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CONSTRUCTION REPORT

HIGH PERFORMANCE CONCRETE PAVEMENT

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16. Abstract

Portland Cement concrete pavements of especially high quality became an area of interest in the early 1990s and precipitated a tour by representatives of industry and government to observe European construction practices. Following the tour the Federal Highway Administration (FHWA) developed a research program to encourage and aid states in constructing High Performance Concrete Pavement (HPCP). Important criteria for research projects were service life and costs, innovative design and materials, and construction productivity and quality. This Kansas HPCP research project was facilitated greatly by the FHWA funding and was conceived to address most of the criteria enumerated above.

Specific test sections generally one half to one kilometer in length were built with the following special features and materials:

1) a single saw cuts without sealing the joint
2) fiberglass dowels
3) an "X" frame load transfer device
4) early cut saws
5) polyolefin fibers
6) longitudinal tining
7) high solids curing compound
8) two-lift construction
9) recycled asphalt pavement millings as intermediate size aggregate in PCCP in bottom lift
10) lower water-cement ratio concrete
11) hard, igneous coarse aggregate in PCCP in top lift with a pozzolan
12) random transverse tining

Laboratory testing was done on innovative materials and mixtures. Fatigue testing of the various dowels and load transfer devices was performed. Most materials and test sections performed as expected with the exception that interpanel cracking occurred between the 18.3 meter (60 foot) joints of the polyolefin fiber section. The cost increase for the two-lift construction was significant even though the first lift was placed using only a spreader. Evaluation and monitoring of the test sections will be carried out for the next five years.

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High Performance Concrete Pavement, concrete pavement, sealant, dowels, saws, fibers, tining, curing, recycled asphalt pavement, two-lift construction, pozzolan, fiber reinforced composite.

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Prepared in cooperation with the

Federal Highway Administration

by

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May 1998

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ACKNOWLEDGMENTS

Mr. Steve Tritsch of the Missouri/Kansas Chapter of the American Concrete Pavement Association was actively involved with initiating this research project. He is also a co-principal investigator along with the author. The test sections for the research project were developed by a task group consisting of Mr. Dick McReynolds, Engineer of Research for the Kansas Department of Transportation, Mr. Ken Archuleta, Technology Transfer Engineer with the Regional Federal Highway Administration Office, Mr. Mike Voth, Pavement Specialist with the Kansas Division Office of the Federal Highway Administration, and the two co-principal investigators. Mr. Alan Farrington, Estimator with Wittwer Paving, Inc., was very helpful in the research aspects of this complex project. Ms. Kathryn Wickam, Construction Engineer and Mr. Barry Santee, Project Coordinator from the Hutchinson Construction Office of the Kansas Department of Transportation contributed greatly to the success of the many test sections.

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High Performance Concrete Pavement
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K-96, Reno County, Kansas
96-87 K 4457-01

Construction Report

Introduction

The State of Kansas as well as the local Chapter of the American Concrete Pavement Association is continually looking for ways to further optimize materials, labor, design, and construction procedures in the construction of portland cement concrete pavement (PCCP). In recent years, there has been national interest in constructing high quality concrete pavements.

During May 1992 a team of State, Industry, and Federal Engineers from the United States participated in the US TECH. Their mission was to review the European concrete pavement experience and obtain information relating to finance, research, design, construction, maintenance, and performance to assist with development of appropriate actions for enhancing the US highway system.

In 1993, a 1.6 km (1-mile) test section was constructed on northbound I-75 (Chrysler Freeway) in downtown Detroit, Michigan. The design and construction procedures of the experimental pavement section were similar to those used in Germany and Austria.

About this time, the Strategic Highway Research Program (SHRP) established some criteria for the definition of High Performance Concrete (HPC).

In September 1994, Federal Highway Administration (FHWA) and industry staff met in Chicago to review (what was then described as) High Performance Concrete Pavement (HPCP). After much discussion, both the FHWA and industry agreed to pursue this effort, that would establish broad, functional or performance criteria, rather than a prescription-oriented definition such as done with HPC-Structures.

What finally emerged was the suggestion that the criteria defining HPCP be reduced to three general categories:

1) Increasing the service life / lowering life cycle costs
2) Enhancing or utilizing innovative designs and/or materials
3) Improving construction productivity and quality

Funding for design and construction of HPCP research projects was accomplished through normal Federal-aid channels and Section 6005, and was limited to 80 percent of the delta cost (i.e., the additional cost of design and construction above the estimated design and construction cost for a comparable, conventional project). Funding for project evaluation, for the appropriate Open-house and for Technology Transfer was accomplished by work order and is being fully funded by the FHWA.

For this Kansas project a technical working group was established that consisted of personnel from the Kansas Department of Transportation, the local and regional Federal Highway Administration, and the local American Concrete Pavement Association. This group produced the plan for the various test sections and selected a project location.

Benefits from the project are expected in the areas of recycling waste materials, utilizing reactive materials with an appropriate pozzolan, the performance of new load transfer devices, extended life from premium materials and concrete mixtures, as well as cost benefit data for the various test sections.

Over the next five years the test sections will be monitored. Data collected will include faulting, spalling, skid resistance, noise, and load transfer efficiency.

Test Sections

As constructed, there were 12 special test sections in addition to a section of the regular project that will serve as a control section. Originally, there were 11 test sections programmed, but the unavailability of a random spaced transverse tining rake led to that variation being placed separately. Most test sections are one kilometer in length (3280 ft.) of two lane pavement. The details of the control section and the variations for each of the test sections are listed below, and a schematic is attached in the Appendix.

1. Control - This was typical construction of a 254 mm (10 in.) pavement placed in one lift with epoxy coated 32 mm (1.25 in.) diameter dowel bars at 305 mm (12 in.) centers. The concrete mixture contained 337 kg/m^3 (564 lb./yd^3) of Type II cement, a water-cement ratio of 0.47 and 6.5 percent air. Other test sections utilizing this mixture had a water-cement ratio generally of 0.45. Three aggregates were used and blended to produce a grading approximating a "Shilstone" haystack gradation curve, when plotted as the percent retained on each sieve individually. The available aggregates did have an excess amount of material on the 4.75 mm (No. 4) sieve, so there is a peak on the gradation curve shown in the Appendix. The aggregate consisted of 35 percent of a coarse limestone[19 mm (3/4 in.)maximum size], 15 percent of a well (pea type) gravel of intermediate size and 50 percent of a relatively coarse sand. Consolidation of the concrete was that regularly specified for this type of mixture, being 98% of the vibrated unit weight when measured by a nuclear density meter in the direct transmission mode. The transverse contraction joints were sawed at a 4.57 m (15 ft.) spacing perpendicular to the center line and sealed with neoprene compression seals. The centerline joint was sealed with a low modulus hot pour asphaltic material, meeting our maintenance specification (TS 109.6).

2. Single Saw Cut - Initially all 110 joints in this section were programmed to have a single saw cut for the transverse joint and no sealant. After learning that this pavement would not have a drainable base, the number of unsealed joints was reduced to the first 31, with the remaining 79 widened and sealed with the same sealant used for the control section centerline joint.

3. Non-Traditional Dowel Type - For a long lasting high performing concrete pavement, the performance of the joints are a critical factor. On this section larger 51 mm (2 in.) diameter fiberglass dowels, FiberCon^{TM} (Figure 1), manufactured by Concrete Systems, Inc. of El Dorado, KS, replaced the epoxy coated bars. These should be non-corroding and reduce the stresses at the joints, providing improved performance.

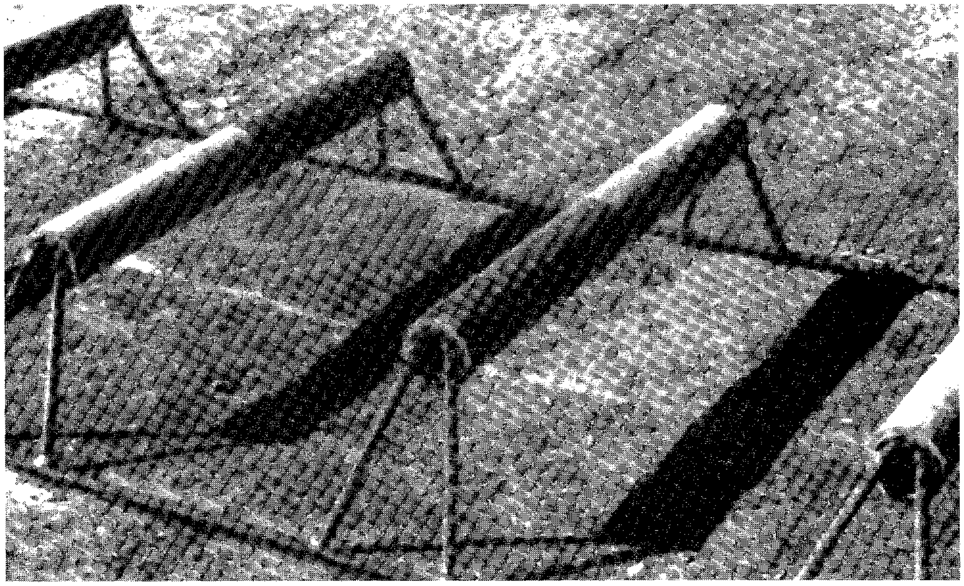
4., 5. & 6. Alternate Saws and 3M Fibers - Three different brands of saws were tried, and shallow depths of cut were made at an early age with the soft-cut saw. A special 152.4 m (500') test section incorporating 3M polyolefin fibers [1.57 mm (0.062 in.) diameter] was placed at the west end of this one kilometer test section. In addition, five joints had a special "X-FLEX^{TM}" load transfer device (Figure 2), developed at Kansas State University, instead of the dowel bars. These were designed to transfer the load by tension in the "x" rather than by shear.

7. Special Pavement Marking and Longitudinal Tining - As an alternate, to transverse tining especially for noise reduction, longitudinal tining was impressed into the surface of the fresh concrete surface with a wire comb. A special long lasting pavement marking with a cementitious base was being developed and was to be tried in this section but was not available at the time of construction.

8. Special High Solids Curing Compound (ASTM C 1315) - This extra curing measure was intended to be compared to our standard cure in both the area of surface integrity and compressive strength. Initially a random transverse tine rake was to be used for the texturing of the surface in this section to test if the randomness could give a quieter ride but it had to be done in an added section (No. 13).

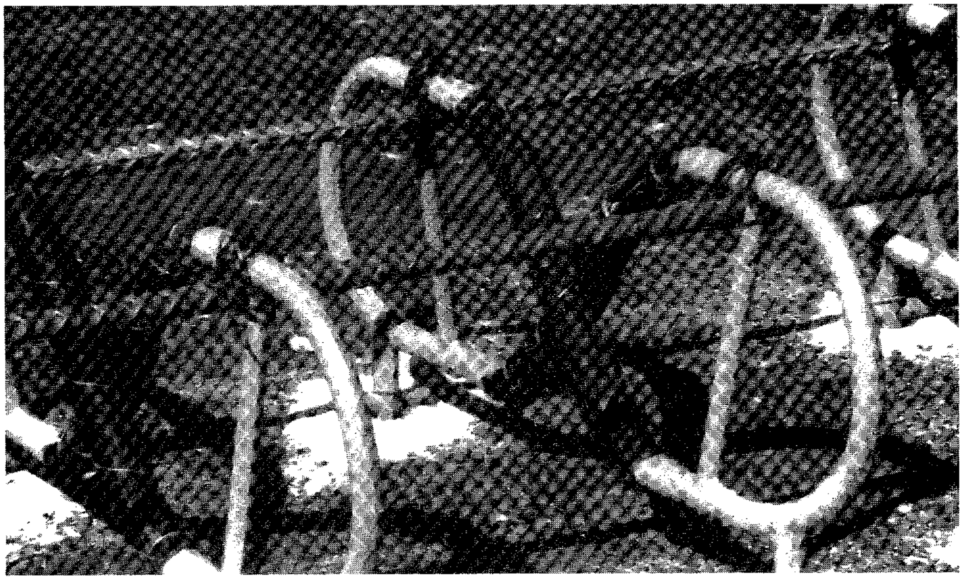
9. Two-Lift Construction with Recycled Asphalt - The bottom 178 mm (7 in.) used recycled asphalt pavement (RAP) in place of the intermediate sized well gravel to test the viability of using this sometimes waste product in the PCCP. The top 76 mm (3 in.) were placed with the standard control mixture.

10. Lower water-cement Ratio Concrete - Given good materials, the water-cement ratio is the number one factor when proportioning a mixture in the determination of the overall quality of the concrete. This section should provide data to assess the effect on pavement performance of lowering the water-cement ratio by about 0.05.



FiberCon™ Dowel Bars

Figure 1



X - FLEX™ Load Transfer Devices

Figure 2

11. Two-Lift Construction with Igneous Rock and a Pozzolan - Most of the PCCP in Kansas is built with limestone as the coarse aggregate since it is much more abundant. These limestones typically have absorptions greater than one percent and may go as high as eight percent absorption, and as typical of limestones, are somewhat prone to polishing. A harder, denser material in the surface of the pavement would likely yield benefits for premium pavement performance. The most available hard rock, a rhyolite, has been known to display the problem of alkali silica reactivity (ASR), a distress which can cause the pavement to fail prematurely.

To mitigate this problem, an effective pozzolan is currently the viable solution. Ash Grove Cement Company has developed a calcined natural clay pozzolan called Dura-Poz^{TM}, that was shown to be highly effective in reducing the ASR when used with this aggregate and other reactive aggregates. Twenty percent of the cement by weight was replaced with Dura-Poz^{TM} when rhyolite was used for the top 76 mm (3 in.) of this two lift pavement construction. The bottom 178 mm (7 in.) used a soft, high absorption durable limestone for economy and efficiency. This rock passed our freeze-thaw durability test at the 25 mm (1 in.) maximum size, and this size was used rather than our 19 mm (3/4 in.) standard.

12. Two-Lift Construction With Lower Water-Cement Ratio Concrete - This section uses the same lower water-cement ratio mixture used in Section 10 for the top 76 mm (3 in.). The bottom 178 mm (7 in.) used the same 25 mm (1 in.) soft high absorption limestone that was used in Section 11.

13. Randomly Spaced Transverse Tining and High Solids Curing Compound - This section was the second one to try a different tining pattern in an attempt to reduce the noise heard inside vehicles.

Project Development

For this project two phases were defined in the work plan. Phase I included evaluating mixture designs using varying proportions of recycled asphalt pavement, evaluating the larger 25 mm (1 in.) maximum size for the soft limestone proposed to be used in the lower lift of one test section, evaluating the alkali silica reactivity of a rhyolite, preparing plans and specifications, doing a construction evaluation, and evaluating and reporting on the project for five years. Phase II consisted of the placement of all of the test sections.

FiberCon^{TM} dowels are a composite fiberglass tube filled with a high strength cement grout. They have a nominal diameter of 51 mm (2 in.) with one half of the length machined to a smooth surface of 48 mm (1.9 in.) to allow easy slippage as the joint opens and closes in response to temperature changes. Different configurations were tested by the manufacturer to bracket the proper design necessary for efficient use of this new product. Both static and fatigue test were done on laboratory specimens that measure 914 x 1829 x 229 mm (36 x72 x 9 in.) . Comparative tests verses steel dowels were also run at the Kansas State University Accelerated Testing Laboratory facility on 6.1 m (20 ft.)

full lane width slabs that simulate field loading conditions. FiberCon^{TM} Dowels in a comparable configuration showed about twice the life of standard steel dowels. Part of the reason is that these dowels do not require a grease coating to slip properly in the concrete slab and therefore contact between the dowel and the concrete is improved. Additionally the stiffness of the fiberglass matches the stiffness of the concrete better than does the steel. The configuration used on the project [bars at 305 mm (1 ft.) spacing] was somewhat stronger than that required for normal strength concrete.

X- Flex^{TM} load transfer devices were also tested under static and fatigue loading in laboratory size specimens and found to be stronger than conventional dowels at transferring the shear load across the joint. The "X" of the patented device, cushioned with a rubber tubing for this project, goes through the joint with the far ends curving around in a loop that make a continuous configuration. The device is made from 13 mm (0.5 in.) steel cast bars and epoxy coated. These devices were spaced at 305 mm (12 in.) centers in the pavement.

Recycled asphalt pavement (RAP) was originally proposed as a replacement for 30 percent of the coarse aggregate. Much if not most of the material available in this area of the state does not contain very much coarse aggregate and the millings are consequently of a smaller size. Since the object of this part of the project was to use the waste materials available, scalping and using only a small amount of coarse material from the RAP did not fit with the project objectives, as well as being uneconomical. Therefore, a decision to use the RAP as middle size aggregate was made. Testing in the laboratory indicated that strengths of 27.6 MPa (4000 psi) in compression could be achieved by using the RAP for 15 per cent of the total aggregate, exactly replacing the mid sized gravel. A very workable mixture similar to that of the standard mixture for the project was maintained.

A soft, absorptive limestone somewhat close to the project had been proven to be durable in laboratory testing and in pavement at the 19 mm (3/4 in.)maximum size. For economy and better consolidation, a larger size of coarse aggregate is desirable. Laboratory testing by ASTM C 666 Procedure B was performed on this material that had a maximum size of 25 mm (1 in.). The coarse aggregate gradation tested had 20 percent retained on the 19 mm (3/4 in.) sieve, and 40 percent individually on both the 12.5 mm (1/2 in.) and 9.5 mm (3/8 in.) sieves. The beams were cured by the Standard Kansas DOT procedure of 67 days in the moist room, 21 days in the cement lab, (50% relative humidity), and soaked in water two days before testing, (for a total of 90 days). This long cure minimizes the effect of the mortar and has proven to give laboratory results that correlate very well with field performance. The larger sized rock passed this test with only a small degradation of performance, compared to 19mm (3/4 in.) material.

A concrete mixture with the coarsest **RAP** was also tested for durability by ASTM C 666 - Procedure B. Results were well within the specification of 95 (minimum) for a durability factor and 0.025 percent (maximum) for expansion, with only a small loss of performance when compared with the control mixture.

The **rhyolite** (a hard igneous rock proposed for the wearing surface in one test section) was tested for alkali silica reactivity by ASTM C 1260, Potential Alkali Reactivity of Aggregates, and found to be quite reactive. A locally available calcined natural clay pozzolan, Dura-Poz^{TM}, had been developed for combating the reactive sand-gravels found in many areas of Kansas and Nebraska. When used as a 20 percent replacement for cement, the expansion at 14 days was found to be 0.013 percent, well under the 0.100 percent that is cause for concern.

Test information was shared with the contractor as soon as possible, who then arranged for the materials and submitted prices.

Project Location and Details

The rural section of highway where this test project on K-96 is located is near Haven, which is between Wichita and Hutchinson. It is being improved to a four lane divided highway as part of the eight year $3.2 billion Kansas Comprehensive Highway Program. The test sections are located in the new concrete pavement being constructed for the eastbound lanes. The soils in the area are typically silty and sandy loams. Design traffic was 4800 vehicles per day in 1995 and is projected to be 8000 vehicles per day in 20 years with 11 percent heavy trucks. The cover sheet of the plans is included in the Appendix.

Construction Details

Phase II of the HPCP Project was the construction of the test sections. The extra (delta) costs were $300,500 which were added to an existing contract by change order.

Section 1. The Control Section (placed on 9/30/97) was the first paving on this project with the contractor using a new four track paver. No problems or unusual occurrences were noted.

Section 2. The Single Saw Cut Section (10/1/97) continued the normal paving and the initial sawing operation. Joints were treated differently later.

Section 3. The Non-Traditional Dowel Section (10/1/97) was again routine with the fiberglass dowels in place in baskets on the subgrade. Some concern had been expressed that the larger diameter dowels and a basket that was designed not to be cut might create a plane of weakness at the ends of the baskets. This location could then be weak enough that some transverse cracking might occur here instead of at the sawed joints. That did not happen.

Sections 4, 5, & 6. The Early Cut Saws were tried in three sections (10/1 & 2/97) for the initial transverse cut for the joint made and were set to various depths. The Soff-Cut^{TM} was tried at depths of 38.1 mm (1 1/2 in.) and 63.5 mm (2 1/2 in.). Sawing began about 3 hours 20 minutes after the concrete was placed and finished 5 hours 30 minutes after the header was placed. The initial concrete temperature was about 21.1 °C (70 °F) and this area was placed late in the day and therefore did not show a large temperature rise. The cracking of the slab below the saw cut for 40 joints was monitored for the 38 mm (1 1/2 in.) depth of cut. After 1 day 6 cracks had occurred beneath a saw cut, after 2 days-18, after 3 days- 23, after 4 days-31, after 5 days-35, and after 7 days 39 of the 40 cut joints had cracked. This is somewhat less vigorous cracking than is seen for the normal 70 mm (2 3/4 in.) saw cut done later, even for this cool fall weather. There were no cracks within the panels for this area nor for any of the other shallow cut joint areas listed below.

A Target saw was used for early cuts with depths of 25 mm (1 in.), 44 mm (1.75 in.) and 64 mm (2.5 in.) for 45 joints total. A Magnum Diamond saw also was used for early cuts of the same depths for 52 joints. These latter two sections were placed earlier in the day which was also much warmer and most joints cracked in one day.

In this one kilometer test section two other special features were tried in short sections. The first one consisted of X-FLEX^{TM} load transfer devices [at five 7.3 m (24 ft.) joints)]of a special "x" design that transfers the shear forces by tension. When placed, these were only about 38mm (1 1/2 in.) below the surface and four of the ten lane width units were struck and dislodged by the paving machine. Regular dowels were then placed in three of these four joints and hand finished.

The second short test section [152.4 m (500 ft.)] incorporated polyolefin fibers at 15 kg/m^3 (25 lb/yd^3) in an attempt to increase the transverse joint spacing and eliminate the longitudinal joint. This section was added as the project was being constructed and was based on the results of research from South Dakota and on the recommendations of Washington DC FHWA Research personnel. The manufacturer's representative suggested, based on the South Dakota experience, that transverse joint spacing could be up 38.5 m (100 ft.) for this 254 mm (10 in.) pavement. To be conservative and because Kansas had previously used a 18.7 m (61 1/2 ft.) joint spacing, a distance of 18.3 m (60 ft.) was selected for the transverse joints and a center line joint was not sawed. The water-cement ratio was increased about 0.04 to 0.49 to obtain the necessary workability and placement proceeded smoothly.

Unfortunately, the test section did not perform as expected. During the first night, intermediate cracks formed between the transverse joints of five panels out of the eight that were placed that day. By five days after placement, five additional cracks appeared for a total of ten cracks in eight panels. Two of the eight panels ended up with two cracks, which were roughly at the third points. These panels were the first two placed that day which had a high temperature of 35 °C (95 °F). The low that night was 21 °C

(69 °F). The other six panels had one crack each, approximately in the middle of the slab. The concrete temperature was about 21.1 °C (70 °F) initially and did not rise markedly. White pigmented curing compound was applied in a timely and proper manner, covering the sides of the slab.

Recently, an analytical software package, called HIPERPAV, focusing on modeling early-age behavior of PCCP has been completed under an FHWA research project. Information has been exchanged with the developers of this package in an attempt to understand more clearly the dynamics involved in the early-age performance of this section.

Section 7. Special Pavement Marking and Longitudinal Tining (10/10/97) were scheduled for this test section. The longitudinal tining was done without any problems but seems to be no quieter for car tires than the transverse tining. However, it does appear to produce a quieter ride for pickup trucks with a very aggressive tread on the tires. The special cementitious based pavement marking material was to be placed in a sawed slot. It is designed to last the life of the pavement and was nearing final development as the project began. None has been delivered for installation as of March 1998. It will be placed if it can be supplied.

Section 8. The Special Curing Compound (10/10/97) meeting ASTM C 1315 must contain a minimum of 25% solids. This section was intended to test if better curing would produce a stronger longer lasting concrete pavement. Unfortunately, environmental conditions were quite mild at the time of application. Additionally, this section received the coverage rate of .03588 L/m^2 (0.03 gallons per square yard) which is the rate for a smooth surface, and is one half of that recommended for a rough surface. The other half of this curing compound was applied at a higher coverage rate to a section of roadway placed the first week of March 1998, in Section 13.

Section 9. A Two-Lift Section with Recycled Asphalt Pavement (10/15/97) was initially designed to use material obtained from millings of an asphalt roadway replacing 30 percent of the coarse aggregate. This material commonly known as recycled asphalt pavement (RAP) was to be produced by milling some of the roadways in the area that were being reconstructed. However, all that was being produced was scheduled to be used in the reconstruction of asphalt pavements. This material, as well as that eventually used (a commercial source from Wichita), came from pavements that were primarily a sand mix and had very little coarse size material. Inspection of the gradation also revealed that less than 10 percent of the material passed the No. 30 sieve, and that the gradation of the RAP was quite similar to the intermediate sized well gravel. Therefore, for this area of the state, the economical use of this material required that it replace some or all the intermediate aggregate which was 15 percent of the total aggregate. Chunks of RAP larger than 19 mm (3/4 in.) that occurred in the millings were scalped off before the millings were incorporated into the mixture. This section was constructed using the mixture with RAP in the bottom 178 mm (7 in.) layer and the control concrete mixture in the top 76 mm (3 in.) layer. The limited amount of money for the special features made it unlikely that all the programmed sections could be constructed if another slip form paver was used for the lower lift. To accommodate this situation, the contractor proposed simply using a belt placer/spreader for the bottom lift and stiffening up the mixture a little. He felt that this would then be sufficient to allow placement of the top lift concrete on top of it without much depression at the center of the pile and that the top lift concrete could slide across the surface with minimal mixing. Trial placements took place a few days before this test section was constructed. Indications were that a stiffer mixture was necessary, and that about thirty minutes of time was needed between placing the two lifts so that the top lift concrete would successfully slide over the bottom lift. This procedure was essentially followed for this section as well as the other two two-lift sections.

A small amount of depression was seen when the first concrete of the top lift dropped on the bottom lift of concrete, but as the pile grew it cushioned the concrete being deposited. On occasion, the top lift of concrete would mix a little with the bottom lift if that lift were too soft but for the most part, the process was workable and adequately controlled. Areas of interest were noted and later cored to determine lift thickness. Results are in the Early Results section of this report.

Section 10. Lower Water-Cement Ratio Mixtures (10/16/97) produce higher strengths easily in proportion to the lower water-cement ratio, (0.05 in this case) usually using a superplasticizer while keeping the slump constant. The effect on the performance of the surface and the structural qualities of this mixture will now be able to be assessed. The lubrication provided by the superplasticizer elicited favorable comments from the finishing crew who had feared that the low water-cement ratio would cause them difficulties.

Section 11. Two-Lift Construction with Igneous Rock (10/17/97) was a new material for our highways. Kansas does not have any quarries with hard igneous rock. A limited supply of siliceous river gravel is available in the southwest part of the state. The available limestones have absorptions considered high by other regions of the country, predominantly over two percent. Some limestones have more than ten percent acid insoluble material that may help them to be non- polishing to a degree but they are uniformly nondurable in pavements. Therefore, high quality stone has to be imported and is relatively expensive. A source 420 km (260 miles) from the project (in Davis, Oklahoma) produces a crushed rhyolite, a material known to cause alkali silica reactivity (ASR) in concrete. This was addressed by using a pozzolan with the cement during the development of project mixtures. Therefore, the use of this hard aggregate along with this pozzolan should result in a strong durable pavement surface. A slightly higher (0.02) water-cement ratio (by weight) is needed with this pozzolan. It is a finely ground material like cement but with a lower specific gravity. This makes the water per unit volume ratio more favorable in addition to the pozzolanic reaction with Ca0 that results in more cement gel (that uses water). For economy and better use of the material a locally available high absorption limestone was used in the lower lift. Paving proceeded routinely except for the shortened length of the section that occurred because of an insufficient amount of the rhyolite aggregate probably caused by misplacement and misappropriation of some of this aggregate.

Section 12. A Two-Lift Construction with Low Water-Cement ratio concrete in the top (10/21/97) put the stronger more costly mix at the contact point of traffic and the environment with the less dense, high absorption limestone mixture used in the bottom 178 mm (7 in.) lift. Paving again proceeded routinely.

Section 13. A Transverse Tining was done here (3/3 & 4/98) because of the unavailability of the special rake earlier in the project. Additionally, the remainder of the high solids special curing compound was applied here at a rate of 0.18 L/m^2 (0.04 gallon per square yard). This section is east and west of the Spring Creek Bridge. The weather at the time of construction called for cold weather concreting procedures . Hot water was used and the slab was covered with polyethylene and two layers of burlap to protect it from subfreezing weather that followed four days after placement. Despite winds above 64 km/h (40 mph) and a -12 °C (10 °F) temperature overnight the slab temperature was 4°C (40 °F) the next morning.

Open House

Part of the FHWA research effort on HPCP is directed at transferring new information and technology rapidly to others in the industry through the use of an Open House. Separate funding was available and Kansas and the contractor scheduled an Open House to coincide with paving a two-lift section on the project. Program speakers for the morning included John Klemunes from the FHWA in Washington, DC, Jim Cable from Iowa State University, Don Strand of the South Dakota DOT, Steve Tritsch of the Missouri Kansas Chapter of the American Concrete Pavement Association, Alan Farrington with the contractor, Wittwer Paving, Inc., and the writer. Approximately 135 attendees representing 14 state DOTs, seven divisions of the FHWA cities, contractors and material suppliers were present. The afternoon tour of the project that was close to the schedule estimated four months earlier was made in the rain, which washed out all construction activity.

Extra Costs of Special Sections

Section 1. Standard operation with the control mixture was bid at \$30.86/m^2 (\$25.80/yd^2) for mainline and shoulders.

Section 2. The single saw cut without the preformed neoprene compression joint seal saved about \$0.80/m^2 (\$0.67/yd^2).

Section 3. The FiberCon^{TM} dowels were \$28.87/m (\$8.80/ft.) each vs. \$8.00/m (\$2.44/ft.) for epoxy coated steel dowels or \$6.84/m^2 (\$5.72/yd^2) extra for this limited quantity. With a reasonable volume the price of these dowels could be expected to be in the \$16.40/m (\$5.00/ft.) range.

Section 4, 5 & 6. The early shallow cut saws gave minimal savings . The polyolefin fibers added \$18.69/m^2 (\$15.63/yd^2). No estimate is currently available for the X-FLEX^{TM} devices.

Section 7. The longitudinal tining rake would replace the transverse rake and add no cost to the pavement price. Individual 1.83 m (6 ft.) sections cost about \$200 each. The special pavement marking material has not been supplied as of this date.

Section 8. The high solids curing compound at 0.07 L/m^2 (0.06 gallons/yd^2) added \$0.99/m^2 (\$ 0.83/yd^2).

Section 9. The two-lift construction with RAP had extra material cost, in this case, of \$0.11/m^2 (\$0.09/yd^2). The two-lift construction costs (spread over three one kilometer sections) included a second plant, extra hauling of material, a concrete belt placer/spreader, and extra labor for paving. The additional cost was calculated at \$29.94/m^2 (\$25.03/yd^2) with 37 per cent of that coming from the second batch plant.

Section 10. The lower water-cement ratio concrete cost using the high range water reducer instead of the regular water reducer was only \$0.04/m^2 (\$0.03/yd^2) higher cost. It would have been \$0.72/m^2 (\$0.60/yd^2) more for the high range water reducer alone.

Section 11. For the rhyolite aggregate section, the cost was again \$29.94/m^2 (\$25.03/yd^2) additional for the two-lift construction. The change to the igneous rock was \$1.16/m^2(\$ 0.97/yd^2) more expensive. The high absorption rock for this job location was about \$0.06/m^2(\$ 0.05/yd^2) higher because of a later bidding time when the price was up, the quantity was small for this non-standard size and the haul was a bit farther with no back haul.

Section 12. The lower water-cement ratio concrete on top of the higher absorption rock concrete was \$0.01/m^2 (\$0.01/yd^2) higher for the high range water reducer, \$29.92/m^2 (\$25.03/yd^2) more for the two-lift construction and \$0.06/m^3 (\$0.05/yd^3) more for the rock in the lower lift.

Section 13. The rake with the random transverse time spacing would add no additional cost to the construction but two \$200 rakes were purchased for just this test section.

Early Results

Section 1. The compressive strength of cores tested at 28 days (standard time) was 31.6 MPa (4583 psi) Seven day beam strengths were 3.6 MPa (525 psi) by third point loading in flexure.

Section 2 and Section 3. No beams were made in these sections and randomly taken strength cores did not fall in these sections that were made with the control mixture.

Section 4. For the polyolefin fiber mixture beam strengths were 3.7 MPa (539 psi) at 7 days, and cylinder strengths were 31.7 MPa (4598 psi). To check for distribution of the fibers in the mixed concrete, portions of cores from two random special cores were examined. Ten random areas of 645 mm^2 (1.0 in^2) each were selected on each core. The first core had an average of 0.017 fibers/mm^2 (11.4/in^2) with a sample standard deviation (ssd) of 0.009 (5.6). The second core averaged 0.016 fibers/mm^2 (10.4/in^2) with an ssd of 0.008 (5.4).

Section 8. The high solid special cure cores averaged 32.8 MPa (4760 psi).

Section 9. The two-lift construction with RAP had core strengths of 26.5 MPa (3843 psi). Beam strengths of the RAP mixture were 3.6 MPa (517 psi) at 5 days. Cylinders at 7 days averaged 23.2 MPa (3370 psi) and at 28 days averaged 32.6 MPa (4730 psi) in compression.

Section 10. The lower water cement mixture had core strengths of 34.8 MPa (5040 psi) and beam strengths of 3.8 MPa (550 psi) at 4 days.

Section 11. The two-lift section with rhyolite had core strengths of 33.0 MPa (4780 psi). The high absorption limestone mixture had beam strengths of 3.3 MPa (475 psi) at 4 days.

Sections 9, 11, and 12. Two lift constructions. The question of how much depression of the lower lift was caused by the second lift of concrete being deposited on the unconsolidated lift was investigated. Along with this was the question of how much, if any, mixing occurred between the lifts as the top lift slid over the lower one.

The second question was addressed by examining the random cores taken to check the thickness of the concrete pavement. Six cores taken in Section 9 (with RAP) showed an average top lift thickness of 89 mm (3.5 in.) with a ssd of 22 mm (0.85 in.). Section 11 (igneous rock) had four cores that averaged 84 mm (3.3 in.) with an ssd of 16 mm (0.64 in.). The four cores in Section 12 , (low water-cement) averaged 76 mm (3.0 in.) with an ssd of 21 mm (0.81 in.), ignoring two cores that had about a 152 mm (6 in.) top lift, and one core that had no lower lift. These were judged to be outliers. Generally the two layers seemed to mix at the interface requiring careful examination to tell the thickness of the top lift except when there was the distinct RAP aggregate in the lower lift.

The depression of the lower lift caused by concrete being placed in a pile by the belt spreader was checked by special cores taken at five documented pile locations. Two locations were in the RAP section, one was in the igneous rock section, and two were in the low water-cement section. Cores taken at the center of the pile (roughly at centerline) averaged 145 mm (5.7 in.). Cores taken 914 mm (3 ft.) away from the centerline in the inside lane averaged 84 mm (3.3 in.), those 914 mm (3 ft.) away in the outside lane averaged 74 mm (2.9 in.), those 914 mm (3 ft.) up station and 914 mm (3 ft.) down station averaged 102 mm (4.0 in.) and 91 mm (3.6 in.) respectively. The overall average of these areas was 99 mm (3.9 in.), which is somewhat greater than the random core average of 84 mm (3.3 in.).

Conclusions

Overall, the special test sections caused little difficulty and went down smoothly. The location chosen offered continuity for the test sections without grade changes or major cross roads.

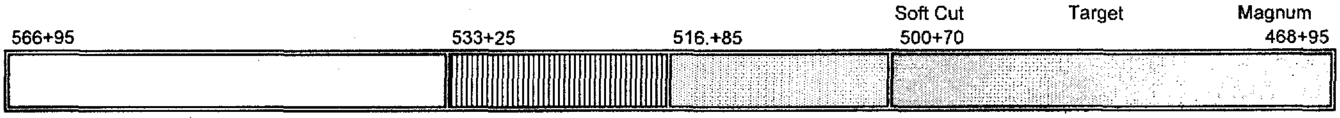
The mixing at the interface of the two lifts should make these sections as homogenous as single lift construction with no chance of debonding. For the three one kilometer test sections the cost of the two-lift construction was higher than expected, almost double the bid price of the regular pavement. Some sort of surface vibration on the lower lift spreader would undoubtedly been helpful in keeping the thickness of the layer close to the design, especially in the area of the pile of concrete placed by the belt spreader.

A single multiple bin concrete plant may have been able to handle both mixes. With two plants producing different concrete, one may break down either leaving the bottom lift uncovered and unfinished or having top lift material with no bottom lift on which to place it, especially if the haul distances are not equal. Significant benefits would have to come from two lifts to make it an economical construction procedure.

Appendix

Kansas High Performance Concrete Pavement Test Sections

96-78 K 4457-01, Reno County



1. Control Section

1 km (3,280 ft.)

Typical Construction

254 mm (10 in.) thickness
1 lift placement
"Shilstone" Design
335 kg/m^3 (564 lb/yd3) cement
6.5% Air
98% consolidation
Typical epoxy coated steel dowels 31.8 mm (1.25")
0.47 w/c used through section

2. Single Sawcut

1/2 km (1,640 ft.)
Single saw cut, no joint sealant in 31 jts. 528+75 last no seal jt.
0.14km open, 0.36km ss
1 lift construction
"Shilstone" Design
335 kg/m^3 (564 lb/yd3) cement
6.5 % Air
98% consolidation
Typical dowels
0.47 w/c ratio 1st day
0.45 w/c ratio 2nd day

3. Non-Traditional Dowel Type

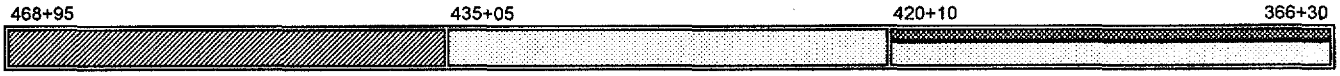
1/2 km (1,640 ft.)

FiberCon Dowels

1 lift construction
"Shilstone" Design
6.5 % Air
98% consolidation
Typical Dowels
0.45 w/c ratio all day

4, 5 & 6 X-Flex, Alternate Saws & 3M Fibers

1 km (3,280 ft.)
(Five X-Flex Joints)
Initial control cuts utilizing:
Soff-Cut, Magnum & Target Early-cut Saws
3M Polyolefin Fibers 152 m (500 ft) section only
1 lift construction
"Shilstone" Design
335 kg/m^3 (564 lb/yd3) cement
6.5 % Air
98% consolidation
Typical Dowels, outside of X-flex
0.47 w/c ratio for Fibers
0.45 w/c ration for all other



7. Special Pvt. Marking/Long. Tining

1 km (3,280 ft.)

Longitudinal Tining
Proprietary pavement marking product

1 lift construction
"Shilstone" Design
335 kg/m^3 (564 lb/yd3) cement
6.5% Air
98% consolidation
Typical Dowels
0.45 w/c ratio through section

8. ASTM C1315 Cure

1 km (3,280 ft.)

Special High-solids curing compound

1 lift construction
"Shilstone" Design
335 kg/m^3 (564 lb/yd3) cement
6.5 % Air
98% consolidation
Typical dowels

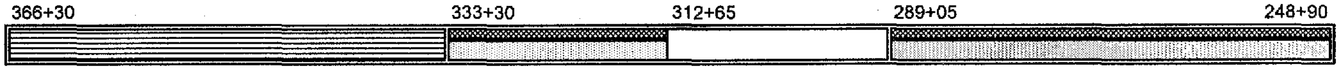
9. Two-Lift , Recycled Asphalt on Bottom

1 km (3,280 ft.)

15% RAP usage in bottom 178 mm (7 in.) layer
Typical concrete mix in top 76 mm (3 in.)

2 lift construction

335 kg/m^3 (564 lb/yd3) cement
6.5% Air in each lift
98% consolidation
Typical dowels
Single Consolidation
196 ml/100 kg (3 oz/100 lb.) cement, Masterpave N in Rap Mix
0.45 w/c ratio in RAP mix
0.45 w/c ratio in normal mix



10. Lower w/c Ratio

1 km (3,280 ft.)

High range water reducer to lower w/c 0.05 from standard mix

1 lift construction
"Shilstone" Design
335 kg/m^3 (564 lb/yd3) cement
6.5 % Air
98% consolidation
Typical Dowels

11. Two-Lift, Igneous Rock on Top

0.63 km (2,065 ft.)

High absorption L.S. in bottom 178 mm (7 in.)
Rhyolite Aggregate in top 76 mm (3 in.)
Dura-Poz to counter ASR of Ryholite
2 lift construction
"Shilstone" Design
335 kg/m^3 (564 lb/yd3) cement
6.5% Air in each lift
98% consolidation
Typical dowels
Single Consolidation

12. Two-Lift, low w/c on Top

1 km (3,280 ft.)

High absorption L.S. in bottom 178 mm (7 in.)
Rhyolite Aggregate in top 76 mm (3 in.)
lower w/c 0.05 from standard mix
2 lift construction
"Shilstone" Design
335 kg/m^3 (564 lb/yd3) cement
6.5% Air in each lift
98% consolidation
Typical dowels
Single Consolidation

13. Random Pattern Transverse Tining & High Solids Cure Sta. 966+44 to 982+15 and 1006+00 to 1026+40
1.1 km (3611f) All else Typical Construction

Sheet Layout is courtesy of Wittwer Paving Inc.

MIX DESIGNS
METRIC UNITS

High Performance Rigid Pavement Test Sections

96-78 K 4457-01, Reno County

Mass of Ingredients in a Cubic Meter

Mix No.	CEMENT kg	WATER kg	W/C RATIO	COURSE AGG.	INTER. GRAVEL	INTER. L.S.	FINE AGG.	RAP kg	FIBER kg	MIX TYPE
5P97101B	309	145	0.47	544	272		997			QC/QA
5P97102A	335	164	0.49	523		262	959			CONTROL
5P97102B	335	157	0.47	528	264		968			CONTROL
5P97106B	309	145	0.47	640	274		914			QC/QA
5P97106C	309	139	0.45	645	276		921			QC/QA
5P97109C	403	182	0.45	578	248		826			HIGH-EARLY
5P97109D	403	173	0.43	586	251		837			HIGH-EARLY
5P97109F	403	157	0.39	600	257		858			H.E. L W/C
5P97112A	335	164	0.49	610	262		872		15	FIBER
5P97112C	335	151	0.45	622	266		889			CONTROL
5P97112F	335	131	0.39	641	275		915			LOW W/C
5P97113C	335	151	0.45	828**			828			HIGH ABS
5P97115C	335	151	0.45	615			879	263		RAP
5P97125B	335	157	0.47	891*			891			IGNEOUS
5P97130B	309	145	0.47	539		269	988			QC/QA

* Igneous Rock

** High Absorption Limestone

MIX DESIGNS
ENGLISH UNITS

High Performance Rigid Pavement Test Sections

96-78 K 4457-01, Reno County

Mass of Ingredients in a Cubic Yard

MIX NO.	CEMENT LBS.	WATER LBS	W/C RATIO	COURSE AGG.	INTER. GRAVEL	INTER. L.S.	FINE AGG.	RAP LBS.	FIBER LBS.	MIX TYPE
5P97101B	520	244	0.47	917	459		1681			QC/QA
5P97102A	564	276	0.49	881		441	1616			CONTROL
5P97102B	564	265	0.47	890	445		1632			CONTROL
5P97106B	520	244	0.47	1078	462		1540			QC/QA
5P97106C	520	234	0.45	1087	466		1553			QC/QA
5P97109C	680	306	0.45	975	418		1393			HIGH-EARLY
5P97109D	680	292	0.43	988	423		1411			HIGH-EARLY
5P97109F	680	265	0.39	1012	434		1446			H.E. L W/C
5P97112A	564	276	0.49	1028	441		1469		25	FIBER
5P97112C	564	254	0.45	1049	449		1498			CONTROL
5P97112F	564	220	0.39	1080	463		1543			LOW W/C
5P97113C	564	254	0.45	1395**			1395			HIGH ABS
5P97115C	564	254	0.45	1037			1481	444		RAP
5P97125B	451+113	265	0.47	1501*			1501			IGNEOUS
5P97130B	520	244	0.47	909		454	1666			QC/QA

* Igneous Rock

** High Absorption Limestone

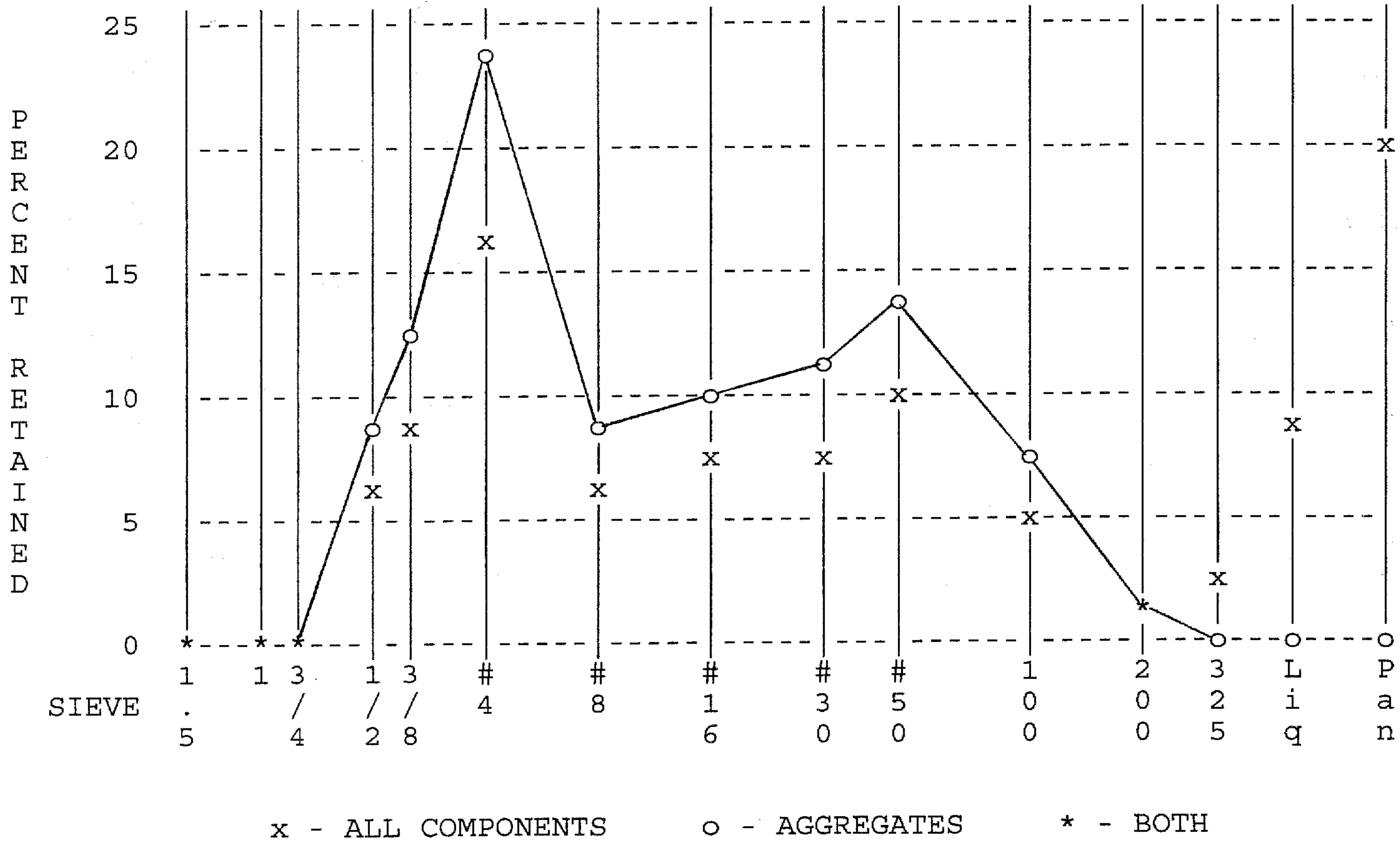
Gradation of the Combined Aggregate

PSI: 4000 PSI   Mix: K4457-01 STD   05/07/98

MATERIALS DISTRIBUTION

SIEVE	STONE 1	STONE 2	SAND	PASTE	TOTAL	AGGR
1-1/2 "					0.0	-
1 "					-	-
3/4 "	100.0				-	-
1/2 "	72.0	100.0			5.8	8.4
3/8 "	38.0	81.0	100.0		9.0	13.1
# 4	5.0	11.0	93.0		16.7	24.3
# 8	2.0	3.0	80.0		6.4	9.2
# 16	2.0	2.0	62.0		6.9	10.0
# 30	2.0	2.0	41.0		7.9	11.5
# 50	2.0	2.0	15.0		9.8	14.3
# 100	2.0	2.0	2.0		4.9	7.1
# 200	1.0	1.5	0.1	100.0	1.0	1.4
# 325	-	-	-	94.9	2.0	0.6
Liquid	-	-	-	65.7	9.1	-

MATERIALS DISTRIBUTION CHART BY SIEVE



STATE OF KANSAS

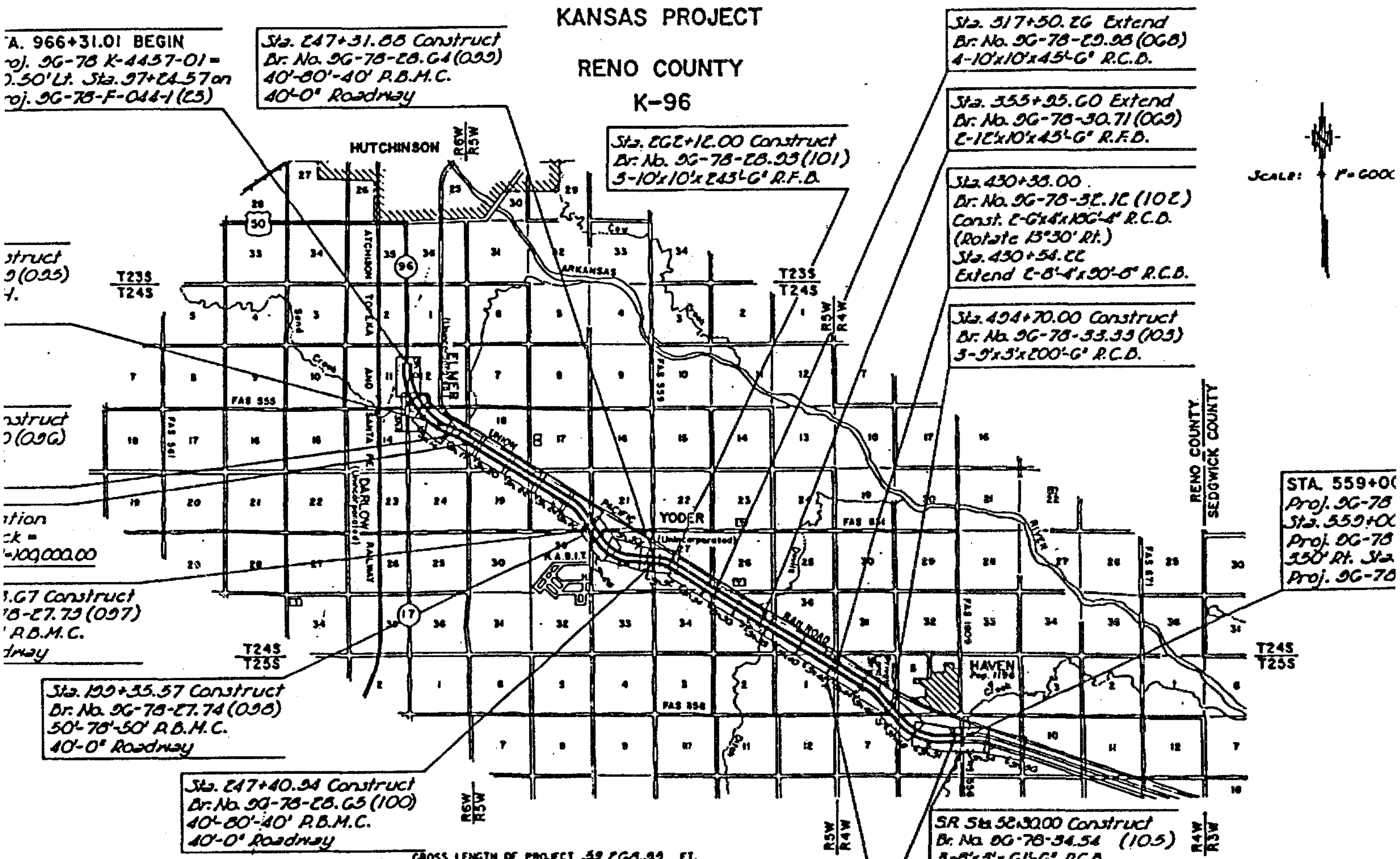
DEPARTMENT OF TRANSPORTATION

PLAN AND PROFILE OF PROPOSED
STATE HIGHWAY

KANSAS PROJECT

RENO COUNTY

K-96



A. 966+31.01 BEGIN
oj. 96-78 K-4457-01=
.50' Lt. Sta. 97+24.57 on
oj. 96-78-F-044-1(23)

Sta. 247+31.88 Construct
Br. No. 96-78-28.64 (099)
40'-80'-40' R.B.M.C.
40'-0" Roadway

Sta. 262+12.00 Construct
Br. No. 96-78-28.93 (101)
3-10'x10'x243'-6" R.F.B.

Sta. 317+50.26 Extend
Br. No. 96-78-29.98 (068)
4-10'x10'x45'-6" R.C.B.

Sta. 355+95.60 Extend
Br. No. 96-78-30.71 (069)
2-12'x10'x45'-6" R.F.B.

Sta. 430+38.00
Br. No. 96-78-32.12 (102)
Const. 2-6'x4'x106'-4" R.C.B.
(Rotate 13°30' Rt.)
Sta. 430+54.22
Extend 2-8'-4'x50'-6" R.C.B.

Sta. 494+70.00 Construct
Br. No. 96-78-33.33 (103)
3-9'x3'x200'-6" R.C.B.

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.67 Construct
78-27.73 (097)
' R.B.M.C.
dway

Sta. 199+35.57 Construct
Br. No. 96-78-27.74 (098)
50'-78'-50' R.B.M.C.
40'-0" Roadway

Sta. 247+40.94 Construct
Br. No. 96-78-28.65 (100)
40'-80'-40' R.B.M.C.
40'-0" Roadway

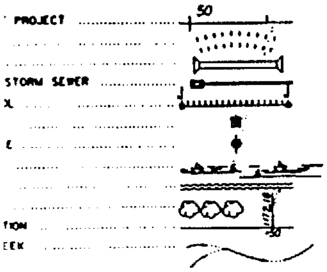
STA. 559+0(
Proj. 96-78
Sta. 559+0(
Proj. 96-78
350' Rt. Sta
Proj. 96-78

SR Sta. 52+30.00 Construct
Br. No. 96-78-34.54 (105)
3-8'x5'x61'-6" R.C.B.

Sta. 554+00.00 Construct
Br. No. 96-78-34.46 (104)
4-8'x4'x265'-6" R.C.B.

S.R. Sta. 48+00.00 Construct
3-8'x4'x57'-6" RCB

GROSS LENGTH OF PROJECT	59,268.99	FT.		
EXCEPTIONS	0.00			
ADDITIONS	0.00			
NET LENGTH OF PROJECT	59,268.99	FT.	11.225	MILES
NET LENGTH OF BRIDGES	467.19	FT.	0.088	MILES
NET LENGTH OF ROAD	58,801.80	FT.	11.137	MILES



RECOM. FOR APPROVAL-DATE

CHIEF, BUREAU OF DESIGN
KANSAS DEPARTMENT OF TRANSPORTA

APPROVED - DATE

STATE TRANSPORTATION ENGINEER
KANSAS DEPARTMENT OF TRANSPORT

EARLY CONCRETE PROPERTIES (Metric Units)

High Performance Rigid Pavement Test Sections

96-78 K 4457-01, Reno County

		STATION HIGH TO LOW	MIX DES. NO.	SLUMP mm	ACT. AIR percent	UNIT WT. kg/m^3	BEAM STRENGTH MPa (AGE)	NUCLEAR DENSITY kg/m^3	% of Std.	COMP. STRENGTH MPa
1	CONTROL SECTION	566+25	5P97112C	19	6.5	2279	3.6 (7)	2275	100	25.0
			5P97112C	13	5.5	2272		2292	101	36.7
								2271	100	33.2
								2281	100	
								2205	99	
								2191	98	
								2260	100	
								2262	100	
								2273	99	
								2251	98	
								2268	99	
								2245	98	
			AVERAGE	**16**	**6.0**	**2275**	**3.6**	**2257**	**99.3**	**31.6**
2	SINGLE SAWCUT	533+25	5P97112C	25	7.1	2279		2280	100	
								2299	101	
								2266	99	
								2263	100	
								2277	101	
								2263	99	
			AVERAGE	**25**	**7.1**	**2279**		**2275**	**100.0**	
3	NON-TRADITIONAL DOWEL TYPE	516+85	5P97112C	25	5.3	2285		2273	100	
								2189	98	
								2204	99	
								2282	99	
								2257	100	
								2260	99	
								2242	98	
			AVERAGE	**25**	**5.3**	**2285**		**2244**	**99.0**	
4	X-FLEX	500+70								
4a	SOFF-CUT	499+95						2258	99	29.0
								2289	100	33.5
								2244	99	
								2261	99	
								2251	100	
			AVERAGE					**2261**	**99.4**	**31.2**
5	TARGET	488+60	5P97112C	25	7.0	2259		2221	98	
			AVERAGE	**25**	**7.0**	**2259**		**2221**	**98**	
6	MAGNUM	481+65						2328	102	
			AVERAGE					**2328**	**102**	
6a.	3M POLYOLEFIN FIBERS	473+75	5P97112A		5.2	2259	3.7 (7)			
			AVERAGE		**5.2**	**2259**	**3.7**			
7	SPEC. Pvt. MARKING/ LONG. TINING	468+95	5P97112C	19	7.5	2259		2274	100	33.7
			5P97112C	19	6.6	2259		2286	101	30.6
			5P97112C	25	6.5	2266		2283	100	
								2289	101	
								2289	102	
								2261	99	
			AVERAGE	**21**	**6.9**	**2261**		**2280**	**100.5**	**32.2**

EARLY CONCRETE PROPERTIES (Metric Units)

		STATION HIGH TO LOW	MIX DES. NO.	SLUMP mm	ACT. AIR percent	UNIT WT. kg/m^3	BEAM STRENGTH MPa	NUCLEAR DENSITY kg/m^3	% of Std.	COMP. STRENGTH MPa
8	ASTM C1315 Cure	435+05	5P97112C	54	7.4	2243		2290	102	33.6
								2286	102	32.0
								2275	101	
								2278	101	
								2203	97	
								2252	100	
								2207	98	
			AVERAGE	**54**	**7.4**	**2243**		**2264**	**100.1**	**32.8**
9	TWO-LIFT,	402+10	5P97115C	13	5.7	2298	3.6 (5)	2241	98	26.3
	Recycled Asphalt on Bottom		5P97112C	13	7.0	2279		2299	101	25.3
			5P97115C	25	5.8	2259		2278	100	27.9
			5P97112C	25	6.5	2272		2303	101	
								2252	99	
								2272	101	
								2273	101	
								2208	98	
								2187	97	
								2214	97	
								2245	98	
								2232	98	
			AVERAGE	**19**	**6.3**	**2277**	**3.6**	**2250**	**99.08**	**26.5**
10	LOWER w/c RATIO	366+30	5P97112F	25	5.5	2311		2337	101	35.8
			5P97112F	30	6.1	2324	3.8 (4)	2313	100	33.7
								2303	99	
								2315	100	
								2325	100	
								2181	97	
								2190	97	
								2197	98	
								2233	99	
								2264	99	
			AVERAGE	**28**	**5.8**	**2317**	**3.8**	**2266**	**99.0**	**34.7**
11	TWO-LIFT,	333+30 to	5P97113C	19	5.9	2233	3.3 (4)	2323	103	37.6
	Igneous Rock on Top	312+65	5P97125B	51	4.3	2279	4.0 (8)	2397	107	28.3
								2274	101	
								2297	102	
								2277	101	
								2217	98	
								2198	97	
								2216	98	
								2253	97	
			AVERAGE	**35**	**5.1**	**2256**	**3.6**	**2272**	**100.4**	**33.0**
12	TWO-LIFT,	289+05 to	5P97112F	25	6.0	2298	4.0 (6)	2302	102	32.8
	low w/c in Top	248+90	5P97112F	25	5.7	2311		2290	102	33.0
			5P97113C	32	5.6	2208	4.0 (6)	2306	102	
			5P97113C	32	5.0	2208		2310	103	
								2299	102	
								2254	98	
								2263	98	
								2291	100	
								2257	98	
								2265	98	
								2260	98	
			AVERAGE	**29**	**5.6**	**2256**	**4.0**	**2281**	**100.1**	**32.9**

EARLY CONCRETE PROPERTIES (English Units)

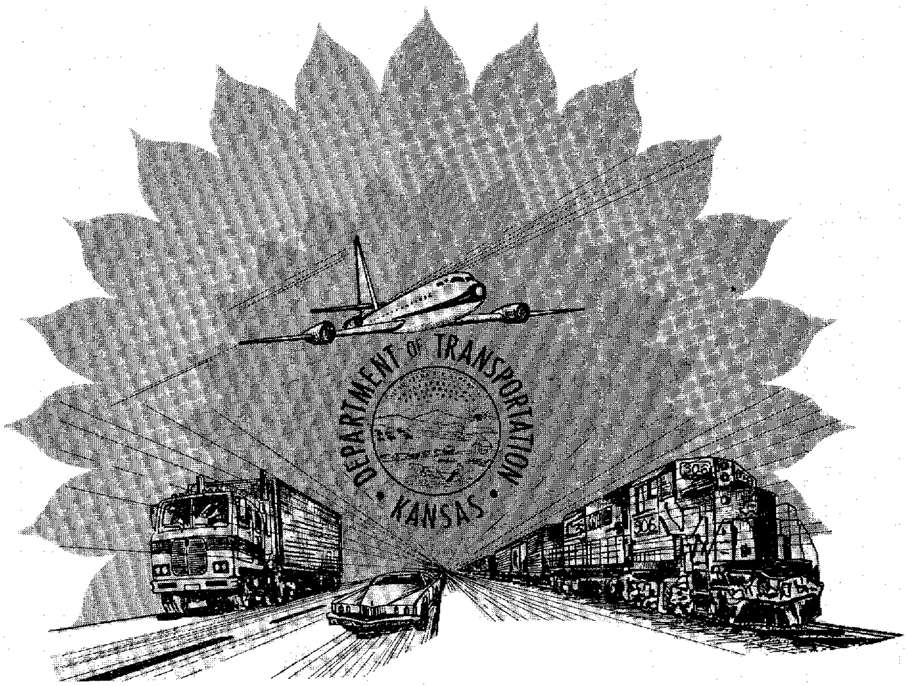
High Performance Rigid Pavement Test Sections

96-78 K 4457-01, Reno County

		STATION HIGH TO LOW	MIX DES. NO	SLUMP inches	ACT. AIR percent	UNIT WT. lb/ft^3	BEAM STRENGTH psi (AGE)	NUCLEAR DENSITY lbs/ft^3	% of Std.	COMP. STRENGTH psi
1	CONTROL SECTION	566+25	5P97112C	0.75	6.5	142.25	525 (7)	142.03	100	3620
			5P97112C	0.50	5.5	141.85		143.10	101	5320
								141.80	100	4810
								142.37	100	
								137.63	99	
								136.80	98	
								141.10	100	
								141.23	100	
								141.90	99	
								140.53	98	
								141.57	99	
								140.17	98	
			AVERAGE	**0.63**	**6.00**	**142.05**	**525**	**140.91**	**99.3**	**4583**
2	SINGLE SAWCUT	533+25	5P97112C	1.00	7.1	142.25		142.33	100	
								143.53	101	
								141.47	99	
								141.27	100	
								142.17	101	
								141.27	99	
			AVERAGE	**1.00**	**7.1**	**142.25**		**142.01**	**100.0**	
3	NON-TRADITIONAL DOWEL TYPE	516+85	5P97112C	1.00	5.3	142.65		141.93	100	
								136.67	98	
								137.60	99	
								142.47	99	
								140.87	100	
								141.07	99	
								139.97	98	
			AVERAGE	**1.00**	**5.3**	**142.65**		**140.08**	**99.0**	
4	X-FLEX	500+70								
4a	SOFF-CUT	499+95						140.97	99	4200
								142.87	100	4860
								140.07	99	
								141.17	99	
								140.53	100	
			AVERAGE					**141.12**	**99.4**	**4530**
5	TARGET	488+60	5P97112C	1.00	7.0	141.01		138.67	98	
			AVERAGE	**1.00**	**7.0**	**141.01**		**138.67**	**98**	
6	MAGNUM	481+65						145.33	102	
			AVERAGE					**145.33**	**102**	
6a.	3M POLYOLEFIN FIBERS	473+75	5P97112A	NONE	5.2	141.04	539 (7)			
			AVERAGE		**5.2**	**141.04**	**539**			
7	SPEC. Pvt. MARKING/ LONG. TINING	468+95	5P97112C	0.75	7.5	141.04		141.97	100	4890
			5P97112C	0.75	6.6	141.04		142.73	101	4440
			5P97112C	1.00	6.5	141.45		142.53	100	
								142.87	101	
								142.87	102	
								141.17	99	
			AVERAGE	**0.83**	**6.9**	**141.18**		**142.36**	**100.5**	**4665**

EARLY CONCRETE PROPERTIES (English Units)

		STATION	MIX DES.	SLUMP	ACT.	UNIT	BEAM	NUCLEAR	% of Std.	COMP.
		HIGH TO LOW	NO		AIR	WT.	STRENGTH	DENSITY		STRENGTH
				inches	percent	lb/ft^3	psi	lbs/ft^3		psi
8	ASTM C1315 Cure	435+05	5P97112C	2.12	7.4	140.04		142.93	102	4880
								142.73	102	4640
								142.03	101	
								142.20	101	
								137.50	97	
								140.60	100	
								137.80	98	
			AVERAGE	**2.12**	**7.4**	**140.04**		**141.33**	**100.1**	**4760**
9	TWO-LIFT, Recycled Asphalt on Bottom	402+10	5P97115C	0.50	5.7	143.46	517 (5)	139.90	98	3810
			5P97112C	0.50	7.0	142.25		143.50	101	3670
			5P97115C	1.00	5.8	141.04		142.20	100	4050
			5P97112C	1.00	6.5	141.85		143.80	101	
								140.60	99	
								141.83	101	
								141.87	101	
								137.87	98	
								136.53	97	
								138.20	97	
								140.17	98	
								139.37	98	
			AVERAGE	**0.75**	**6.25**	**142.15**	**517**	**140.49**	**99.08**	**3843**
10	LOWER w/c RATIO	366+30	5P97112F	1.00	5.5	144.26		145.90	101	5190
			5P97112F	1.20	6.1	145.07	550 (4)	144.40	100	4890
								143.80	99	
								144.50	100	
								145.13	100	
								136.13	97	
								136.70	97	
								137.17	98	
								139.40	99	
								141.33	99	
			AVERAGE	**1.10**	**5.8**	**144.67**	**550**	**141.45**	**99.0**	**5040**
11	TWO-LIFT, Igneous Rock on Top	333+30	5P97113C	0.75	5.9	139.43	475 (4)	145.00	103	5450
			5P97125B	2.00	4.3	142.25	583 (8)	149.63	107	4110
								141.97	101	
								143.40	102	
								142.17	101	
								138.40	98	
								137.20	97	
								138.36	98	
								140.63	97	
			AVERAGE	**1.38**	**5.1**	**140.84**	**525**	**141.86**	**100.4**	**4780**
12	TWO-LIFT, low w/c in Top	289+05 to 248+90	5P97112F	1.00	6.0	143.46	583 (6)	143.73	102	4750
			5P97112F	1.00	5.7	144.27		142.93	102	4780
			5P97113C	1.25	5.6	137.82	583 (6)	143.93	102	
			5P97113C	1.25	5.0	137.82		144.23	103	
								143.50	102	
								140.70	98	
								141.27	98	
								143.00	100	
								140.90	98	
								141.40	98	
								141.07	98	
			AVERAGE	**1.13**	**5.6**	**140.84**	**583**	**142.42**	**100.1**	**4765**


DEPARTMENT OF TRANSPORTATION
KANSAS