Special Attachment No. 1

PROPOSAL

to

MIDWEST STATES ACCELERATED PAVEMENT TESTING POOLED FUNDS PROGRAM

for

THIN BONDED RIGID OVERLAY ON PCC AND HMA PAVEMENTS

(ATL EXPERIMENT NO. 13)

Period of Performance: 09/01/03 - 08/31/04
Project Monitor: ***Andrew J. Gisi, P.E.***
Funds Requested: $269,973

from

Kansas State University
Fairchild Hall, Room No. 2
Manhattan, KS 66506-1103.

Project Personnel:

Stefan A. Romanoschi, Ph.D.,P.E.
Mustaque Hossain, Ph.D., P.E.
Department of Civil Engineering
Kansas State University
Manhattan, KS 66506-2905.

APPROVALS:

Stefan A. Romanoschi
Principal Investigator

Paul R. Lowe
Assistant Vice Provost for Research

ABSTRACT

This document presents the proposed test plan for the full-scale accelerated pavement test, ATL Experiment No. 13, to be conducted at the Civil Infrastructure Systems Laboratory of Kansas State University during Fiscal Year 2004. The experiment was selected by the Technical Committee overseeing the Midwest States Accelerated Pavement Testing Pooled Funds Program. This program is administered by the Kansas Department of Transportation (KDOT) and is supported by the States of Iowa, Kansas, Missouri and Nebraska. The purpose of this proposed experiment is to evaluate the performance of thin bonded rigid overlays on existing Portland cement concrete (PCC) and Hot-Mix Asphalt (HMA) pavements.

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INTRODUCTION

Despite fifty years of experience accumulated in the U.S. with the construction of Portland Cement Concrete (PCC) overlays on existing distressed rigid and flexible pavements, research is needed to determine optimum construction and design procedures for these overlays. Two major PCC overlay types that are used to rehabilitate distressed PCC pavements are bonded and unbonded overlays. Unbonded overlays are effectively used to strengthen highly distressed Jointed Plain Concrete Pavement (JPCP) and Continuously Reinforced Concrete Pavements (CRCP). These overlays are designed based on the assumption that no bond exists between the overlay and the underlying existing pavement. Figure 1 shows the schematic of an unbounded overlay. Bonded overlays are used when the underlying rigid pavement does not exhibit severe structural distresses and are designed on the assumption that the overlay and the underlying concrete slab are fully bonded and form a monolithic layer. Thus, bonded overlays are typically thinner than the unbonded overlays. Figure 2 illustrates the schematic of an unbonded PCC overlay.

The technology of rehabilitating distressed hot-mix asphalt (HMA) pavements using a PCC overlay is called "whitetopping." Conventional whitetopping has a thickness between 4 to 12 inches (100 to 305 mm) and has traditionally been designed based on the assumption that no bond exists between the PCC overlay and the distressed HMA layer. The PCC overlay is designed as a new rigid pavement, with the HMA layer assumed to be a base layer with high stiffness underneath the concrete slab as shown in Figure 3. The composite stiffness/support capacity of the existing pavement and the underlying subgrade is used to compute the design thickness of the PCC overlay. However, despite design assumption of no bond between the PCC overlay and the existing HMA layer, some partial bonding may occur, which can contribute to the performance of the overlaid pavement (Smith et al. 2002)

A more recent but increasingly popular technology is the ultra-thin whitetopping (UTW), where the thickness of the PCC overlay is between 2 and 4 inches (50 – 100 mm). UTW is used on structurally sound asphalt pavements that exhibit mainly surface rutting. The overlay thickness is designed based on the assumption that the PCC overlay bonds well to the distressed HMA layer. Milling of the distressed HMA layer is normally done to ensure a good bond. The use of UTW is relatively new but has grown rapidly in the last decade, with over 200 projects built in 35 states since 1992 (Smith et al. 2002).

More recently, a new class of whitetopping, called thin whitetopping, has been used primarily on state highways. The thickness of this PCC overlay ranges from 4 and 8 inches (100 -200 mm) and joint spacing between 6 and 12 ft (1.8 – 3.6 m) are used. The overlay is designed assuming bonding between the existing HMA pavements and the new overlay (Tarr et al. 1998; Wu and Sheehan 2002; Transtec 2003). This assumption minimizes the need for additional thickness (Transtec 2003).

The proposed study aims to evaluate the performance of thin bonded PCC overlays on existing PCC and HMA pavements through accelerated pavement testing. The advantage of using accelerated pavement test when compared to a field test is that the results of the

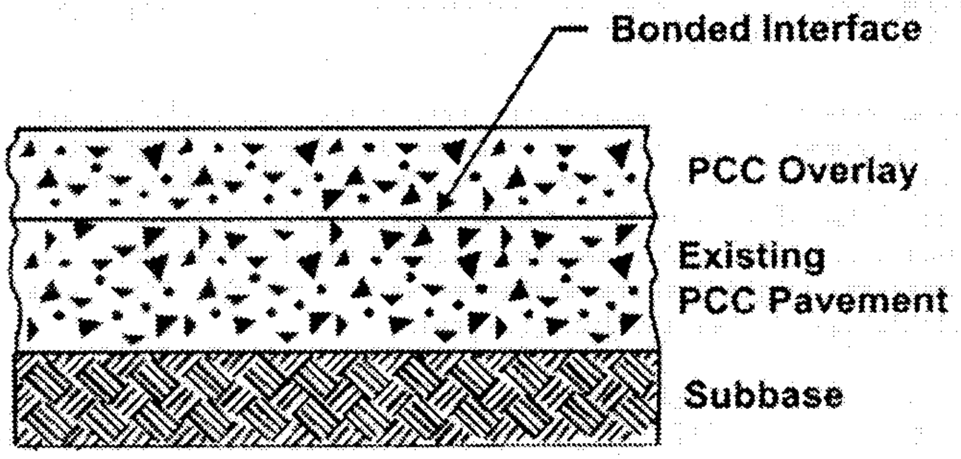


Figure 1 Bonded PCC overlay

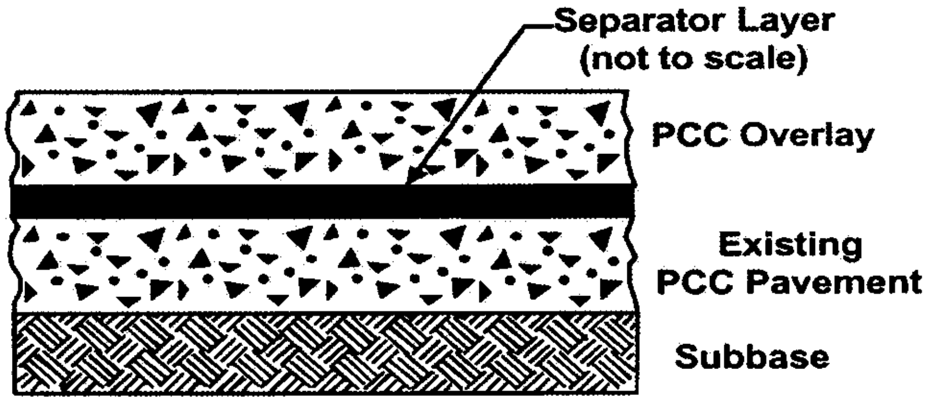


Figure 2 Unbonded PCC overlay

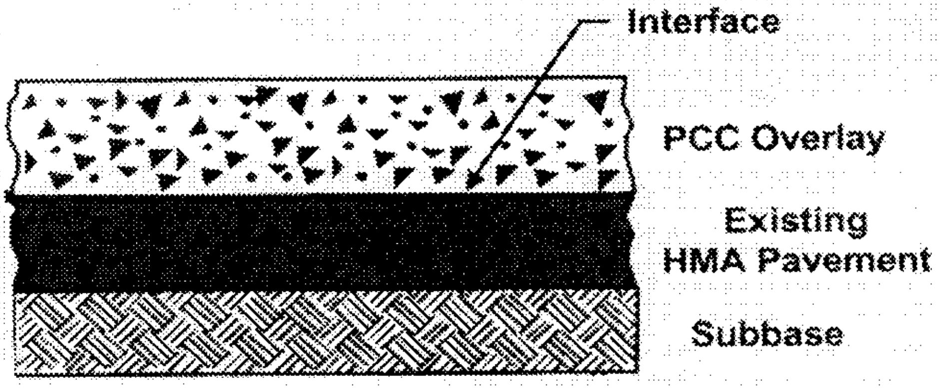


Figure 3 Whitetopping- PCC ovrelay of HMA pavements

comparative study can be obtained in a few months. In a field test, the results are obtained after observing the behavior of the road test sections for a five-year period as a minimum. Also, on a field test section, some of the environmental factors and traffic loadings cannot be controlled. The proposed study will be conducted at the Civil Infrastructure Systems Laboratory (CISL) of Kansas State University.

II BACKGROUND

a. Accelerated Testing Laboratory (ATL)

The Department of Civil Engineering at Kansas State University, in cooperation with KDOT, has developed the Accelerated Testing Laboratory (ATL) (Melhem 1997). The facility allows full-scale accelerated tests on pavement structures using the ATL machine as the loading device. The loading device is placed on a full-scale road structure constructed in a pit. A full-size truck axle passes over the pavement at about every five seconds, applying a total single or tandem axle load between 18,000 to 36,000 lbs (9 and 18 kN) depending upon axle type. The system relies on an air bag suspension placed between the axle and a metallic reaction frame in which the air pressure can be automatically controlled. When the air is compressed in the airbag, the generated reaction force between the frame and the suspension is transmitted to the pavement. Both single and dual tires, single and tandem axles can be accommodated in this system. A detailed description of the facility was given by Melhem (1997).

The major benefit of the tests developed at ATL is that the performance of road materials and structures can be evaluated at a reduced cost and in a short period of time, since the cumulative traffic passing on an in-service road section in ten years will be applied here only in several months. The ATL facility allows control and monitoring of the temperature at the surface and in the pavement layers. This assures that the pavement materials and structures are subjected to identical load and environmental conditions.

b. Thin Bonded Overlays on PCC Pavements

Bonded PCC overlays are typically 3 to 6 in (75 to 150 mm) concrete overlays bonded to the existing rigid pavement to function as a monolithic layer. Their purpose is to increase the structural capacity and/or to improve the ride quality of existing PCC pavements. Bonded overlays are an effective rehabilitation strategy for rigid pavements that are in good condition, but are in need of structural capacity enhancements. Typically the extra structural capacity is needed by an unexpected increase in traffic level or by signs of structural deficiency (e.g. corner cracks, transverse cracking). These overlays should not be used on severely distressed pavements, pavements with severe "D" cracking or reactive aggregate problems. Bonded overlays are typically used to correct functional deficiencies, such as, surface roughness, insufficient surface friction or a pavement surface that is excessively noisy.

The construction of bonded overlays requires the following operations:

- Pre-overlay repairs;

- cold milling or shot blasting of the existing pavement to produce a rough surface for bonding to take place;
- air, water, shotblasting or sand blasting of the milled surface to obtain a clean surface;
- optional placement of a bonding agent;
- placing, finishing and curing of the PCC overlay;
- sawing of joints in the overlay to overlap the joints in the existing pavement.

Bonded overlays have provided good performance on many projects and have been shown to an effective way of improving the structural capacity of existing rigid overlays (Zollinger et al. 2001). The condition for a successful rehabilitation is that the rigid pavements must be in an acceptable condition before the bonded overlay is placed. Otherwise, there is a high potential that the unrepaired, working cracks in the old pavement will reflect through the overlay. Therefore, the pre-overlay repairs are necessary to achieve long life for the of the bonded PCC overlay. The pre-overlay repairs may consist of replacing shattered slabs, cross-stitching of cracks in the wheelpath and placing of crack control cages.

Achievement of an adequate bond between the overlay and the underlying pavement is essential for a good performance of the overlay, since the design of these overlays is based on the assumption that the existing concrete slab and the overlay form a monolithic slab. Debonding can lead to rapid deterioration of bonded overlays, mainly due to the construction method used, the climatic condition during construction or the bonding agent (Zollinger et al. 2001). The HIPERPAV program developed by McCullough and Rasmussen (1999) predicts the interface bond stresses and strengths during the first 72 hours after the PCC placement function of the PCC mix composition and the climatic conditions during construction.

Past experience has not clearly indicated the best bonding method to be used. Research conducted in Texas showed that the spraying of cement grout right before placement of the overlay may not increase the performance of the overlay. It was also found that better interface shear strength may be achieved when shotblasting is used instead of milling during surface removal, as shown in Figure 4. Similar conclusions were reached by Rowden (1996) after conducting an extensive field and laboratory study on thin bonded concrete overlays in Illinois. Rowden (1996) found that the surface preparation is essential for obtaining a good overlay, that the bond strength of the overlay did not vary significantly either with or without the grout, and that placement of grout was cumbersome and slowed down the paving process. A typical cement grout for this application consists of a mix of water and cement in a ratio by weight between 0.55 and 0.62. The grout is placed on the dry surface, right in front of the slipform paver, before the concrete mix is placed. In a 2000 bonded PCC overlay project on US-54 in Kansas, the surface was milled and then sand blasted. No grout was used nor the surface was wetted prior to placing the PCC overlay. The performance of this project has not been satisfactory (Barezinsky 2003).

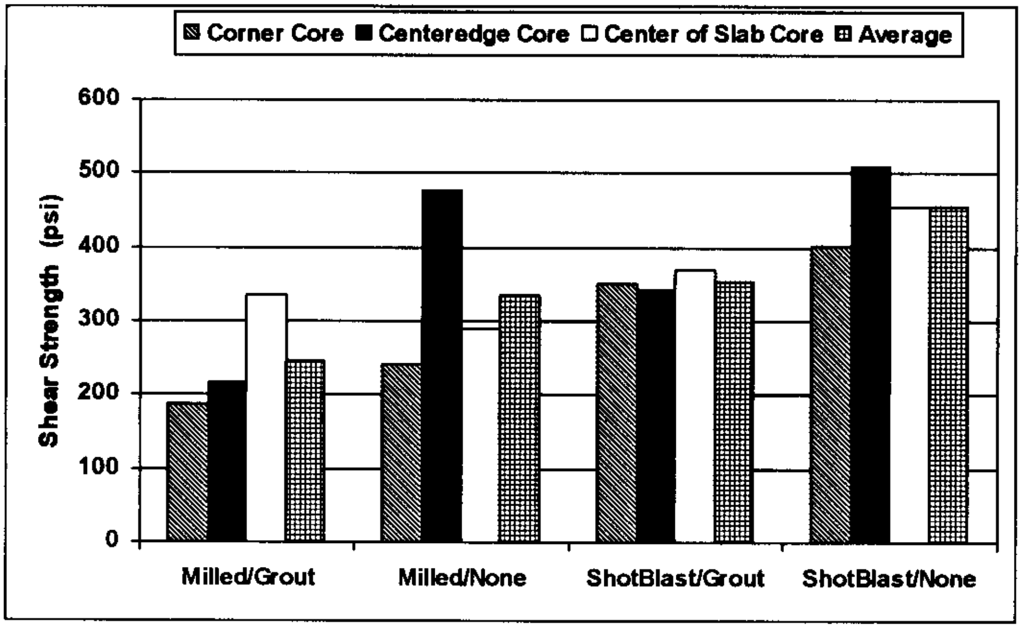


Figure 4 Comparative performance of interface shear strength for several surface preparation methods (Smith et al. 2002)

c. *Thin Whitetopping*

As mentioned earlier, the overlay thickness for this class of whitetopping ranges from 4 to 8 inches (100 to 200 mm). The general design considerations are: (a) existing pavement condition, (b) Overaly pavement type, and (c) Preoveraly repair (Smith et al. 2002). In general, whitetopping overlays are most appropriate for HMA pavements that are extensively deteriorated such as, with excessive rutting, shoving, or alligator cracking. The most common whitetopping overlay type is JPCP. Preoverlay repair of the existing HMA pavements for thin whitetopping should ensure that uniform support is provided for the PCC surface. ACPA (1998) has provided guidelines for preoverlay repairs of conventional whitetopping shown in Table 1.

Three surface preparation methods are commonly used for whitetopping: (a) direct placement, (b) milling and (c) placement of leveling course. Direct placement has been used extensively by the Iowa counties. However, milling has been found to increase the interface shear strength (Tarr et. al 1998).

The thickness design procedure for thin white topping had been based on the new PCC pavement design with the existing HMA pavement as a stabilized base. Thus existing design procedures for new pavements, such as, the 1993 AASHTO Design Guide or the 1998 Supplemental procedure could be used. ACPA (1998) also provided simple design charts for selecting PCC overlay thickness for whitetopping. Most recently Colorado DOT has

Table 1 Guidelines for whitetopping preoveraly repair (ACPA 1998)

General Pavement Condition	Recommended Repair*
Rutting (< 50 mm [2 in])	None or milling**
Rutting (≥ 50 mm [2 in])	Milling or leveling
Shoving	Milling
Potholes	Fill with crushed stone cold mix or hot mix
Subgrade failure	Remove and replace or repair
Alligator cracking	None
Block cracking	None
Transverse cracking	None
Longitudinal cracking	None
Raveling	None
Bleeding	None

*Other factors to consider: adding edgedrains; costs of direct placement vs. milling or leveling.

** Consider increasing the joint sawing depth.

developed a mechanistic design procedure based on field instrumentation and observation of several thin whitetopping projects in Colorado (Tarr et al. 2000). Currently, TransTec Group is also developing a new procedure for designing whitetopping overlays (Rasmussen et al. 2002).

ACPA (1998) recommends that satisfactory whitetopping design should consider three factors: (1) Quality concrete considering both strength and durability, (2) Adequate slab thickness to limit the load stresses, and (3) Joint design that will control unwanted cracking and provide adequate load transfer.

ACPA (1998) recommends concrete with 28-day compressive strength of 4,000 psi (30 MPa). For structural design, the recommended methodology considers supporting strength of the existing asphalt pavement, flexural strength of the concrete, design period and traffic. The other features in design are joint spacing to control cracking and load transfer across the joints. Tables 2 and 3 show the ACPA recommended joint spacing and dowel bar sizes and spacing. The maximum joint spacing recommended for conventional whitetopping constructed as JPCP is 21 times the slab thickness (in inches). However, a Colorado study has found that the effects of different joint spacing are not significant (Tarr et al. 1998). This observation is currently being revisited in another study (Wu and Sheehan 2002).

In the design of conventional whittopping overlays, the effects of any bonding between the PCC overlay and the underlying HMA layers are typically ignored. However, past research has shown that some degree of bonding does occur between the two layers. Recent

Table 2 ACPA Recommended Joint Spacing (ACPA 1998)

Slab thickness, mm (in.)	Maximum joint spacing,[1] m (ft)
100 (4)	2.1 (7)
150 (6)	3.2 (10.5)
200 (8)	4.3 (14)
250 (10)	5.3 (17.5)
300 (12)	6.4 (21)
350 or more (14 or more)	7.6 (25)

[1] Joint spacing may also be based on local experience for pavements that have provided good service.

Table 3 ACPA Recommended Dowel Bar Size and Spacing (ACPA 1998)

Slab thickness, mm (in.)	Dowel diameter, mm (in.)	Dowel length, mm (in.)	Dowel spacing mm (in.)
Plain (unreinforced) pavements			
<200 (<8)	Dowels not required		
200 (8)	32 (1.25)	450 (18)	300 (12)
225 (9)	32 (1.25)	450 (18)	300 (12)
250 (10)	32 (1.25)	450 (18)	300 (12)
280 (11)	38 (1.50)	450 (18)	300 (12)
300 (12)	38 (1.50)	450 (18)	300 (12)
350 (14)	44 (1.75)	500 (20)	380 (12)
400 (16)	50 (2.00)	600 (24)	450 (18)
Reinforced pavements			
150 (6)	20 (0.75)	350 (14)	300 (12)
175 (7)	25 (1.00)	400 (16)	300 (12)
≥200 (≥8)	Same dowel size and spacing as above		

design methodology for thin whitetopping developed by Colorado takes this into account (Tarr et al. 2000).

The issue of the bond between the two layers also brings into picture the method of surface preparation. A study in Iowa found that tack coat may reduce the bond (Grove et al. 1993). Milling and air blasting generally produced enhanced bond. Also, cement and water grout demonstrated no significant advantage in bond strength. A study in Colorado showed that milling significantly enhanced interlayer bond over surface with no special preparation (Tarr et al. 1998). The degradation of this interface bond is intuitively expected due to environmental factors (curling, shrinkage and moisture damage of the HMA layer) and associated normal loading from the traffic. However, in the Colorado study the bond strength was found to increase after one year as shown in Table 4 (Tarr et al. 1998). The increase is higher for the thin whitetopped pavement where milling was used in surface preparation. There is one possible explanation for

Table 5 Interface Shear Strength at the Colorado Experimental Sections (Tarr et al. 1998)

Site	Test Slab	Longitudinal Joint Spacing, in.	Transverse Joint Spacing, in.	AC Surface Condition	28 Day Interface Shear Strength, psi	365 Day Interface Shear Strength, psi
Santa Fe	1	60	60	New	45	80
	2	60	60	New	30	60
	3	60	60	New Milled	10	80
Longmont	1	72	72	Existing	100	****
	2	120	144	New	60	105
	3	72	72	New	70	105
	4	72	144	Existing Milled	65	100
	5	144	144	Existing Milled	****	155
Lamar	B	144	120	Existing Milled	80	****
	E	72	72	Existing Milled	90	****
	F	72	72	Existing Milled	110	****

this: a coefficient of thermal expansion of 5 to 6 x $10^{-6}/^{\circ}F$ (9 to 10.8 x $10^{-6}/^{\circ}C$) is often assumed for the Portland cement concrete (Huang 1993). These values for asphalt concrete have been found to be 1.2 to 1.4 x $10^{-5}/^{\circ}F$ (2.0 x $10^{-5}/^{\circ}C$) (Monishmith 1985). Although the values for HMA and PCC are quite dissimilar, the expansion and/or contraction in the HMA layer probably roughly equals that of the PCC overlay due to lower temperature gradient. In fact, Tarr et al. (1998) observed that slab upward warping effects due to moisture differentials (surface drier than the bottom) were greater than measured downward temperature curling effects. However, stripping would be a very detrimental factor as was evident on a conventional whitetopping project on I-70 in Kansas (Gisi 1985; Gisi 2003). In thin whitetopped pavement, stripping could happen due to the saturated interface of the two layers in presence of a significant thermal gradient and loading due to the traffic.

Another important factor is the existing HMA pavement thickness and properties. A minimum HMA thickness of 2 in (50 mm) (after any milling) has been recommended for conventional whitetopping overlays by Grogg et al (2001). However, Tarr et al. recommends a minimum HMA layer thickness of 5 inches (127 mm) for thin whitetopping overlays. A miinimum subgrade modulus of reaction (k) value of 150 pci is also recommended by them for thin whitetopping projects.

OBJECTIVES

The objectives of this research are:

- to construct and evaluate thin PCC overlays on existing PCC and HMA pavements;
- to determine the parameters that effect the performance of these sections;
- to develop design input parameters and to modify/ enhance the existing design procedure (s) for thin PCC overlays.

The objectives will be accomplished by conducting a full-scale accelerated pavement test at the Civil Infrastructure Systems Laboratory on thin PCC overlays on existing PCC and HMA pavements.

BENEFITS

The results of this research will lead to improved practices related to the design and construction of thin bonded concrete overlays on distressed PCCP and HMA pavements. This will finally lead to the optimized use and design of bonded concrete overlay technology and extended life of flexible and rigid pavements rehabilitated with this method.

Data collected during this experiment will be analyzed and the analysis results will be made available to the four state agencies involved in this project for implementation. The findings of this experiment will be summarized in scientific journal publications and presentations delivered at scientific conferences and meetings with specialists and practitioners in the field of highway engineering.

V WORK PLAN

The time line of the work plan for this research project is presented in Table 6. Individual tasks are discussed below.

Table 6 Time line for the work plan

TASK	Schedule
1	September 1, 2003 - October 31, 2003
2	November 1, 2003 - December 15, 2003
3	November 1, 2003 - December 31, 2003
4	January 1, 2004 - June 15, 2004
5	January 1, 2003 - June 15, 2004
6	March 15,2004 - August 1, 2004
7	June 15, 2004 - August 31, 2004

Task 1: Experiment Preparation

The literature related to design, construction and performance of thin bonded PCC overlay and thin whitetopping will be thoroughly reviewed. Special consideration will be given to the methods used for surface preparation before PCC overlays are placed and to the methods for assuring the bond between the overlay and the distressed pavement (cement wash, grout, etc.). The States and agencies experienced in these techniques will be contacted for further consultation on the design and performance aspects. Relevant four-state practices will also be reviewed.

A major component of the experimental design will be the instrumentation to capture the critical responses. Although a preliminary instrumentation plan is being proposed in this document, further refinement to this plan will be made based on the investigation to be done in this task. After finalizing the instrumentation plan, all sensors will be fabricated and/or purchased and tested to make sure they are in proper working condition.

Task 2: Construction of the Pavement Sections

This task will include construction of four test lanes at CISL. Two pavements will be constructed for this experiment:

a. A 6" PCCP slab will be constructed over a 4" treated dense graded subbase (KDOT PCTB or equivalent) in the North pit. A middle 10 ft long and 12 ft wide slab will be tied with dowelled joint to 5 ft long and 12 ft wide end slabs. The joint will be formed by sawing at least one-third of the PCCP thickness. Careful attention will be paid to curing of the PCTB layer so that it does not show any shrinkage cracking. The dowel size in the joints will be 1.0" in diameter and 18 inch in length. The dowels will be spaced at one foot intervals.

The slab will be built 6" deep in the pit and will be loaded at the joint by the pulse loading system at ATL. The drop weight device will be used to monitor the load transfer efficiency of the joint. The loading will be stopped when the joint load transfer efficiency falls below 70%. Some mid-slab loadings will also be applied to weaken the slab. Some degradation of the mid-slab concrete modulus will be ensured through loading and will be monitored by the PCC modulus backcalculated from the deflections measured with the weight-drop device.

Rigid (PCC) overlay (6") will be then be placed. Before overlaying, the surface of the existing PCCP will be shot blasted, cleaned with a broom, followed by an application of a bonding material. The bonding material (cement wash, grout, or no-grout) will be selected in consultation with the Project Monitor, after the literature review in Task 1 will be performed. Transverse joints will be cut in the rigid overlay; they will match the joints in the original slab. The concrete mixture will be air entrained (4 ± 1%) with a 28-day compressive strength of 4,000 psi (30 MPa). Curing will be continued for at least 28 days with water ponding.

Moisture will be periodically sprayed on the constructed and cured overlay to induce saturation of subgrade and base layers. Periodic freezing and thawing will be applied to induce contraction and expansion of the slab during loading.

b. The thin whitetopping pavement will be constructed as 14 ft wide and 20 ft long. The HMA pavement will be sawed in the middle to have two 7' x 20' sections. A 9" HMA pavement over compacted soil subgrade will be constructed in the northern half of the South pit where as the HMA on the southern half of the South pit will be 11" thick. The pavement sections will be loaded with a 22-kip single axle for a sufficient number of repetitions to cause at least ½ in. surface rutting. The surface of the HMA pavement will be heated so that the temperature in the middle of the HMA layer will be 100°F.

The sections will then be milled and broomed. The milling depth on the northern half of the South pit will be four inches and that on the southern half will be six inches, such that the remaining HMA base after milling will be five inches thick for both sections. If, after milling, the HMA layer shows no visible deterioration, attempts will be made to cracks the layer by using the ATL thumping system or by making longitudinal and transverse sawcuts in the HMA layer.

Then four and six inch PCC overlays will be placed on the existing HMA layers. A longitudinal spacer board will be placed to separate the two sections. The surface of the HMA will be wetted during overlay placement. The concrete mixture will be air entrained (4 ± 1%) with a 28-day compressive strength of 4,000psi (30MPa). Curing will be continued for at least 28 days with water ponding.

No dowels will be used on the whitetopping sections. It is to be noted that the maximum ACPA recommended joint spacing for this section would be 21 x 4 = 84 inches (7 ft). Previous experience at ATL has shown that if the 20 ft long section with 4" PCC overlay is sawn in the middle, a transverse crack appears in the section. Thus, on this section, there will be two joints at approximately 6.66 ft (= 20ft /3) intervals.

During loading on this section, water will also be sprayed so that the interface of the HMA and the PCC overlay layer will be saturated. The moisture is expected to degrade the bond at the interface.

Before construction, the pavement sections tested in Experiment No. 12 will be removed. New soil will be placed in the pits and compacted. The moisture of the new soil will be controlled to be close to the optimum value.

The instrumentation for monitoring pavement response will be installed in the lanes during construction. The proposed instrumentation consists of strain gages, thermocouples and soil moisture gages. A detailed description of the type and location of each sensor is given in the pavement monitoring section.

Laboratory tests will be performed at the Bituminous Materials, Soil, Concrete and Mechanics of Materials laboratories at the KSU Civil Engineering Department on the material samples taken from the construction site as well as on the laboratory-prepared specimens. The material characteristics to be measured on the samples include:

- Asphalt concrete: density, resilient modulus, creep, and rutting properties.
- Stabilized soil: plasticity and unconfined compression strength at 28 days.
- Subgrade soil: plasticity and gradation.
- Portland cement concrete: Compressive strength, flexural strength, and modulus of elasticity, fatigue, slump and air content.

- Task 3: Design and Construction of the Single Axle Bogie

Currently, a double axle bogie is used to apply the axle load to the pavement. To generate enough damage to the pavements under test, a tandem axle load of 30-34 kips is applied by adjusting the pressure in the hydraulic system. At this high load, the ATL machine exhibits fast wearing and the circulation of hydraulic fluid is not fast enough to compensate adequately for the irregularities of the pavement surface under test.

The research team proposes replacement of the tandem axle bogie with a single axle bogie. If a single axle load of 20 to 24 kips is used, damage similar, if not greater, to the tandem axle is expected. This change will greatly reduce the wearing of the ATL load assembly. Thus, this modification will reduce the possibility of malfunctioning and down time of the ATL machine, as well as the costs of machine maintenance and repair.

Currently, the use of a single axle load is done by lifting the front axle of the tandem axle load assembly. Measurements of the wheel loads and stresses in the pavements under test, as well as the observation of the movements of the load assembly during loading revealed that the tandem axle load assembly in this mode becomes unbalanced. Therefore, the axle loads depending on whether the load assembly travels East or West, may differ of up to 2,000 lbs. The research team believes that, with the current tandem axle configuration, it is not possible to apply an adequate, uniform single axle load.

The proposed single axle bogie will be designed and constructed by Daptech, Inc. Mr. Dennis Pauls, President of Daptech, collaborated in the design and construction of the original ATL machine and in all subsequent modifications and improvements. Daptech also has presented a proposed outline for the required modifications to the ATL machine.

According to a preliminary estimate of Daptech, no more than two weeks will be necessary for the installation of the single axle bogie. The bogie will be installed in about four weeks after construction of the pavement test sections is finished. At that time the concrete will be cured. Thus, the proposed modifications to the machine will not affect the progress of this experiment. Equipment usage funds from this experiment will be used for modifying the ATL load assembly. The single axle bogie change will be permanent.

Task 4: Full-Scale Accelerated Pavement Testing

After construction, the lanes will be tested under the full-scale truck loading provided by the ATL loading frame. The lateral position of the ATL load assembly will be changed automatically. Bi-directional trafficking is recommended, since the testing time is half of that required for unidirectional trafficking.

It is proposed that a 22,000 lb (100 kN) single axle load and a tire inflation pressure of 100 psi (690 kPa) will be used in this experiment. The axle load and tire pressure will be kept the same during the entire duration of the experiment. The lateral position of the ATL machine will be changed during testing such that it will follow a normal distribution. Loading will be continued till the appearance and rapid progression of any visible distresses (such as, cracking, faulting, etc.) or at the discretion of the Chair of the Technical Advisory (in consultation with the project investigators).

The North pit PCCP with PCC overlay will be subjected to high moisture levels in the soil subgrade by periodical spraying of water at the pavement surface. It is expected that the moisture, will all contribute to the gradual degradation of the bond between the PCC overlay and the existing PCCP. This is necessary since previous experience has shown that debonding happens typically before the structural capacity of the whole section gets exhausted.

During testing, the South pit HMA sections with PCC overlays will also be subjected to saturated subgrade. The moisture may also induce stripping of the HMA layer and/or loss of bond between the existing HMA pavement and PCC overlay.

Task 5: Pavement Monitoring

The condition of the pavement as well as strains in the tested pavement structures will be monitored during the entire duration of the experiment. Longitudinal and curled profiles will be measured on the test lanes at every 25,000 cycles of the ATL machine. Longitudinal profile measurements will be made on each lane to determine the evolution of roughness with the accumulated traffic. After surface cracks are first observed, crack mapping will be performed simultaneously with the profile measurements. The cracking extent and severity will be determined from the mapped data.

The Weight Drop NDT device will be used to perform surface deflection tests at every 25,000 cycles of the ATL loading. The deflection data will be used to backcalculate the elastic layer moduli to determine the degradation of the materials with the accumulated traffic.

Strain measurements under the passing axle will be performed at 0, 5,000 cycles, and then at every 100,000 cycles of the ATL axle. The proposed locations of the strain gages and pressure cells are presented in Figures 5 and 6. The same configuration (9 strain gauges, 4 temperature sensors and 2 TDR gauges) will be used for all lanes. Moisture and temperature data will be monitored periodically. The strain gages will be put at the HMA/PCC overlay interact on top of the HMA pavement, one inch into the PCC overlay above the HMA/PCC layer and one inch from the top of the PCC layer. The strain gages at the interface and one inch above the interface will detect any slip happening at the interface, and the strain gage one inch from the top of the PCC overlay will detect any critical strain causing top-down cracking.

Falling Weight Deflectometer tests will be conducted by the KDOT crew. The tests will be scheduled in consultation with the KSU-CISL research team. The FWD tests will be performed on four test lanes as follows:

- After construction of the lanes
- After milling on the HMA pavements and shot blasting the existing PCC
- After 5,000 loading cycles
- After 100,000 loading cycles
- After loading is completed on each pair of lanes.

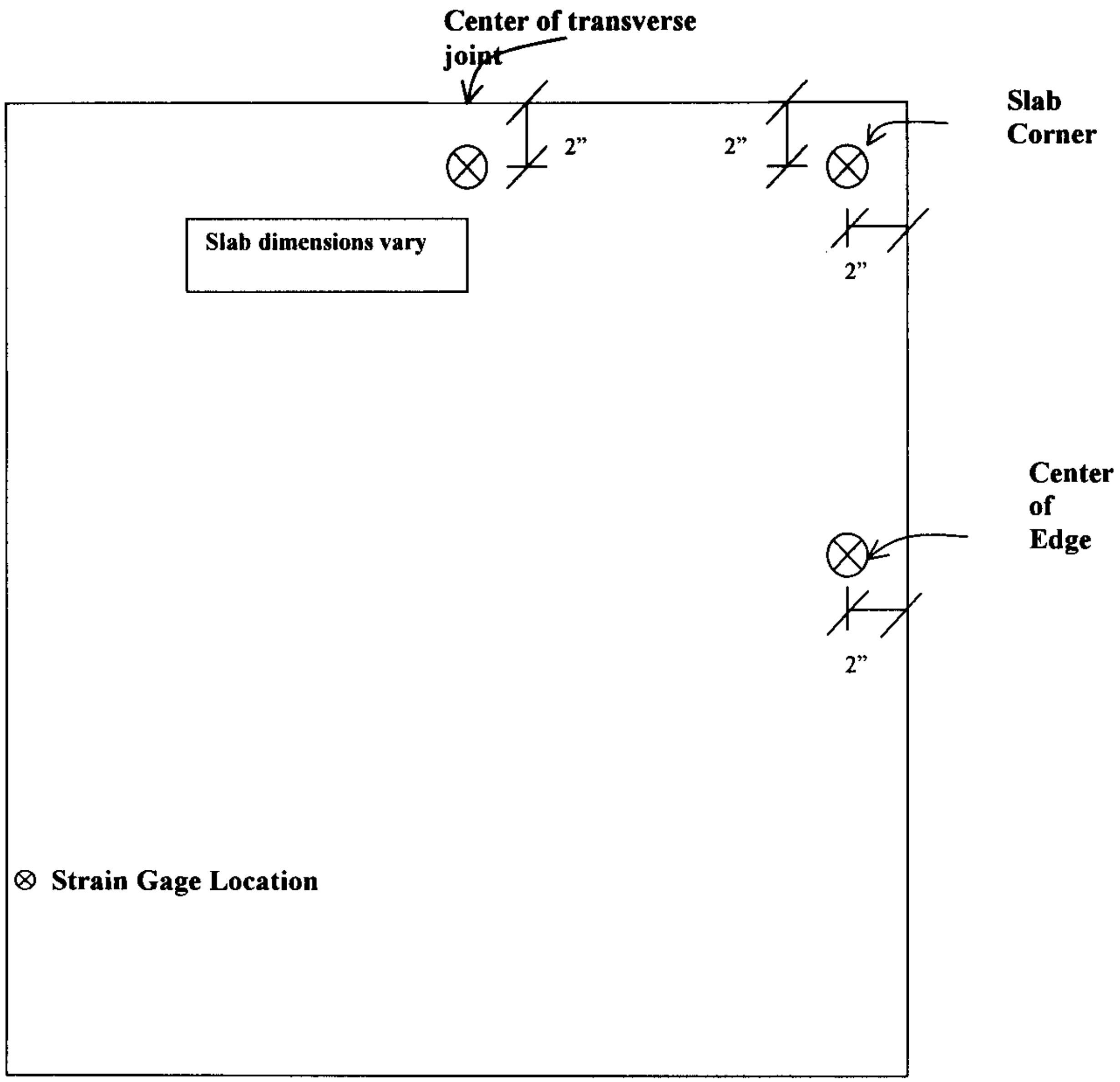
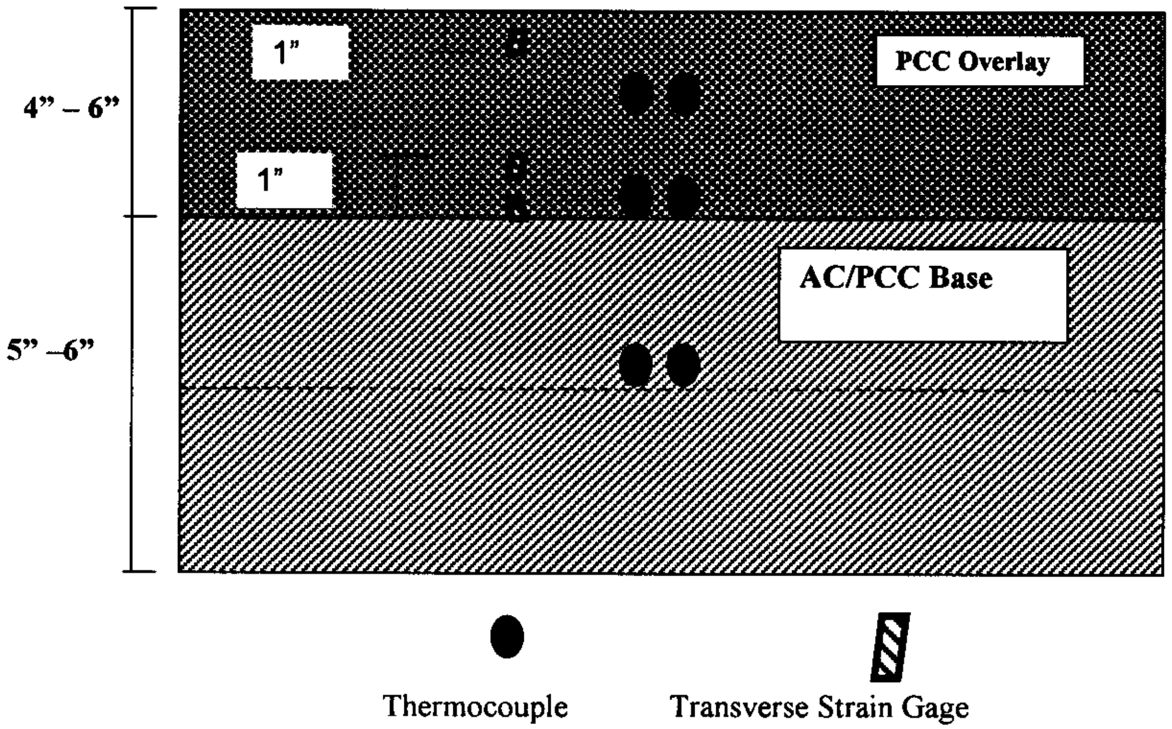


Figure 5 Plan view of strain gage locations

Figure 6 Typical Sensor Location in The Cross Section for the CISL Experiment #13



The FWD test sequence covers a period of approximately six months. The FWD tests will be performed at three locations per lane, with drop configurations selected by the KDOT crew and the KSU-CISL research team. The drop configuration currently used in Experiment 12 may be used. The KDOT crew will provide the deflection data to the KSU-CISL research team, who will be responsible for data processing and moduli backcalculation.

The forensic evaluation of the tested lanes will be performed in order to investigate the failure mode and the causes of failure. After failure, one trench will be cut in each test lane down to the level of the subgrade soil for the PCC overlay section on the existing HMA pavement. No trenching is needed for the thin bonded PCC overlay on existing PCC pavements.

Task 6a: Analysis of Results

The deflection data from the FWD/CISL NDT will be used to backcalculate the elastic layer moduli for the PCC overlay, ACP/PCCP pavement and the subgrade and the joint load transfer efficiency. This will help determine the in-situ degradation of the materials with accumulated traffic.

The data collected during pavement monitoring will be analyzed in order to determine the response of the overlaid pavement to the applied loading, the evolution of distresses, and changes in material properties. The backcalculation of the interface reaction modulus from the surface deflection will be done with the ABAQUS finite element software. The backcalculation process will be manual. Several ABAQUS runs will be performed using successively adjusted sets of materials and structural parameters (layer moduli, interface reaction modulus) until the computed deflections match the measured values. The interface reaction modulus values resulting from the backcalculation will be compared to the laboratory-measured values on cores and the interface constitutive model.

Finally, the Colorado or the Transtec (if available) mechanistic design models will be tested and/or calibrated for use in the four states. Using results from the calibrated method, a design catalog could be developed.

Task 6b: Measurement of Interface Bond

Cores will be extracted from the overlaid sections immediately after construction and after trafficking. The cores will be tested in the laboratory under a special set up in an IPC UTM-25 machine at KSU Advanced Asphalt Laboratory, to develop a constitutive model for the interface between the PCC overlay and the existing pavement. Fatigue tests of the concrete in the existing PCCP and PCC overlay will be conducted in the laboratory to establish the fatigue curve for the concrete mixture used. Compressive strength, modulus of rupture, slump and air content tests of the concrete used in the sections will be done.

Figure 7 presents the schematic diagram of the direct shear test with normal load. In this test, the sample is placed between two metal cups such that the interface is subjected to shear only. A piston is used to apply the normal stress at the interface. Then, while the normal stress is kept constant, the interface is sheared at a constant shear displacement rate. The test is repeated for several normal stress levels and a relationship between the interface shear strength or reaction modulus and the normal stress is obtained by regression analysis.

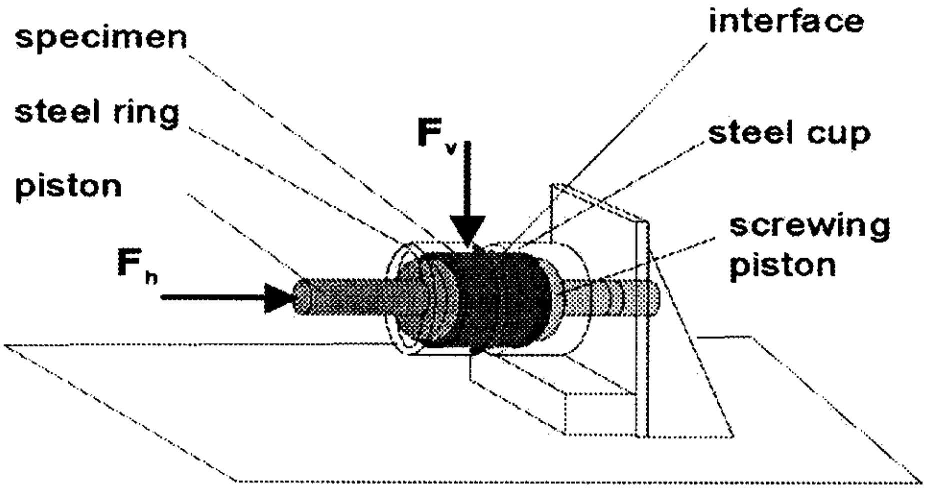


Figure 7 Interface Shear Test With Normal Load (Romanoschi 1999)

This test presents a series of advantages over Iowa Test Method No. 406 (Grove et al.), a direct shear test without normal load:

- A direct shear test without normal stress is misleading because it does not detect the dependency of shear strength on the normal stress. When normal stresses are present at the interface, the interface is 'closing' and the surface of contact between the asperities at the interface increases and thus, the interface shear strength increases.
- No shearing stresses can be caused by wheel loads without normal stresses being present. Also, the shear stresses at the interface caused by the wheel loads reach the maximum values directly under the wheel, where normal stresses are also maximum. Therefore, any interface shear test that does not include the normal stress is unrealistic.
- The direct shear test with normal load allows formulation of constitutive models for the shear behavior of the interface because the shear and normal stresses are decoupled. Romanoschi (1999; 2001a; 2001b) has developed a constitutive model for the asphalt layer interfaces. Models available in the literature for the shear transfer across cracks in Portland Cement Concrete or across discontinuities in rock masses (Romanoschi 1999) will be investigated if they can be adapted for the PCC-PCC and PCC-AC interfaces.

Task 7: Report Writing and Results

A final report containing a detailed description of the construction, test methodology, and results will be delivered at the end of the experiment. The report will contain all information related to the construction of the test lanes, results from the laboratory and field tests of the materials, pavement condition and monitoring data, data analysis methods, summary of the test results, conclusions and recommendations. The research team will also deliver a detailed presentation on the experiment at the end of this project.

From the results, it is expected that a design catalog be developed for the design of PCC overlays on existing PCC or HMA pavements to provide more guidance for the pavement design engineers in the four states in designing and specifying this rehabilitation strategy.

VI PROPOSED BUDGET

For the Period 9/1/03 to 8/31/04

		KDOT	KSU
A.	Personnel		
	1 Stefan Romanoschi		
	0.2 time, 9 mos. acad. yr.	5,928	5,928
	1.0 time, 2 mo. Summer	13,173	
	2 Mustaque Hossain		
	0.1 time, 3 mos. acad. yr.	1,220	1,220
	1.0 time, 1 mo. summer	8,136	
	3 Graduate Research Assistants(2)		
	0.5 time, 6 mos. cal. yr.	8,000	
	0.5 time, 12 mos. cal. yr.	15,000	
	4 Research Technologist(Paul Lewis)		
	1.0 time, 10 months cal. yr.	37,917	
	5 Undergraduate Students(4)	6,600	
	Subtotal Personnel	95,974	7,148
	6 Fringe Benefits		
	30.0% of A1-2 & 4	19,912	2,144
	5.0% of A3	1,150	-
	1.32% of A5	87	-
	Subtotal - Fringe Benefits	21,149	2,144
	Subtotal - Personnel	**117,123**	**9,292**
B.	Equipment-Instrumentation	7,000	
C.	Travel	1,000	
D.	Materials and Supplies	10,000	
E.	Other Direct Costs		
	Fees for ATL equipment usage	55,800	
	Service for Soil and Pavement Placing and removal	17,000	
	Telecommunications	300	
	Duplication	300	
	Tuition/9 hrs fall and spring,3 hrs summer	9,054	
	Subtotal - Other Direct Costs	82,454	-
	Subtotal - Direct Costs	**217,577**	**9,292**
F.	Facilities and Administrative Costs		
	26% of MTDC	52,396	
	46% of MTDC		44,579
	Total Project Costs	**269,973**	**53,871**

VII STAFF AND FACILITIES AVAILABLE

Staff

The principal investigator for this project will be Dr. Stefan Romanoschi. Co-Principal investigator will be Dr. Mustaque Hossain. Mr. Paul Lewis is the Research Technologist at the ATL. He will be fully supported using funds from the proposed project, during the estimated duration of pavement construction and testing. Also, undergraduate engineering students at KSU will be employed on an hourly basis. Graduate students will help do laboratory tests, collect and analyze test data, and help in the implementation and calibration of the control and sensing devices.

Dr. Romanoschi is an Assistant Professor at the Department of Civil Engineering at KSU. His expertise is related to pavement condition monitoring, pavement instrumentation and full-scale accelerated pavement testing, pavement structure modeling and design, Finite Element Analysis of pavement structures, and applied statistics in civil engineering. Dr. Romanoschi is the author and co-author of several publications related to field and laboratory testing of soil and highway materials, and full-scale accelerated pavement tests.

Dr. Hossain is a Professor of Civil Engineering at KSU. Dr. Hossain is author and co-author of many publications related to field and laboratory testing of soil and highway materials, and full-scale accelerated pavement tests and, a Principal and Co-Principal Investigator in many research projects in the ATL. Dr. Hossain is also a member of TRB Committee A2B09: Full Scale Accelerated Pavement Testing.

Mr. Paul Lewis is the full-time research technologist hired by the KSU Civil Engineering Department to work at the ATL on pavement-related testing experiments. He has been employed at the ATL for over three years and has demonstrated excellent abilities to perform the different tasks required to conduct the work at the facility. Prior to that, he was affiliated with KSU where he worked for several years at the University Power Plant, Division of Facilities. As in the past he is totally supported by the Accelerated Testing Pooled Funds Program, and his time is entirely dedicated to the development of the ATL pavement testing experiments.

Facilities

The experimental investigation, which constitutes the majority of the work on this project, will be conducted at the Civil Infrastructure System Laboratory at KSU. The laboratory is located in the Manhattan industrial park in the east part of the city. The facility includes the Kansas Accelerated Testing Laboratory (ATL) where the tests will be performed, the Falling Weight Deflectometer (FWD) calibration facility, and a shake_table for earthquake research. The equipment purchased/donated, installed, and hooked up during the previous projects will be used in the proposed activity to conduct the tests. This includes mechanical, electronic, and thermal equipment presently available at the ATL.

Administrative and secretarial work, library search, etc. will be conducted on the main KSU campus and in the Civil Engineering Department.

VIII REFERENCES

American Concrete Pavement Association (ACPA). *Whitetopping- State of the Practice.* Engineering Bulletin EB210P, Skokie, Illinois, 1998.

Barezinisky, R. Personal Communication, June 2003.

Gisi, A. Personal Communication, June 2003.

Gisi, A. Portland Cement Concrete Overlay Over a Bituminous Pavement. In *Transportation Research Record No. 1040*, Transportation Research Board, Washington, D.C., 1985, pp. 12-17.

Grogg, M. G., K.D. Smith, S.B. Seeds, T.E. Hoerner, D.G. Peshkin, and H.T. Yu. *HMA Pavement Evaluation and Rehabilitation.* Reference Manual, NHI Course No. 131063, National Highway Institute, Arlington, Va., 2001.

Grove, J.D., G. K. Harris and B. J. Skinner. *Bond Contribution to Whitetopping Performance on Low Volume Roads.* Construction Report, *Iowa Highway Research Board Project No. HR-341*, Iowa Department of Transportation, January 1993.

Huang, Y. J. *Pavement Analysis.* Prentice Hall, Ist Edition, New Jersey, 1993.

McCullough, B.F. and Rasmussen, R.O. *Fast Track Paving: Concrete Temperature Control and Traffic Opening Criteria For Bonded Concrete Overlays. Volume II: HIPERPAV User's Manual*, FHWA –RD-98-168. Federal Highway Administration, McLean, Va, 1999.

Melhem, H.G. *Development of an Accelerated Testing Laboratory for Highway Research in Kansas.* Report No. FHWA-KS-97/5, Kansas Department of Transportation, Topeka, Kan., November 1997.

Monismith, C. L. *Class Notes for CE 269-Asphlat Paving Mixtures.* The University of California, Berkeley, 1985.

Rasmussen, R.O, Chang, G.K, Ruiz, J.M., Wilde, W.J., Nelson, P.K., Dick, J. and Rozycki, D,K. New Software Promises to Put Whitetopping on the Map, *Public Roads*, Vol. 66, No. 1, July/August 2002.

Rasmussen, R.O. e-mail communication. June 2, 2003.

Romanoschi, S.A. and J.B. Metcalf. *The Characterization of Asphalt Concrete Layer Interfaces*. Paper presented at the 80th Annual TRB Meeting, January 7-13, 2001 and in-print in the TRR Series.

Romanoschi ,S.A., *Characterization of Pavement Layer Interfaces*. Ph.D. Dissertation, Louisiana State University, Baton Rouge, 1999.

Romanoschi, S.A. and J.B. Metcalf. *The Effects of Interface Condition and Horizontal Wheel Loads on the Life of Flexible Pavement Structures*. Paper presented at the 80th Annual TRB Meeting, January 7-13, 2001 and in-print in the TRR Series.

Rowden L. R. *Thin Bonded Concrete Overlay and Bonding Agents*. Report No. FHWA/IL/PR-123, Interim Report, Illinois Department of Transportation, Springfield, Illinois, June 1996.

Smith K.D., Yu H.T. and D.G. Peshkin. *Portland Cement Concrete Overlays: State of the Technology Synthesis*. Publication No. FHWA-IF-02-045, Federal Highway Administration, McLean, Va, 2002.

Tarr, S.M., Sheehan, M. J. and Ardani, A. Mechanistic Design of Thin Whitetopping Pavements in Colorado. In Transportation Research Record No. 1730, Transportation Research Board, Washington, D.C., 2000, pp. 64-72.

Tarr, S.M., Sheehan, M. J. and Okamoto, P.A. *Guidelines for the Thickness Design of Bonded Whitetopping Pavement in the State of Colorado*. Final Report No. CDOT-DTD-R-98-10, Colorado Department of Transportation, Denver, December 1998.

Zollingher D., Tayabji S., Smith K. and H.T.Yu. *Repair and Rehabilitation of Concrete Pavement: State-of-the-Practice, Volume 1*, Report No. FHWA-01-C-00080, March 2001.