

**Kansas State University
University Transportation Center**



**Center Theme: *The Sustainability
and Safety of Rural Transportation
Systems and Infrastructure***

Quarterly Report

Brian A. Coon, Ph.D., J.D., P.E.
Director, University Transportation Center

Renee Reitz, Ph.D.
Associate Director, University Transportation Center

Kansas State University
2118 Fiedler Hall
Manhattan, KS 66588
(785) 532-1573
<http://transport.ksu.edu>

May 8, 2007

1) TABLE OF CONTENTS

- 1) TABLE OF CONTENTS 1
- 2) INTRODUCTION..... 2
- 3) PROJECT STATUS REPORTS 5
 - a) Rural Transportation Initiative Supporting Agricultural Transition and Sustainability 6
 - 1. Overview 6
 - 2. Progress report: Pilot Cattle Transport Sensor Field Evaluation 7
 - b) National Rural Transportation Symposium 11
 - c) Development of a Comprehensive Rural Transportation Safety Research Program for the 21st Century 12
 - d) Intelligent Structural Health Monitoring of Rural Bridges..... 14
 - 1. Introduction..... 14
 - 2. Objectives..... 14
 - 3. Progress Towards Objective 1..... 15
 - 4. Progress Towards Objective 2..... 17
 - e) Advanced Modeling of Interfaces between Asphalt Concrete Layers and of Permanent Deformation in Subgrade Soils..... 19
 - f) Ensuring Longevity of Rural Highway Pavements Using Pavement Preservation Concepts..... 20
 - g) Development of Efficient Asset Management Practices for Transportation Infrastructure in Rural Communities..... 21

2) INTRODUCTION

Kansas State University's (K-State's) University Transportation Center (UTC), has begun operation as part of the Region VII consortium of UTCs, including the Mid-American Transportation Center (MATC) at the University of Nebraska-Lincoln, the University of Kansas, the University of Missouri-Rolla, Lincoln University of Missouri, and the University of Iowa. After nearly a full year under Dr. Lakshmi Reddi's leadership as Interim Director, Dr. Brian A. Coon has taken over as Director of the Center as of December 2006.

As Center Director, Dr. Coon has begun engaging the K-State transportation research faculty in establishing and implementing the Center's research initiatives—as well as establishing a vision for the center. The UTC's Advisory Committee has met, setting the research agenda, as outlined in the 2006 and 2007 Budget Proposals. The Strategic Plan has also been written, focusing on *The Sustainability and Safety of Rural Transportation and Infrastructure*. The advisory Committee members are:

Richard McReynolds, KDOT

Paul Malir, TranSystems

J. Michael Bowen, FHWA

W. Michael Lackey, KDOT, Retired

Jim Jones, Kansas Asphalt Pavers Ass'n.

E. Dean Carlson, Carlson Associates

Edward J. Mulcahy, Transystems

Robert Thorn, Finney & Turnipseed

Leon Hobson, Riley County Public Works

Greg Harkrader, Kansas Highway Patrol

Matt Ross, Am. Concrete Pavement Ass'n

Keith Browning, Douglas Co. Public Works

Dr. Renee Reitz also joined the UTC as the Associate Director. Dr. Reitz is a organizational and industrial psychologist, with extensive expertise in driver training and instruction. Specifically, Dr. Reitz has worked with the Department of Defense in examining driver behavior of soldiers and is a member of the Defense Safety Oversight Council Private Motor Vehicle (PMV) Task Force, which oversees the PMV research for all five branches of the United States military.

The UTC website is now available at <http://transport.ksu.edu>, with links to ongoing research to be added in the immediate future. Dr. Coon was able to obtain donated software for hosting a bulletin board, the National Transportation Forum, which will provide an opportunity

for discussion for transportation professionals around the nation, focusing on the areas of expertise of the faculty of K-State.

The UTC has also become actively involved in the Riley County Area Transportation Agency (aTa Bus program) in Manhattan. Dr. Coon is a member of the Board of Directors, serving as an advisor on transit system. Additionally, an undergraduate student will be working for course credit to evaluate the aTa Bus program and help progress the Agency towards its goals as Manhattan forms a Metropolitan Planning Organization (MPO) in 2010.

A student chapter of the Institute of Transportation Engineers (ITE) has also been formed at K-State, which previously did not have a student chapter. Seven students have now joined ITE and have begun looking at activities to increase the awareness of transportation engineering at K-State.

Dr. Coon has also been working with Nancy Mattson, looking at options of GIS mapping bike trails. One concept is teaching Boy Scouts, as part of a merit badge or Eagle project, how to use GIS mapping and equipment to map local trails.

The Office of Chief Counsel has also been directly involved with the UTC, developing plans to train local officials on transportation contracts. As tort litigation is already well-covered by the University of Kansas, Leslie Fowler identified a need of local officials to better handle transportation contracts when dealing with non-state-funded projects.

Finally, the Advisory Committee has chosen the projects to receive funding. These projects include:

Table 1. Projects Selected for Funding.

PI	Project Title	Project Cost	Accumulative Amount
Peterman	Establishing A Mobile Laboratory for Transportation Research and Education	\$32,650	\$32,650
Rys & Russell	Promoting Center Line Rumble Strips to Increase Rural, Two-lane Highway Safety	\$20,000	\$52,650
Dissanayake	Factors Affecting Fatal Crash Involvement of Older Drivers	\$75,000	\$127,650
Hossain, Romanoschi, Testa	Kansas Pavement Preservation Initiative	\$120,000	\$247,650
Russell	Increased Pedestrian Safety and Decreased Motorist Delay with a HAWK Pedestrian Signal	\$35,000	\$282,650
Rys & Russell	Effectiveness of Larger Traffic Signs, High-Performance Sheeting and Clearview Font on Accident Reduction	\$49,000	\$331,650
Dissanayake, Stokes	Improving the Usage of Demand Response Transit Services in Rural Kansas	\$80,000	\$411,650
Najjar, Dissanayake, Romanoschi	Knowledge Discovery in Transportation Databases (KDiTD)	\$180,000	\$591,650
Najjar	Characterizing KDOT's Chloride Permeability Testing Protocol: Reducing the Duration of the Rapid Chloride Permeability Test	\$95,000	\$686,650
Dissanayake	Speed Management in Rural Communities: Innovative Low Cost Approaches	\$82,000	\$768,650

3) PROJECT STATUS REPORTS

Due to the lack of availability of graduate students in transportation, several of the projects funded last year by the UTC have neither used significant funds nor made significant progress. This has primarily been due to a lack of graduate students to perform research projects, as there were too few graduate students and the graduate students available were already actively participating in one or more other research projects.

Now, as a center director has been hired and graduate students have become available for projects, project completion is accelerating at a rapid rate. Additionally, with the new projects funded for the 2007-2008 school year have ensured faculty that they will be able to hire the needed graduate students and be able to promise research projects.

Below is a list of the active projects and their status, as funded in 2006 by the UTC.

a) Rural Transportation Initiative Supporting Agricultural Transition and Sustainability

Principal Investigators: Dissanayake, Apley, Steward, and White

Theme: Intelligence, Knowledge, and Information Systems in Transportation

Budget: \$50,000

1. Overview

Twenty percent of Kansas' population works within the agriculture sector, bringing \$9B in revenues annually to Kansas with \$6.5B from cattle production alone. The cattle production industry is supported by a transportation network whereby grains are produced in close proximity to feedlots, which in turn are located close to packing plants. This sector depends upon an irrigated agriculture base, which is going through transition as groundwater-use practices change due to economic externalities and limited availability. This initiative supports key components of this system including:

Animal Production: The quality of transportation infrastructure plays a key role in the welfare of animals being moved through the system. Cattle are moved at least 2 times and as many as 3-4 times over their lives, and stress levels from driving conditions are key factors in the quality of meat (dark cutters) and shrinkage (weight loss).

Transportation Network: Driving conditions are directly related to pavement and bridge quality, traffic controls, type of road (e.g., freeway vs. gravel), and roadway design characteristics (grades, curves) and operation (speed).

Resource Proximity and Mobility: The transportation network (rail and road) connects the components of grain and animal production with markets and the resources (water, soils, etc.) necessary to support the agriculture industry. Whereas 95-98% of groundwater is used in irrigation over a limited growing season in western Kansas, animal production, which requires access to water throughout the year, requires long-term safeguarding of a reliable stock of water.

GIS Support: Geographic Information Science provides a means to overlay different types of geospatially referenced data (transportation network, location of animal production, water availability) and provides support for resources management.

Economic Impact: While a direct correlation between animal stress and quality/value of meat is known, the impact of stress induced through transportation is an untapped area of

research. Relationships amongst transportation networks and animal production, within a water-dominated system, are also untapped.

Intellectual Merit: This initiative brings together, for the first time, an interdisciplinary team that synergistically exploits areas of strength at K-State in transportation engineering, water resources/GIS, computing/information sciences, and animal sciences/veterinary medicine. This team will forge new research partnerships across campus and addresses critical issues.

Broader Impacts: This initiative addresses a transportation programmatic focus with tremendous implications to cattle production and agriculture. Results will support societal decisions in transportation development, animal production practices, and resources utilization. The GIS infrastructure developed here could synergistically leverage other geospatial needs for endeavors related to pavement quality, bridge repair, and the environment.

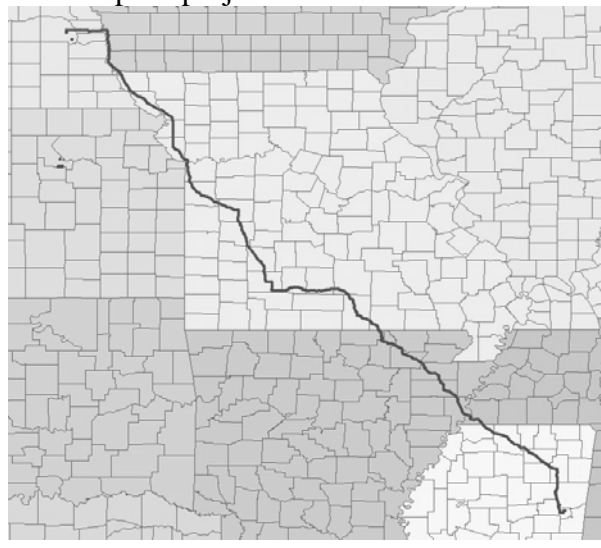
2. Progress report: Pilot Cattle Transport Sensor Field Evaluation

Purpose: To evaluate remote movement sensor systems on animals transported through commercial mechanisms and to collect pilot data that will be used to evaluate system and pursue further funding.

Materials and Methods: A college of veterinary medicine student (Curt Vogel) employed on project traveled to Mississippi to a cooperating facility. The student placed wireless accelerometers on 16 animals (2 animals in each section of a standard cattle transport truck), and each section of the truck (8 sensors). One sensor was placed on the truck in a fashion to record GPS readings of truck through trip. Figure 1 illustrates the route of the truck over the 19 hour journey. All sensors recorded and logged data to

internal memory cards throughout the trip. The student traveled to a feedlot in Nebraska to meet the calves upon arrival and will remove the sensors and bring them back to KSU.

Figure 1: GPS record of cattle transport route in pilot project

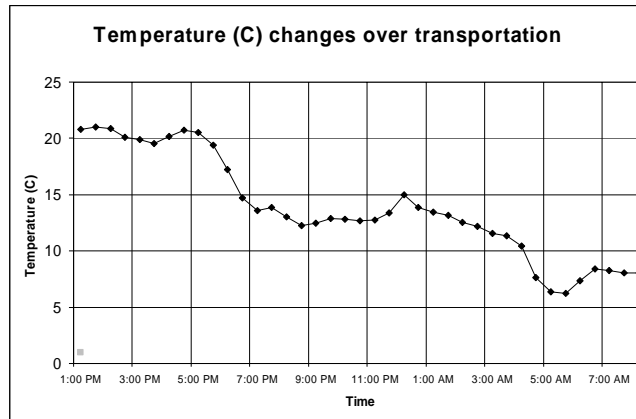


Initial Results: Animal sensors consisted of 3-D accelerometers and truck mounted sensors consisted of temperature and barometric pressure monitors in addition to accelerometers.

There were 12 sensors placed on the cattle transport trailer throughout the various sections. Temperature data was recorded once per second and acceleration data was logged at a rate of 10 Hz. Due to hardware issues, the 16 animal sensors did not record data through the entire journey; therefore were not included in the analysis.

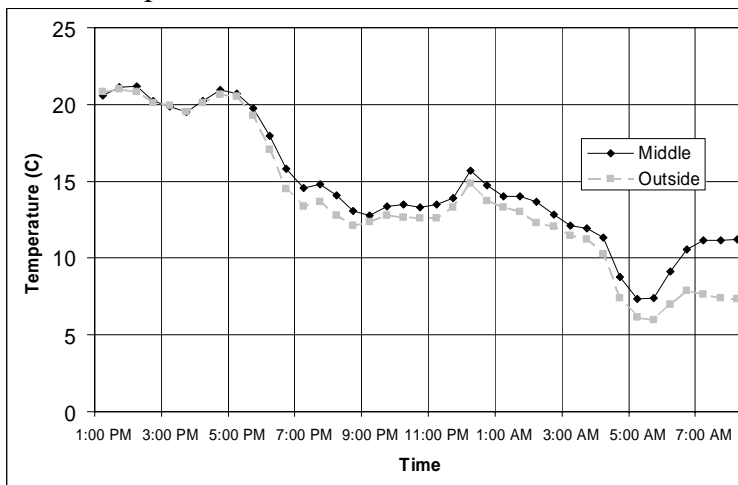
One goal of the project was assess environmental changes throughout the journey. Figure 2 represents the difference in temperature as measured by the truck mounted sensors over the journey.

Figure 2: Variation in mean trailer temperature over a 20 hour pilot project



Cattle are commonly divided into 6 or 8 sections on most cattle transport vehicles. The sensors were strategically placed in sections of the trailer to evaluate potential environmental

Figure 3: Differences in mean temperature over time as recorded by sensors in the middle compared to the outside of the transport vehicle



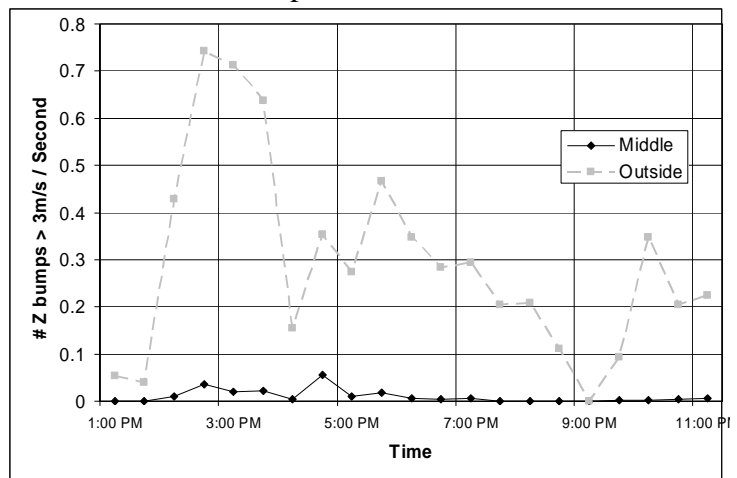
differences by region of the trailer. Minor temperature differences were identified between sections of trailer, but most were related to larger trends within the truck. Differences were also related to specific events that occurred during the journey.

For example, Figure 3 represents the mean temperature collected by sensors in the middle (near the center) and the outside (placed on the lateral walls of

the trailer near ventilation). The two areas mirror each other through most of the journey with the middle sensors maintaining a slightly higher temperature until a little after 5 am when the two have a significant separation. The GPS data illustrates that the truck stopped at 5 am and waited in the same location until 7:15 am to unload the cattle. Thus, the middle of the trailer warmed back up after stop while the outside (near ventilation) stayed relatively cool. This information could be very valuable when generating guidelines for required rest stops or potential implications for animal health.

Truck sensors also measured forces registered in 3 directions: vertical (Y-axis), horizontal parallel to direction of driving (X-axis) and horizontal perpendicular to direction of travel (Z-axis). These measurements are used to evaluate forces faced by calves during commercial transport. Preliminary data comparison of forces faced by calves in each

Figure 4: Difference in the number of Z-axis events greater than 3 m/s^2 per second over time in middle versus outside of transport vehicle



section of the truck during the trip illustrated differences by area. Published literature has illustrated the potential impact of vibrations or large stressors on animal health. Figure 4 illustrates the difference in the frequency of events greater than 3 m/s^2 during the journey comparing sensors in the middle and outside of the transport vehicle.

Summary:

The pilot project data revealed several interesting trends and opportunity for utilization of the data. More data needs to be collected from similar journey's to solidify findings and expand the project. This data will be useful to formulate hypotheses and generate applications for funding from external agencies in the varied fields represented by investigators on the study. Work is planned to continue this summer to augment existing information.

b) National Rural Transportation Symposium

Principal Investigator: Hossain

Theme: Outreach

Budget: \$50,000

Funds expended (03/31/07): \$0

A group meeting of representatives from Kansas State University (KSU), the Kansas Department of Transportation (KDOT), the Federal Highway Administration, the Kansas Asphalt Pavement Association, and the asphalt pavement industry in Kansas was held on April 30, 2007, on the KSU campus. The objective and targeted audience of this symposium were reevaluated in light of other regional and national conferences and role of the KSU University Transportation Center. It was decided that the Principal Investigator will work with the Director of K-State's UTC and will try to arrange a symposium to primarily target the local government management and engineering staff.

c) Development of a Comprehensive Rural Transportation Safety Research Program for the 21st Century

Principal Investigators: Dissanayake, Russell, Rys, and Stokes

Theme: Rural Transportation Safety

Budget: \$100,000

The objectives of this research project are to: 1) develop a comprehensive, multi-disciplinary rural transportation safety research program for the Kansas State University UTC; and 2) outline the organizational and administrative infrastructure needed to implement the recommended safety research program. It is envisioned that the recommended research program will serve as a guide for the UTC Advisory Committee in the selection of safety research projects in the future.

The research work plan consists of the following basic tasks. Task 1: Conduct literature reviews to identify current and emerging issues in the area of rural transportation safety. The literature review will be supplemented with the knowledge of the research team and personal contacts. Task 2: Develop criteria for selecting research topics to be included in the research program. Task 3: Prepare interim report. The interim report will provide a summary of potential research areas, a preliminary prioritization of research areas in terms of implementation potential and expected benefits, and a preliminary identification of the disciplines/areas of expertise best suited to address the individual problem areas. The interim report will also outline the organizational and administrative structure needed to implement the research program. Task 4: Conduct interviews, meetings and visioning seminars with KSU faculty whose areas of expertise could be brought to bear on the problems identified in the interim report. The purpose of these interviews will be to link the research needs identified in the interim report with the appropriate KSU faculty. Task 5: Prepare final report. The final report will provide a detailed description of the research “agenda” in the form of individual project statements, a preliminary prioritization of research areas in terms of implementation potential and expected benefits (procedures for selection and funding of projects will need to be determined by the UTC advisory/review committee), a proposed organizational structure (e.g., creation of a “Safety Institute” within the UTC) to implement the research agenda, estimated short and long term costs to implement the various research agenda items, identification of short and long term funding

sources for the research program, and a proposed technology transfer program to disseminate information on the research program and its findings.

Project Status: A preliminary draft of the project Interim Report has been prepared. The project is currently supporting one MS graduate student. It is anticipated that the research project will generate one MS thesis. It is estimated that the Interim Report will be available for distribution to KSU faculty and the UTC Advisory Committee by Fall 2007. It is estimated that the final project report will be submitted to the UTC Advisory Committee by January 2008.

d) Intelligent Structural Health Monitoring of Rural Bridges.

Principal Investigators: Rasheed, Peterman, Esmaily, and Melhem

Theme: Intelligence, Knowledge, and Information Systems in Transportation

Budget: \$100,000

Prepared by Brandon Decker and Hayder Rasheed

1. Introduction

The need to repair, upgrade or replace infrastructure elements on the Kansas and National bridge inventory is increasing due to the aging of structural components and materials as well as the expanding volume and weight of traffic. In the year 2005, 22% of the 25,511 bridges in Kansas were labeled either structurally deficient or functionally obsolete. Of the total Kansas bridges, 23,168 were not on the national highway system (NHS) with 5,285 deficient and obsolete bridges. A significant number of these bridges serve rural Kansas, which has very limited funding and low priority for rehabilitation or upgrade. There has been evidence of severe cracking of prestressed concrete girders on Kansas rural bridge inventory due to frequent overloads during harvest season. The Federal Highway Administration estimated that funding of \$215 billion is necessary to repair all the bridges and roads in their current conditions. Replacement costs are expected to be larger by many folds. Accordingly, there is a clear need for objective methods to assess and evaluate the condition of the structurally deficient and functionally obsolete bridges to prioritize the need for repair, strengthening, replacement or closing and detouring.

2. Objectives

There are two main objectives running in parallel for the purpose of advancing the state of the art in bridge monitoring and repair. The first objective deals with the establishment of a robust FRP repair and strengthening technique that ensures achieving the actual ultimate capacity of repaired members without the predominant separation failure mode. The second objective addresses the intelligent health monitoring of bridge elements using state of the art wireless technology.

3. Progress Towards Objective 1

In this part of the study, the effectiveness of using external U-wrap stirrups to increase the strength contribution of externally bonded FRP composites for flexural members. Flexural strengthening and anchorage strips were achieved using V-Wrap C100 high strength, carbon-based, FRP strengthening system.

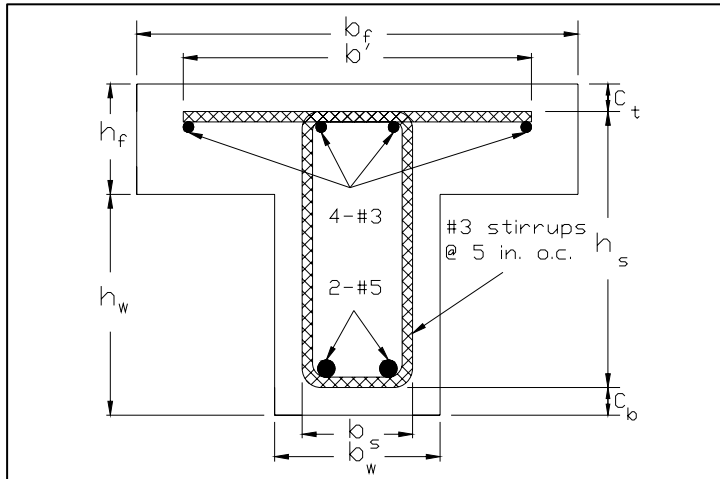


Figure 1: Typical T-Beam cross-section.

$b_f =$	16 in
$h_f =$	4 in.
$b_w =$	6 in.
$h_w =$	8 in.
$C_t =$	1 in.
$C_b =$	1 in.
$h_s =$	10 in.
$b'_f =$	13 in.
$b'_s =$	4 in.

Table 1: Cross-section dimension.

Three identical T-beams were constructed and tested under this program, Figures 2-3. Typical beam geometry and reinforcement are given in Figure 1 and Table 1. Strain gages were installed on the top and bottom of the beam and also along the side. Two LVDT's were installed on both sides of the beam to measure the mid-span deflection. All reinforcing steel was grade 70 ksi. Beams were cast with 5000 psi concrete.



Figure 2: Casting of the T Specimens



Figure 3: Testing the Control T Specimen

The test system used is a servo-hydraulic system called FlexTestGT designed by MTS systems. The beams were tested in four-point bending using a 4 foot long spreader beam to create a constant moment region. Schematic of the test setup showing spans and loading location is given in Figure 4. The first beam was a control specimen without any carbon fiber reinforcement. This control beam failed at 15.6 kips experiencing typical failure mode of yielding of steel followed by concrete crushing, Figure 5. The theoretical calculations indicated that the control beam would fail at a load of approximately 15.8 kips.

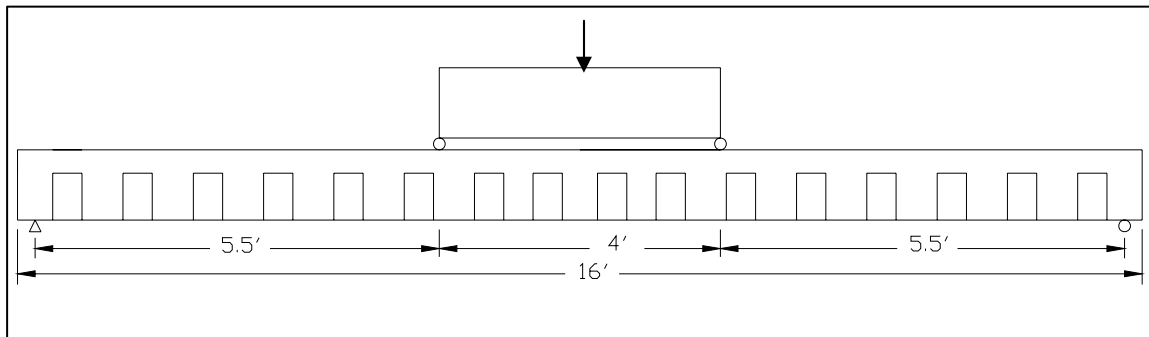


Figure 4: Test setup of typical beam.

The second T-beam was reinforced with flexural CFRP reinforcement on the bottom of the beam only. Five flexural layers of CFRP reinforcement were applied along the bottom side of the beam. These layers were stopped just before the supports. According to calculations per ACI 440.2R-02, failure of the strengthened beam would be controlled by delamination or debonding of the FRP that would occur between the reinforcement and the beam. To determine how many layers of V-Wrap to use on the bottom of the beam to ensure delamination to occur, a computer program was used that was developed by a former PhD student at Kansas State University. The program divides the beam into segments and calculates the tension force in the FRP layers at each segment. This tension force was made higher than those predicted by using two separate methods for delamination.

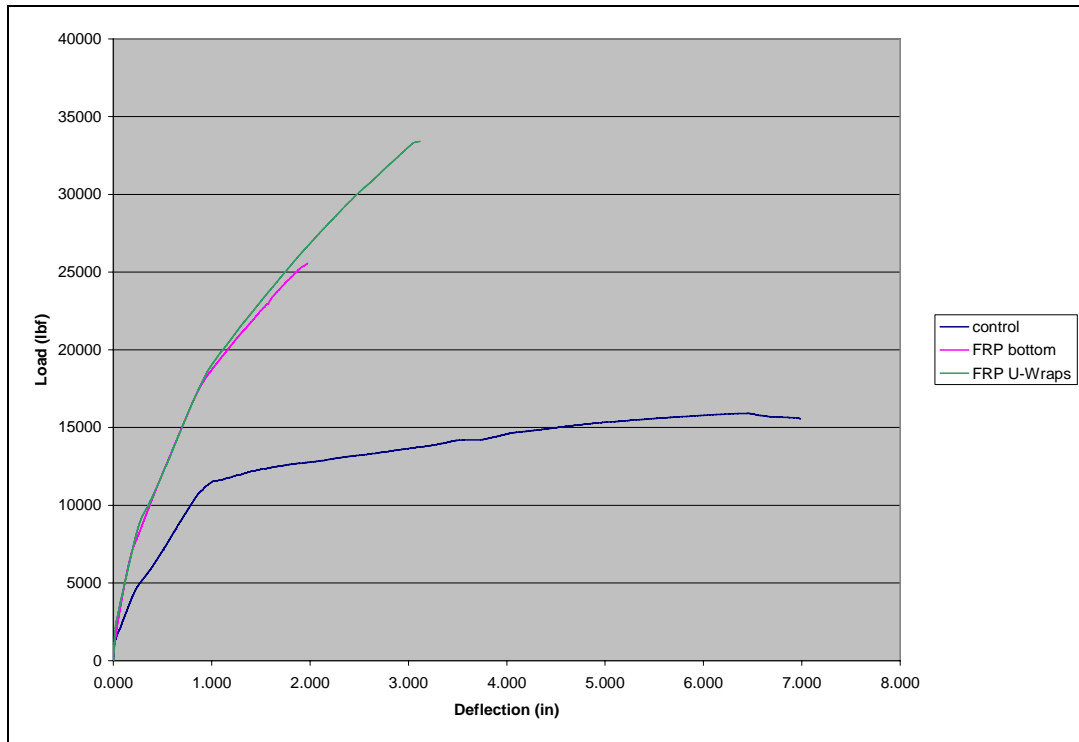


Figure 5: Load-Deflection diagram showing effects of carbon fiber reinforcement.

During the test, some local delamination was observed to initiate at a load of approximately 18 kips. At a load of 25.5 kips, the 5-layer reinforcement completely delaminated with tremendous energy release. This debonding failure mode provided a strength increase ratio of 1.63. The actual delamination occurred between the reinforcement and the concrete with a little bit of concrete cover spalling in some spots.

The next step was to demonstrate that debonding of the same five layers of reinforcement could be prevented (or delayed) using external FRP U-wraps along the span that can help achieve rupture of the FRP reinforcement. The purpose of these U-wraps was to provide horizontal shear resistance by friction once the resistance by adhesion is consumed. This would help hold the five flexural layers of reinforcement and keep them engaged to higher loads closer to ultimate flexural capacity, predicted based on FRP rupture.

4. Progress Towards Objective 2

After an extensive literature review and search for an efficient system, the wireless technology provided by Micro strain was selected and an initial module was selected to collect

acceleration and strain gage data. The system was examined on an exploratory basis yielding excellent results of the acceleration data gathered. During the next reporting period, a prestressed T girder will be used as a model bridge element for which data will be collected in terms of acceleration and strain due to the effect of moving loads, impacts and both, Figure 6.

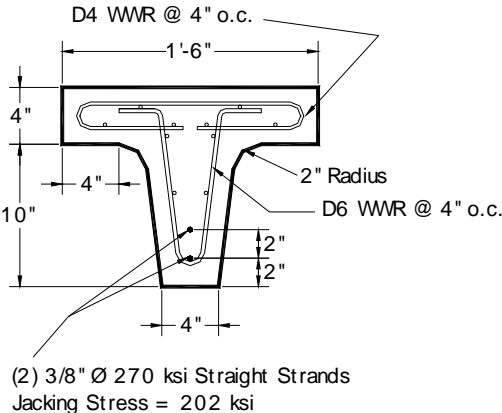


Figure 6. Cross section geometry of the bridge beams.

e) Advanced Modeling of Interfaces between Asphalt Concrete Layers and of Permanent Deformation in Subgrade Soils.

Principal Investigators: Romanoschi, Najjar, and Peric

Theme: Advanced Modeling of Pavement and Subgrade Systems

Budget: \$100,000

Project Timeframe: May 01, 2006 to May 31, 2008

This project has encountered significant problems in the recruitment of appropriate graduate students to complete the project objectives. Two masters degree students were finally located after an extensive, eight-month search. These students, Tito Nyamuhokya and Maurice Wheat, have now begun working on the project.

Task	Percent Completed
Literature Search	60%
Laboratory Equipment and Tests	40%
Analytical Modeling	10%
Reporting	10%

PI's report of progress:

Project within budget? **Yes**

Changes in project description? **No**

Problems encountered (current or anticipated):

Two MS students (Tito Nyamuhokya and Maurice Wheat) started working on this project in early January 2007. It took 8 months to recruit two graduate students for this project.

Significant products this period (reports, journal articles, proceedings, etc.):

None

f) Ensuring Longevity of Rural Highway Pavements Using Pavement Preservation Concepts.

Principal Investigators: Hossain and Cai

Theme: Infrastructure Preservation / Renovation

Budget: \$100,000

Funds Expended (03/31/07): \$0

The objective of this part of this project is to develop a chip seal design based on Hamburg wheel load tester results. The study will be based on actual construction projects. The project start was delayed because it missed the 2006 construction season. The seal coats projects in the current (2007) construction season have been identified. A graduate research assistant has been hired in early April and a literature survey has been conducted. Significant progress on this project is expected to be made during this summer.

g) Development of Efficient Asset Management Practices for Transportation Infrastructure in Rural Communities.

Principal Investigators: Najjar, Romanoschi, Dyssanayake, and Esmaily

Theme: Infrastructure Preservation / Renovation

Budget: \$75,000

This project has also encountered significant problems in the recruitment of appropriate graduate students to complete the project objectives. A masters degree student was finally located after an extensive, eight-month search. This student, Kevin Friedrichs, began work on the project in January 2007.

Task	Percent Completed
Literature Search	70%
Field Surveys	10%
Evaluation of Current Practice in Relation to the State of the Art	10%
Reporting	10%

PI's report of progress:

Project within budget? **Yes**

Changes in project description? **No**

Problems encountered (current or anticipated): The MS student (Kevin Friedrichs) started working on this project in early January 2007. It took 8 months to recruit a graduate student for this project.

Significant products this period (reports, journal articles, proceedings, etc.): None