I. RESEARCH PROJECT TITLE

Implementation of Non-Contact Strain Measurement Device for Bridges and Piers—Phase II

II. BACKGROUND AND IMPORTANCE TO THE TRANSPORTATION INDUSTRY

The ability to accurately determine the stresses carried by in-situ bridge elements is extremely valuable when assessing the condition of an existing structure. This is especially important for rural bridges on county roads, where many existing bridges are structurally deficient and in need of repair. However, the ability to obtain this information is often too expensive and time consuming to justify its use.

Typically, for a bridge or pier, obtaining information about stresses would necessitate the use of strain gages that are mounted to the bridge member surface in order to detect the internal movements (strains) caused by loads traveling across the structure. During the past 4 ½ years, the investigators have been working as a team to develop a non-contact optical strain measuring device that utilizes Laser Speckle imaging. Using this prototype device, the strains in a bridge member may be obtained by simply imaging the speckle pattern that is generated when a laser beam is reflected by the surface of the member at 2 simultaneous points (refer to Figures A1-A3).

One of the most attractive features of this new measurement technique is that there is typically no surface preparation required. The reflective properties of the member's surface serve as a "fingerprint" of the unique location. Thus, an engineer or technician can begin taking initial baseline measurements within minutes after arriving at a bridge site. In addition, since this is a non-contact measurement technique, hundreds of measurements can be obtained using the same hand-held device. While the majority of the work conducted thus far has involved strain measurements on concrete surfaces, the researchers have also had excellent success with measurements on several other surfaces, including steel, as long as these surfaces were not excessively smooth or polished.

III. WHAT HAS ALREADY BEEN DONE?

To date, the research team has fabricated a prototype device using "breadboard" optical components and have rigorously tested the device in both indoor and outdoor environments (Figure A4). The device was directly compared with electrical-resistance strain gages and found to have an excellent correlation within 6 micro-strain (refer to Figure A5). Thus, the prototype device has been successfully developed and now needs to be "hardened" to a usable state as explained below.

Since the current optical components in the prototype device are breadboard-type (meaning the internal mirrors each have many adjustments for positioning flexibility) and because the current housing is not air-tight, the current prototype is not robust enough for deployment in the dusty conditions associated with typical field applications. In addition, to obtain readings with the current prototype device, three different pieces of software are sequentially used by the graduate student.

IV. PROPOSED WORK PLAN

The investigators seek funding to implement this new technology by performing the following 4 tasks:

1. Design and create a “hardened” instrument that incorporates fixed mirrors and optical components instead of the current breadboard type components (used in the prototype shown in Figure A4) which are prone to loosening if jarred. Note, the breadboard components were initially used to allow flexibility as numerous optical arrangements were explored. Figure A6 shows an isometric Pro/E drawing of the new hardened sensor concept, which incorporates all the essential features of the prototype along with more permanent mounting of the optical hardware and encasement in a rigid sealed unit. A functioning hardened prototype based on this concept will be developed and implemented as one of the deliverables for this project.
2. Streamline the data collection and reduction process into one software package to enable the device to be readily used by others. A devoted portable laptop will be used to consolidate all data acquisition software and hardware necessary for communication (A/D) with the sensor.
3. Prepare documentation that includes a user’s manual for both the device and the software created in task 2.
4. Conduct a training session for UTC associates who would like to learn how to use the device.

Note: Phase II will fund the creation of the actual hardened sensor device.

The key to meeting these objectives is to utilize the expertise of the individuals who developed this new technology, and to work as a multi-disciplinary team towards accomplishing this goal. Thus, this proposal is being jointly submitted by faculty members of Kansas State University who have the technical background and a proven track record of working together, and includes personnel with backgrounds in Civil, Mechanical, and Industrial Engineering. In particular, the graduate student, Weixin Zhao, has been working with the investigators for the past 3 years and received a fellowship from the Precast Prestressed Concrete Institute towards his work in this critical area.

V. URGENCY AND PAYOFF POTENTIAL

The timing of this funding is critical. The industrial engineering graduate student specializing in optics, Weixin Zhao, has been working on the development of this measurement device for the past 3 years. Weixin has the fundamental understanding necessary to “harden” the device and develop the software to enable others to use the device. Weixin will likely complete his Ph.D. studies and leave the university within the next 18 months. Unless this hardening process and software development is completed during his time at KSU, most of the implementation possibilities for this technology will be lost. However, if this project is funded, the new device has several other foreseeable advantages for the transportation industry. These include the potential to readily determine the modulus of elasticity of concrete and asphalt samples during routine compression tests.

VI. PROJECT BUDGET AND DURATION

Project duration: September 1, 2008 – January 31, 2010
Budget for Phase II: $62,138*.

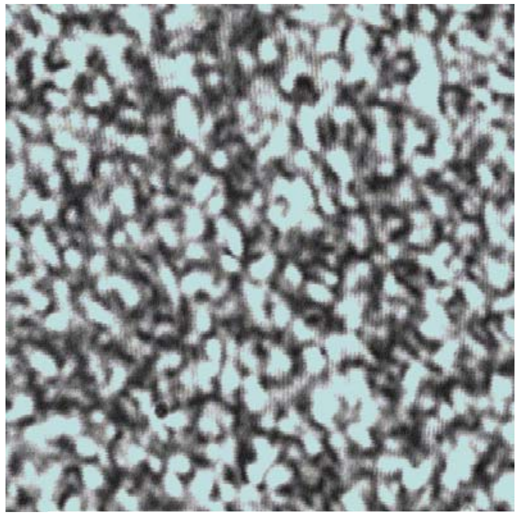
* To date, more than $245,000 of "matching" funds have been provided for the development of this non-contact Laser Speckle measurement technique, including more than $160k from the Kansas Advanced Manufacturing Institute (AMI), $18k from PCI, $12k from KDOT, and $60k from Kansas State University in terms of the use of multiple labs and faculty time during the past 4 years. Thus, the requested funding to implement the technology represents about 20% of the total development effort. This is analogous to moving the technology "from the red-zone to the end-zone."

VII. IMPLEMENTATION STRATEGY

The essence of this proposal is to implement the already-developed laser-speckle method by creating a strain measurement device that can be used by trained personnel in field applications (refer to tasks 1-4 above). This effort will ensure that the money already spent will have the maximum return on investment, and will make Kansas a leader in this new technology.

VIII. PROJECT PERSONNEL

Dr. Robert Peterman KSU)	- Civil Eng. - Experimental Testing and Evaluation of Structures
Dr. Terry Beck (KSU)	- Mechanical Eng. - Optical Measurement Techniques
Dr. John Wu (KSU)	- Industrial Eng. - Non-Contact Measurement
Weixin Zhao, M.S. (KSU)	- Industrial Eng. Ph.D. Student with expertise in optics



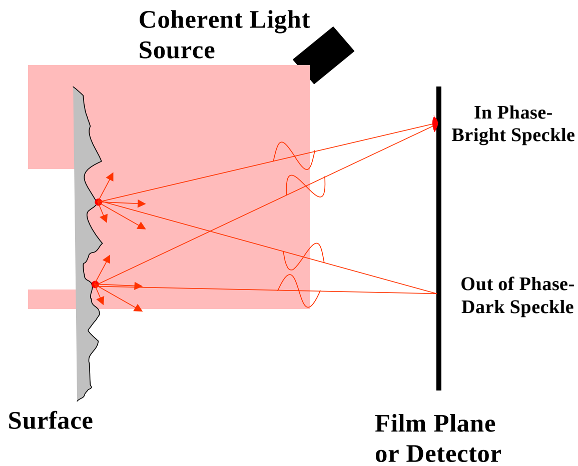


Figure A1 (top). Illustration of the laser-speckle concept.

Figure A2 (bottom). Laser-speckle image from concrete surface.

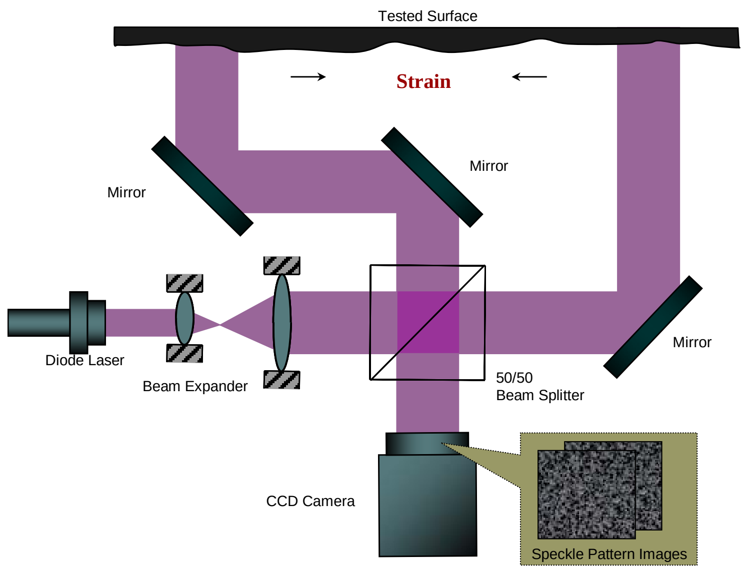


Figure A3. Schematic of laser-speckle strain measurement device.

Figure A4. Testing the prototype laser-speckle strain-measurement device on a prestressed concrete member. In this experiment, the data were compared with data collected using de-mountable mechanical (DEMEC) gage points.

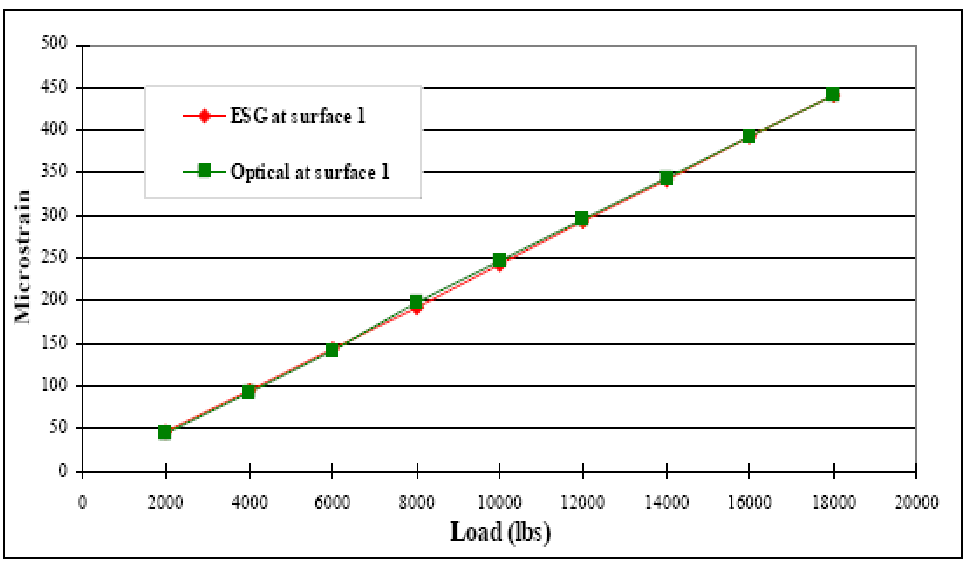


Figure A5. Graph showing excellent correlation between the optical (laser-speckle) strain measurement device and a traditional electrical-resistance strain gage

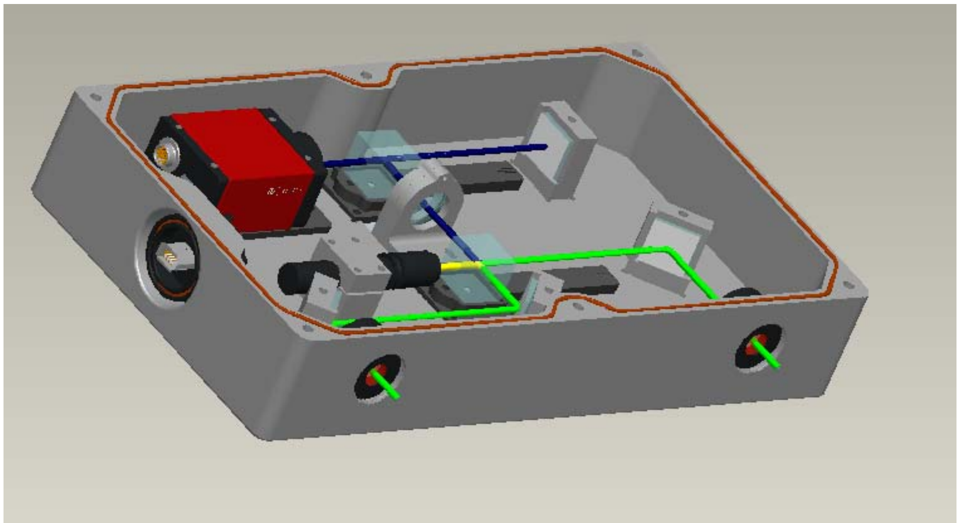


Figure A6. Preliminary Pro/E Isometric Drawing of Hardened Strain Sensor Concept