CENTER FOR
PORTLAND CEMENT CONCRETE
PAVEMENT TECHNOLOGY

Two-Lift Portland Cement Concrete Pavements to Meet Public Needs

Final Report
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Department of Civil, Construction and Environmental Engineering
IOWA STATE UNIVERSITY

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The mission of the PCC Center is to advance the state of the art of portland cement concrete pavement technology. The center focuses on improving design, materials science, construction, and maintenance in order to produce a durable, cost-effective, sustainable pavement.

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16. Abstract

The report reviews the past work in the United States and internationally in the development of two-lift pavements. It points out the strengths and limitations in the construction of such portland cement concrete pavements. Certain cost, mix design, and construction problems are inhibiting the growth of this product. Changes in the availability of aggregates, knowledge of materials and new construction equipment, and the desire for specific surfaces to meet noise, durability, and safety are prompting the need to reconsider this type of construction.

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TWO-LIFT PORTLAND CEMENT CONCRETE PAVEMENTS TO MEET PUBLIC NEEDS

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Final Report • September 2004

TABLE OF CONTENTS

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INTRODUCTION

This report on the current status of two-lift paving in the United States and Europe was developed to identify factors that are prohibiting growth in this market. This report also identifies steps that can be taken by state and federal officials to move this concept forward.

Two-lift paving is a paving technique that has been tried in different ways in the past and with varying degrees of success. It is used in Europe to develop a strong base pavement and a superior, but thin, wearing surface. The two-lift paving technique was brought to Detroit, Michigan, and used in the replacement of a major freeway in downtown Detroit. This pavement consisted of two layers placed, wet on wet, with the top layer consisting of a special surface mix. Coarse aggregate was placed in the surface layer and built as an exposed aggregate surface to provide a quiet, but rough surface texture for durability and friction resistance.

Research Objectives

This research effort was focused on a synthesis review of two-lift paving in Europe and the United States. It determined the following:

- The location, design, and construction parameters used, as well as the current condition of the two-lift construction projects in the United States and Europe.
- The need for a high-quality and durable surface such as the one provided by two-lift paving.
- The research gaps and limitations in design and construction that are restraining the use of the two-lift paving technique in the United States.

Research Plan

Data were collected through email and phone conversations with American Concrete Pavement Association (ACPA) chapter representatives and state highway officials in the research areas. Data collection focused on identifying basic information about current or recent two-lift paving projects. During the data collection phases, the research staff attempted to determine what factors have prevented more two-lift paving projects from being built. The research staff also conducted an electronic search of two-lift paving information.

DATA COLLECTION

Data for this project were collected in two ways. The first method was an electronic and paper search of existing experience from international sources. This included reviews of Federal Highway Administration (FHWA)-sponsored scanning trips and literature reviews. The second method involved asking ACPA representatives in each state to identify two-lift construction projects as well as individuals or contractors involved in these projects. The results of the data collection are summarized in the following paragraphs. Significant projects and aspects of the design or construction are noted.

International Experience

Examples of two-lift paving in Europe were most prevalent in France, Austria, and Germany. These countries cited safety, noise, and economic reasons for implementing the two-lift paving method.

France

In France, continuous reinforced concrete pavement was place on two traffic lanes of highway A71 using the two-lift paving method. The bottom layer, which is greater than 2 inches, used local limestone aggregates. The top layer of this pavement, approximately 2 inches in depth, was made up of harder aggregates. These aggregates provided low noise and high friction for the pavement surface, but they had to be hauled from long distances and increased the cost of the layer. Therefore, using the two-lift method reduced costs because it requires less of the expensive concrete to obtain the desired concrete surface.

Austria

In Austria, the government has placed regulations stating that most, and sometimes all, site materials must be recycled into the new paving project. Freeway A1, a connecting road between Vienna and Salzburg, is just one example of how Austria recycles its old pavement into new pavement. The original road, which had been made from jointed reinforced concrete, was first shattered and then hauled to a crushing plant. Depending on what size the recycled material was crushed to and the amount of asphalt (from overlays) it contained, the materials were used for two purposes: subbase and aggregate. The aggregate was secured with cement and then a two-inch layer of asphalt was placed on top. The recycled aggregate was then mixed into the bottom concrete layer (8.5 inches deep), while the top layer (1.6 inches deep) was composed with a harder aggregate of a higher quality. Once again, the purpose of using a higher quality concrete for the top layer was to reduce noise and increase friction, while keeping cost low by using a lower quality concrete for the bottom layer. A photo of this paving is shown in Figure 1.

Figure 1. Two-lift paving in Austria
(Source: http://www.walter-heilit-vwb.de/english/toechterg/wien.htm)

Germany

The case is very similar in Germany. Two-lift paving is often used to reduce noise and increase friction. Germany also uses this method to reduce cost and achieve a smoother profile. In addition, Germany has somewhat drastic climate changes, which require the use of higher quality aggregate in the top layer to resist freezing and thawing effects. For example, the Munich airport was paved using the two-lift method. The bottom layer was approximately 9.5 inches deep and used local gravel as an aggregate. The top layer was 5.5 inches deep and used crushed granite as an aggregate. The same two aggregates were used for the two layers of an Autobahn project in Berlin.

A German company, Wirtgen GmbH, produces a two-lift slip-form paver. The company advertises that the two-lift paver's advantages include "easy transport, minimum assembly work, and operational readiness." Wirtgen also claims that the paver has a high paving velocity and produces a high-quality surface.

The Wirtgen paver is actually two separate machines (one for each lift) capable of working independently. The Wirtgen paver paves a width between 16.4 feet and 50 feet and a depth of up to 17 inches. The top paver can be equipped with a super smoother or an oscillating beam to produce the desired surface texture.

The Federal Highway Research Institute of Germany is researching two-lift paving. The Federal Highway Research Institute of Germany has found that because the two layers of concrete display different properties, the layers can create stress intensities from the "bimetallic" effect. This effect takes place in the bonding between the two layers. The Federal Highway Research Institute of Germany is investigating the chemical contraction in the top concrete layer, which is stiffer than the bottom layer, in order to develop a design technique for realistic stress registration. The Federal Highway Research Institute of Germany is also examining the property differences in the two layers to make recommendations on the concrete composition, thickness, and curing of the layers.

U.S. Experience

The idea of two-lift paving, wet on wet, has been around almost as long concrete pavements. Fourteen years after the first concrete street construction was completed in Bellefontaine, Ohio, a process called "Granitoid Concrete Streets" was patented in 1906 in Chicago, Illinois. The Granitoid two-lift paving process required the use of normal ready mix concrete for the first five inches placed into the forms with less expensive aggregates and a then common mix design of one part cement, two parts sand, and four parts rock. The top lift required a crushed granite rock, often referred to as "monument granite," and a reduction in the amount of fine aggregate to provide a very hard durable surface to withstand the expected wear by horse drawn wagons with steel wheels. These streets, which were constructed in 1909 and 1910, are still in service today in Duluth, Minnesota, and Grand Forks, North Dakota, and listed in the National Register of Historic Places.

In 1915, a similar process was used to construct streets in Madison and Sheboygan, Wisconsin. In Madison, the bottom layer of the street was constructed from locally available dolomite limestone rock and the top layer from quartzite rock obtained from Baraboo, Wisconsin. The streets in Sheboygan used locally available limestone for the bottom lift and used granite for the top even though the closest granite quarries are over two hundred miles away.

The two-lift paving technique was implemented extensively from 1950–1990 in many states to facilitate the placement of mesh in concrete interstate pavement construction. The first lift of concrete was placed at approximately one-half the final pavement thickness and then a welded wire mesh was placed on the wet concrete between the dowel baskets. Before the concrete had a chance to stiffen, a second lift of concrete was placed on top of the mesh and a paving machine finished the surface. This process used the same concrete mix for both lifts and was quite successful in many states around the country including Iowa, Wisconsin, Illinois, Michigan, Pennsylvania, and Minnesota.

From 1970 to 2000, the concrete paving industry moved from a mesh dowelled design to a plain pavement design, with or without dowels, based on traffic volumes. Eliminating the mesh and shortening panels from as great as one hundred feet to a fifteen or twenty foot pattern eliminated the need to pave with a two-lift process. Today, there are still some rare instances where the two-lift process is used on airport construction to facilitate the placement of mesh between dowel baskets.

Conversations with engineers across the nation found that four experimental two-lift construction projects were completed from 1970 to 2004. During these conversations, many ACPA promoters and engineers expressed interest in using different quality concretes for the lower and top lifts, but many of them felt that the cost of such a two-lift process outweighs the benefit of building an improved top lift. Costs on documented two-lift projects in Kansas and Michigan showed that the concrete costs about doubled when compared to the normal concrete pavement construction on the same project when test sections were between 500 and 1000 feet long.

Many ACPA promoters and engineers also expressed concern about the extra permits and land space needed to set up the two paving plants necessary for a two-lift paving project because contractors don't usually have an extra plant available. The biggest expense for using two paving plants is the cost of hiring more workers to run the batch plant and second paving machine. Many promoters and engineers recognized that the benefits of the two-lift technique may be greater in the future, when aggregate sources become scarce in some locations. It is also possible that if a contractor could use a lower-quality (lower durability or strength) concrete in the bottom lift (like recycled asphalt or concrete rubble) and place higher-quality concrete in the top two to three inches, the savings might be enough to justify the additional costs in equipment and permits.

The definition of lower quality concrete can be accomplished in many different ways. In the state of Washington, the use of studded tires has created a rutting problem for concrete pavements. Here, it could involve the use of different concrete flexural strengths with two-lift construction.

In 1995, test sections were constructed in the state of Washington. The sections were constructed using a one-lift paving technique, and had sections with flexural strengths of 550 psi, 650 psi, and 900 psi. At the time of this report, the 900 psi concrete test section is exhibiting minimal wear from the use of studded tires while the other concrete sections are showing significant signs of wear from the use of studded tires. The state of Washington could use two different concrete strengths with the same plant and aggregates in a two-lift paving application by changing the flexural strength of the top lift. Such a solution would reduce overall costs by only requiring one plant and eliminating the need to stockpile different aggregates.

Iowa

In Iowa, a project was built in Lyon County on U.S. 75 to demonstrate the ability to recycle composite pavements and build wet on wet two-lift pavement. In this case, the old composite pavement was removed, crushed, and used as aggregate for the bottom lift. The upper lift was constructed with virgin aggregate and placed immediately behind the lower lift in the same day. To date, this pavement is performing well.

Florida

In Florida, econocrete test sections were constructed in 1978. These test sections are an example of a two-lift pavement built with a lower lift that has a lower flexural strength and a top lift that has a higher flexural strength. This roadway is still in service today.

North Dakota

In 1976, the state of North Dakota decided to build a two-lift concrete pavement. This was an effort to build a section of U.S. Highway 2 between Rugby and Leeds, North Dakota over some terrible soil conditions (AASHTO A-6, A-7). The locally available aggregate was blended into a one-aggregate mixture and mixed with cement to form an econocrete bottom layer 6” thick. The top lift was placed 3” thick, with a 1-foot widened section (27 feet wide) over the 25-foot-wide bottom lift. This was constructed in the eastbound land for approximately 25 miles.

Kansas

The state of Kansas has a locally available limestone in the southwest part of the state that has a tendency to polish, thus lowering skid numbers. Kansas could use a two-lift paving application to place a higher quality aggregate in the top lift to prevent the polishing of their locally available limestone aggregate.

Michigan

In 1994, the state of Michigan used the European two-lift system to place a high quality aggregate in the top lift to construct an exposed aggregate concrete surface for noise reduction. The two-lift process could be used in locations where noise is a concern and the use of smaller aggregates would facilitate the exposed aggregate design.

In addition to these specific situations, implementation of a two-lift system could help some agencies around the country consume growing recycled asphalt piles, since most asphalt specifications only allow up to 40% recycled asphalt in their product and generally only on the lower sections. If recycled asphalt is available, it could be used to reduce costs, because less of the more expensive aggregates would need to be imported.

Using recycled asphalt would also be beneficial to the environment by removing stockpiles of recycled material, whether it is concrete or asphalt rubble. This was the intent of the construction that took place in Iowa in 1976 on U.S. Highway 75. For that project, the existing composite concrete pavement with an asphalt overlay was recycled back into a two-lift concrete pavement. The bottom lift was seven inches thick and included the recycled product and the top four inches were placed with a virgin concrete mix. This experimental pavement is still in service today.

The state of Alabama has designed three projects to be considered in 2004–2005 as alternative bid proposals to more traditional asphalt and concrete pavements. With the traditional concrete options, the use of a non-wear aggregate in the final surface, such as granite, quartzite, gravel, or sandstone is required. The concrete contractors have been required to provide a final pavement thickness of 13 inches. If an alternate two-lift paving technique is selected, a 9 inch lower lift and a 4 inch top lift will be constructed. The bottom lift can be constructed with locally available limestone aggregates that have a history of polishing. The top lift must be constructed with a non-wearing rock (granite, quartzite, gravel, or sandstone). Another option would be the construction of a one-lift 13 inch thick concrete pavement with an approved non-wearing rock source. This one-lift bid is competing against an 11.5 inch asphalt section, designed by the Alabama Department of Transportation (DOT), in lettings scheduled for November 2004, January 2005, and May 2005.

The Alabama DOT has not constructed very many miles of concrete pavements, which is partly due to the negative polishing effects of the locally available limestone aggregates. After about twenty years, Alabama DOT found that skid numbers generally fall to low levels. When diamond grinding was performed, skid numbers initially improve dramatically, but then return to a low level after as little as two years.

The inclusion of alternate bids (asphalt/PCC) is an attempt to compare the bid price of using a better quality aggregate in the top surface with bid prices of other methods. This bidding process will help the Alabama concrete industry decide if it's possible for a two-lift concrete paving system to compete with the asphalt industry under specifications set forth by the Alabama DOT.

DATA ANALYSIS

Existing research in the United States indicates that the only two-lift concrete paving projects completed since 1970 were experimental roads in five states. Iowa, Florida, and North Dakota constructed their test roads in the 1970s. Kansas and Michigan constructed two-lift projects in the 1990s as part of the FHWA High Performance Concrete program. While all these roads are performing well, no state agency or concrete promoter has pursued the idea of regularly building two-lift concrete pavements as an alternative to the standard design model.

From the four two-lift concrete paving projects completed since 1970, the following conclusions were drawn:

Florida—US 41 (constructed in 1978)

- Waiting 30–60 minutes before placement of second lift helps prevent mixing of the two concretes.
- Using three levels of compressive base strengths (750 psi, 1250 psi, and 2000 psi) can be done successfully.
- A two-lift concrete pavement with a three-inch top lift on a nine-inch base lift, with dowels placed in the bottom lift is the most successful. Of the 33 test sections, 23 are still in service, with no maintenance costs to date. The other ten sections were removed within two years after construction.
- The bottom lift was placed with a spreader box and the top lift was placed with a slip-form paver.

Iowa—US 75 (constructed in 1976)

- Successfully recycled existing concrete pavement with an asphalt overlay into a base course by first separating the asphalt overlay and then utilizing approximately 40% asphalt in the final concrete base course.
- Air entrainment content proved to be a problem with the addition of the recycled asphalt into the base course. Very little additional air entrainment agent was necessary in this course.
- Capped the lower quality concrete on all exposed edges by placing a 24-foot-wide top lift over a 23-foot-wide bottom lift.
- This rather large pavement was placed with nine inches of base course and four inches of conventional concrete mix design; the old concrete was successfully used as aggregate in the final top lift.

- Separating the asphalt overlay from the underlying concrete pavement proved that an old pavement can be recycled into a new two-lift pavement.

- The lower lift was placed with a Rex Belt Placer and the top lift was placed with a paving machine. From this experience, the contractor said that he would rather have two belt spreaders and two pavers on future projects.

North Dakota—U.S. 2 (constructed in 1976)

- Successfully placed a two-lift pavement from the same batch plant with no problems with bonding between the two layers.

- The concrete plant had three aggregate bins; rock, sand, and base material. The bottom lift was constructed with only the base material. The rock and sand were used to mix the top lift.

- Placed the top lift 27 feet wide over a bottom lift with a width of 25 feet.

- Used locally available aggregates for in the 6 inch bottom lift as a one-material econocrete mix. Place good-quality concrete in the 3 inch top lift and the one foot widened section on each edge to cap the bottom lift on both sides.

- Placed the bottom lift with a belt placer that carried a pan with pan vibrators to consolidate the bottom lift.

- Used a second belt placer for the top lift concrete and paved with a slip-form paving machine.

- Project suffered from extensive longitudinal cracking the right-hand lane immediately after construction. The truck lane was constructed 15 feet wide and the crack emanated from the right wheel path.

- Project was cracked and seated with an asphalt overlay in 1997.

Michigan—I-75 (constructed in 1994)

- Proved that the European system of two-lift construction can be accomplished in a paving project in the United States.

- The cost for this type of construction on this small project was twice the cost of a conventional U.S. concrete pavement.

- The Michigan DOT's Materials and Technology Division found no perceptible noise difference in a July 1994 report when the two-lift section was compared to adjacent concrete pavement sections.

Kansas—K-96 (constructed in 1997)

- Successfully placed the bottom lift with 15% Recycled Asphalt Material.
- Proved that waiting about 30 minutes was necessary to prevent mixing of the two-lifts and create the desired bonding to make a homogenous pavement.
- Wear resistance was improved by placing a different aggregate in the top lift.
- Used a lower water-to-cement ratio (W/C) mix in the top lift without any problems with debonding of the two-lifts.
- The cost of this small project proved to be twice the cost of a conventional concrete pavement.
- The lower lift was placed with a spreader and the top lift was placed with a conventional slip-form paving machine by making the lower mix stiffer than the top lift.

Research also identified examples of two-lift paving on city streets from the early part of the twentieth century that are still in service. These are individual survivors from a larger data set and should not be construed as examples of a process that was always successful.

With the success of the four experimental roadways, there are remaining research gaps to be filled to facilitate the construction or design of two-lift concrete pavements. By the large number of successful mesh-dowelled pavements constructed between 1950 and 1990, it is evident that the industry can build two-lift pavements. In fact, the evidence shows that in 2004 there are still airport projects being constructed as two-lift pavements to facilitate the placement of mesh in a mesh-dowelled design.

The research indicates that the use of the plain concrete pavement designs and the need for high production has moved the concrete industry away from the two-lift construction method. High production is necessary to compete with the asphalt industry, which has also improved production as a way to sell their product, and the concrete industry has to be competitive in the low-bid approach taken by government agencies.

In the current low-bid pavement construction environment, the concrete industry has been forced to find ways to remain competitive. The following are obvious factors that would add costs to a two-lift paving operation:

- Additional costs for two plants, including equipment, permits, land area, fuel costs, trucking costs and labor costs.
- Costs for two slip-form paving machines, including equipment, labor, repairs, fuel costs, and setup costs.

- The need for a haul road next to the mainline paving operation or in tight urban environments removing another lane from service by the traveling public.

Many roads are paved with dowel bar inserters that allow the roadway to act as the haul road for concrete trucks. When the construction equipment costs or scarcity of locally available aggregates exceeds these additional costs, then the industry will look at two-lift paving as a method to utilize recycled rubble from concrete and asphalt projects.

The risk of unforeseen problems with two-lift construction, such as the wrong truck going to the wrong paving machine, should also be noted. In the Michigan and Iowa projects, the contractor either put red flags on the trucks or painted the trucks different colors to reduce the risk of a driver going to the wrong paving machine. Both contractors realized the risk of a breakdown in either the paving plant or the paving machine, but found it difficult to build contingency plans for such a breakdown in the current low-bid environment.

Equipment malfunctions could cause a number of potential problems. If the top lift operation experiences an equipment malfunction that is not fixed within 30 minutes, it is possible that whatever bottom lift concrete is exposed will be lost. Also, if the bottom lift operation experiences an equipment malfunction, then whatever top lift concrete already loaded into trucks will be lost because there will be no location for its placement. Conversely, in a normal one-lift paving application, a contractor only loses concrete en route or at the slip-form paver due to an equipment malfunction. If a paving plant breaks down, a construction header can be placed in the field and paving can resume after repairs are performed. The inherent risk and additional costs of two-lift paving operations are two of the reasons that have kept the industry from proceeding with the promotion of two-lift paving.

When the industry was using a two-lift paving technique, the goal was to place one mile of 24 foot-wide roadway in one day of paving. The two-lift construction process makes this goal difficult. With the adoption of the plain pavement design, the standard paving operation routinely places one mile of paving each day, which makes the process competitive with other pavement construction types.

The current economic climate indicates that production will continue to be the driving force for both the asphalt and concrete industries. As the traveling public continues to demand total access to their roadways even while they are under construction, two-lift paving will have an uphill struggle to a gain a foothold in the marketplace.

RECCOMENDATIONS

Recognizing the regions in the country where two-lift paving could be cost effective and promoting two-lift projects in these locations are the first steps to making this technology available for future engineers. This will require both research studies and demonstration construction projects to work toward optimization of mix designs and construction/performance objectives.

Research

Necessary research to promote two-lift paving includes determining the following:

1. Characteristics and materials needed to provide a surface layer of portland cement concrete that meets the future durability, safety, and noise requirements of the public.

2. Optimal amount of recycled asphalt that could be used in a lower lift. So far, it has been done successfully with 15% and 40% recycled asphalt in the bottom lift.

3. Materials that can be present in mixed recycled material and be placed in the lower lift. Many landfills are depositories of a combination of concrete, asphalt and concrete pipe rubble from reconstruction projects. Researchers need to determine if this material can be mixed and made durable enough for a bottom lift.

4. Characteristics of each lift to provide compatibility and increase construction ability and performance of each lift such as skid, durability, and strength.

5. Joint spacing, formation, and reinforcement requirements and placement in the two-lift design.

6. If limits exist for variability of the coefficient of thermal expansion between lifts before lift debonding would occur.

7. If there is an application for roller compacted concrete (RCC) in the lower lift.

Demonstration Projects

The following demonstrations would promote two-lift paving:

1. If the industry can build a higher flexural strength in a top lift with the same aggregates, then most of the issues of using two plants can be eliminated. The concrete industry can then optimize its most expensive component, cement, to build a concrete roadway to withstand the effects of studded tire wear.

2. Use of the local ready-mix operations to build two different mixes for a two-lift paving operation. Local ready-mix plants are accustomed to handling different

mixes on a regular basis and have many different aggregate bins available to accommodate many types of aggregate products.

3. Use of a ready-mix operation for one lift and a paving batch plant for the other lift. This would allow the use of a belt placer for the bottom lift and a slip-form paver for the second lift. To reduce costs, delays, and opportunities for errors, loaded trucks would travel in both directions and the belts would be on opposite sides of the roadway for delivery.

4. Construct a project in a very congested location where the public demands that the roadway stay open during reconstruction efforts. These types of projects are sensitive to local politics and are not subject to the normal high production requirements of rural interstate reconstruction efforts. This project could investigate the idea of pumping concrete from an overhead bridge down to a major interstate roadway. This would remove the competition between construction trucks and the traveling public for valuable roadway space. This test section pavement would have to be placed in forms which would allow as much of the roadway as possible to remain open for the traveling public. The final surface texture could be applied with current diamond grinding techniques such as the “White Velvet” approach used in Missouri and New York.

5. Promote a plant with enough bins to provide different types of aggregates and build different mixes to produce the required characteristics of the surface and base materials.

6. Construct a two-lift pavement on a local, rural road when the existing composite pavement is recycled at the location. Cement and high volume fly ash would be used for the lower lift (possibly RCC) and high quality concrete would be used for the top lift. Different designs for the top lift could be used as trial sections, some with non-polishing aggregates and used for an exposed aggregate surface. Other sections may use steel fibers and different, longer joint spacing.

Two-lift paving is feasible and could be used to meet emerging needs in the surface characteristics area. By encouraging the use of two-lift paving in these special situations, the industry will have expertise in this area available in some locations when aggregates become so scarce that two-lift paving becomes a viable economic option, or for when other factors make two-lift paving an attractive option.

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Appendix: Two-Lift Paving Database

Record Number	Facility	Agency	State	Highway	Beginning milepost	Ending milepost	Contractor	Year	Thickness of lower lift	Aggregate in lower lift	Thickness of upper lift	Aggregate in upper lift
1	Street	Duluth, Mn	MN	6th & 7th St.				1910–11	5"	Local gravel	2"	Granite
2	Street	Grand Forks, ND	ND					1915	5"	Local gravel	2"	Granite
3	Street	Madison	WIS					1915		Dolomite limestone	2"	Quartzite
4	Street	Sheboygan	WIS					1915		Limestone	2"	Granite
5	Highway	Kansas DOT	KS	K-96	Station 402+10	Station 366+30	Wittwer Paving Inc.	1997	7"	Recycled asphalt 15%	3"	Limestone
6	Highway	Kansas DOT	KS	K-96	Stattion 333+30	Station 312+65	Wittwer Paving Inc.	1997	7"	High absorption limestone	3"	Rhyolite
7	Highway	Kansas DOT	KS	K-96	Station 289+05	Station 248+90	Wittwer Paving Inc.	1997	7"	Limestone & pea gravel	3"	Limestone & pea gravel
8	Highway	Florida DOT	FL	US 41	12,600 feet			1977	9"	Limestone	3"	Limestone
9	Highway	Florida DOT	FL	US 41	4,000 feet			1977	9"	Limestone	3"	Limestone
10	Highway	Iowa DOT	IA	US 75	Lyon County	Near Rock Rapids, IA	Irving F. Jensen	1976	7"	Recycled concrete & asphalt	3"	Gravel
11	Highway	Michigan DOT	MI	I-75	NB from Warren Ave Exit	to Picquette Avenue	Ajax Construction	1993	7.5"		2.5"	100% crushed basalt

Record Number	Width of construction	Steel in pavement	Load transfer	Panel size	Traffic ADT of overlay during construction	HCADT of overlay	Cement/cubic yard	Fly ash/ cubic yard	W/C Ratio	Joint sealant	Condition pavement rating of overlay (mm/km)	Performance
1	32'	None	None		1,500 ADT	2%				Asphalt		Still in service
2	32'	None	None		1,500 ADT	2%				Asphalt		Still in service
3		Mesh	None							Asphalt		Still in service
4		Mesh	None									Still in service
5	24'	None	Yes	15'	4,800 ADT	11%	564		0.45	Neoprene	178	
6	24'	None	Yes	15'	4,800 ADT	11%	451	113	0.45	Neoprene	178	
7	24'	None	Yes	15'	4,800 ADT	11%	564		0.45 & 0.39 in upper lift	Neoprene	166	
8	24'	None	None	15'	11,000 ADT	12%				Neoprene	186	Has experienced faulting
9	24'	None	Yes	20'	11,000 ADT	12%				Neoprene		Excellent, no faulting
10	24'	None	Yes				564 (upper lift), 470 (lower lift)					
11	36'	Yes	None	15'			752		0.40 (top layer), 0.42 (bottom layer)	Ethylene propylene diene terpolymer (EPDM) seal	IRI # of 80 inches/mile	

Record Number	Paving equipment	Two-lift materials (strength or requirments)	Remarks 1	Remarks 2	Remarks 3
1	Forms				
2	Forms				
3	Forms				
4	Forms				
5	Slip-formed	4000 psi	30 minutes was given between placement of the bottom lift and the top lift to ensure that the bottom lift was stiff enough to resist mixing with the top lift.		
6	Slip-formed	4000 psi	Due to the reactive Rhyolite aggregate in the top lift, fly ash was used to mitigate expansion problems.	This pozzalon was a product developed by Ash Grove Cement Company.	This was a calcined natural clay pozzolan called Dura-Poz.
7	Slip-formed	4000 psi	This section was designed with a lower W/C for the top lift.	This section used the same aggregate for both lifts.	
8	Slip-formed		The lower 9" was designed to develop a flexural strength of 322–419 psi.	The top lift was designed for a flexural strength of 524–755 psi	The contractor waited about 30–60 minutes before placing the second lift, which allowed the sheen to leave the base course.
9	Slip-formed		The lower 9" was designed to develop a flexural strength of 322–419 psi.	The top lift was designed for a flexural strength of 524–755 psi	The contractor waited about 30–60 minutes before placing the second lift, which allowed the sheen to leave the base course.
10	Slip-formed		Air entrainment agent was not neccesary with the lower combined PC/AC aggregate	Consistent air was difficult to maintain	
11	Slip-formed		This section did not reduce the noise as expected		