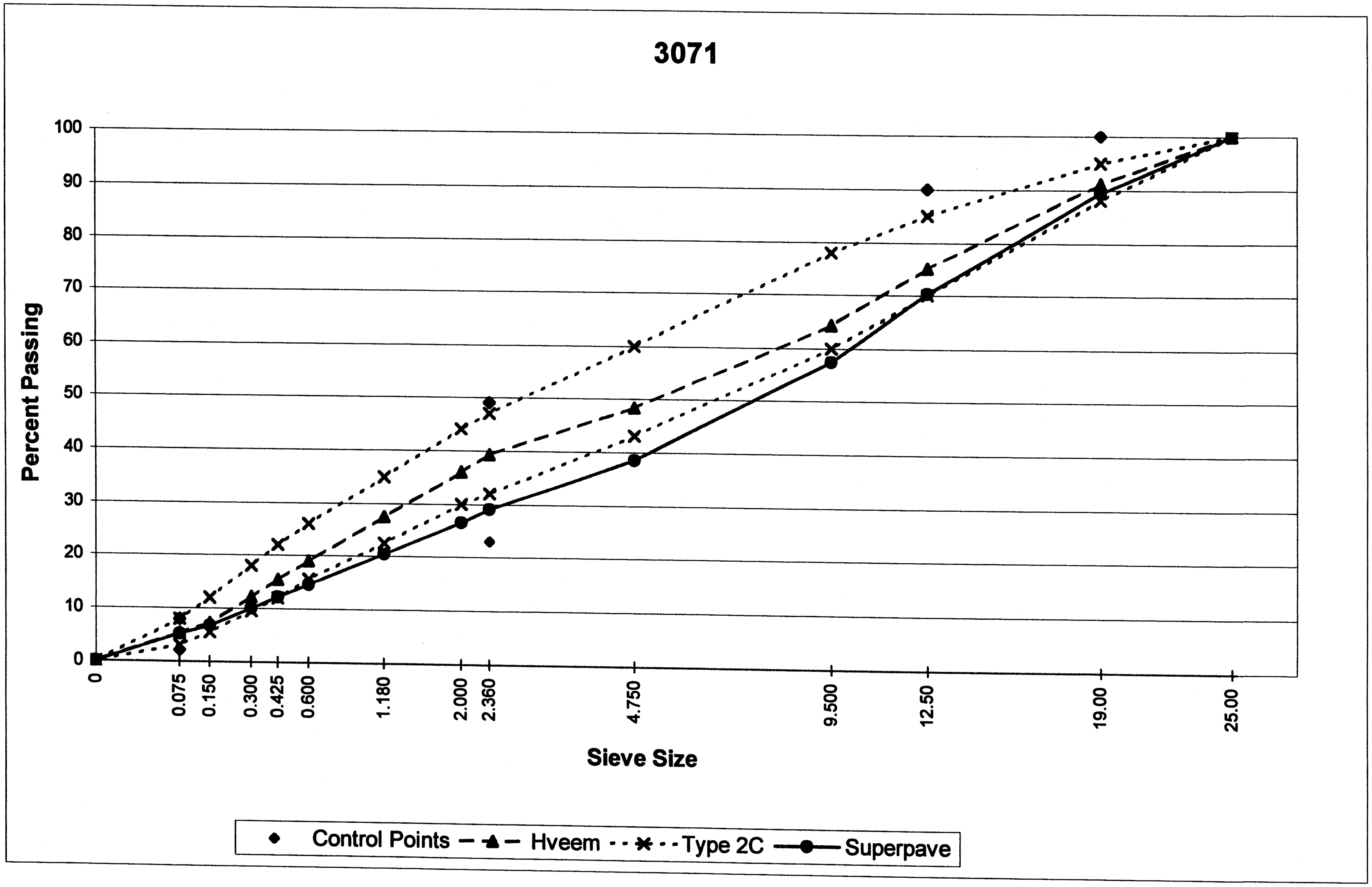

Figure 3. Aggregate gradation curves for the Superpave and Hveem sections on 3071.

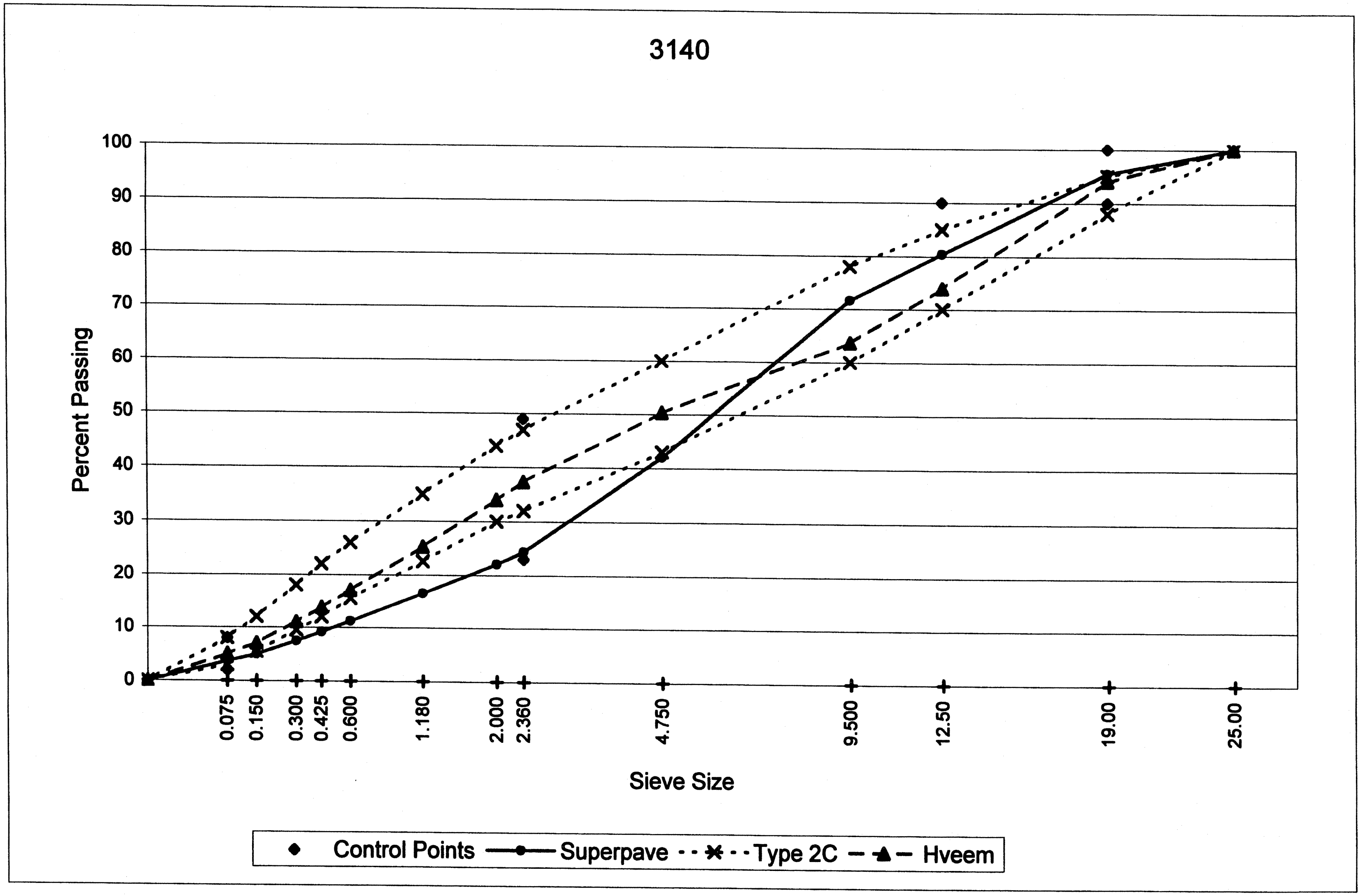

Figure 4. Aggregate gradation curves for the Superpave and Hveem sections on 3140

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