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Final Report

BRIDGE MONITORING – APPLICATIONS FOR ALABAMA

Submitted to

Alabama Department of Transportation
Research Project 930-734

Prepared by

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December 2008

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PLANNING FOR THE FUTURE

Alabama Department of Transportation (ALDOT) is continuously searching for ways to improve the efficiency and safety of Alabama's transportation system. With the rapid growth of electronics and monitoring technology it is important to ask whether new technologies can provide cost effective improvements to the management of that system. ALDOT studied that question and created this document to identify bridge monitoring applications that are of interest to ALDOT. By identifying applications of interest, ALDOT hopes to encourage vendors to focus product development and marketing efforts on those applications.

APPLICATIONS FOR TODAY

ALDOT considered a large number of possible applications of bridge monitoring systems. Applications with the most immediate promise for providing clear benefits have the common characteristic of "detection of a significant event". Events of interest are those that have a reasonable likelihood of occurring and have the potential to make a bridge unsafe within a short time. Barge impacts, hurricanes, streambed scour, and crossing of overweight vehicles are specific events of interest.

ALDOT is also interested in monitoring technologies and equipment that can improve in-house capabilities. Alabama invested in equipment, technology, and people in 1991 and established the Bridge Rating and Load Testing (BRLT) Section of the Maintenance Bureau. The BRLT Section in conjunction with the Bridge Bureau and a rigorous bridge inspection program gives ALDOT a wide range of capabilities to address special conditions that are not available in the department of transportation of many other states. ALDOT is interested in keeping these capabilities at the state-of-the-art.

Barge Impact

ALDOT owns and maintains several bridges across navigable waterways where barges can and do hit the bridge piers. Barge impacts are typically reported by barge captains, fishermen, or motorists. In fact, there are more barge impacts reported than actually occur. ALDOT investigates reports of barge impacts each year that are concluded to be second or third reports of a previously investigated event. For example a fisherman may see a bridge member that appears bent and report the damage. Because there is no system in-place to detect and record actual barge impacts, ALDOT investigates each new report as if a new barge impact has occurred. A benefit will result from having a record of when an impact actually occurs. That record will allow ALDOT

to more accurately assess the significance of a telephone report of a barge impact.

A benefit will also result from a record of the magnitude of a barge impact. Additional useful information is the location and direction of the impact. These pieces of information will allow ALDOT to quickly focus attention most effectively after a barge hits a bridge.

Ideally a barge impact detection system would detect the event, evaluate the consequences and initiate appropriate action whether that action was simply sending a message to an ALDOT contact person or whether it was closing the bridge by means of warning signals and crossing arms. However, a very elaborate and expensive system can easily be made ineffective if it is prone to false alarms. False alarms erode the confidence of motorists and emergency responders who will eventually ignore alarms and warning signals.

As a minimum a barge impact detection system must detect and record the impact event, categorize the magnitude of the event, and immediately transmit this information to designated contact persons by telephone and email.

Hurricane Surge Damage

ALDOT owns and maintains many bridges in coastal areas where storm surge due to hurricanes can cause damage to the bridge. A primary concern is the effect of lateral loading due to wave action on the bridge superstructure during a storm surge. After a hurricane makes landfall along the Alabama Gulf Coast, quick visual inspections of bridges in the path are performed to assess the effects of the storm. An improvement in these inspections is possible through the use of a system that can rapidly establish the overall geometry of a bridge and compare it to the geometry determined from data collected prior to the storm. For example, the ideal system would be mounted in a vehicle and be capable of detecting displacement of specific points on a bridge when the vehicle is driven across the bridge.

A system of the type envisioned here can have many uses beyond inspections immediately following a hurricane. This system would be an excellent supplement to a barge impact detection system. A system of this type would also be an excellent addition to the ALDOT bridge inspection program.

ALDOT is not aware of the existence of a vehicle mounted system that can establish the geometry of a bridge. There may be less sophisticated systems that can provide a level of convenience close to that of a vehicle mounted system. GPS and standard surveying technologies have the potential to meet the object of rapidly establishing the geometry of a structure if the equipment is adapted for a specific structure with a single objective in mind. Field data collection will be performed by bridge inspectors, so it is important that

the data analysis is preprogrammed into the system so that surveying expertise is not required.

Minimum capabilities required of a system for evaluating the geometry of a bridge are as follows. The system must allow bridge inspectors to rapidly collect all the necessary field data, be pre-programmed to use the field data to establish the vertical and horizontal positions of points on the structure, compare the position of each point relative to established locations, and report the change of position of each point. All this should be accomplished within an hour.

Streambed Scour

Streambed scour can pose a significant threat to the stability of a bridge depending on the combination of stream flow, bridge geometry, foundation type and soil conditions. Loss of soil adjacent to bridge foundations is most likely during periods of peak stream flow associated with very heavy rains. Increased water velocities at the bridge piers can create scour holes that cause a decrease in the foundation's load carrying capacity. Scour holes created during heavy rains can fill with sediments soon after a period of peak flow. This adds an extra challenge to the task of detecting scour holes. Scour holes must be detected during the period of peak flow. During periods of peak flow it is also common to have debris such as tree limbs and trunks to collect around the bridge piers. The debris can hinder the detection of scour holes and damage the detection system.

An effective system for detecting detrimental streambed scour must be capable of detecting the loss of soil from a ten-foot radius around a bridge pier at anytime, including periods of peak flow. The system must have an independent power source such as solar power and a mode of communication such as cellular telephone. The system must transmit a warning when the loss of soil adjacent to a pier exceeds a programmable threshold or when the stream velocity exceeds a programmable threshold. The system must be capable of recording and transmitting raw data to an ALDOT computer. Computer software must be provided that interprets the raw data and provides a real-time, or essentially real-time, output of the streambed topography at critical locations. Viewing of real-time output must be possible on-demand at an ALDOT office location, or at the bridge site.

Overweight Vehicles

ALDOTs BRLT Section has been successful in increasing the posted truck weight limits of many of Alabama's two-lane bridges on state routes. The increased weight limits are justified by a combination of refined structural analyses and field load testing. Establishing a load limit requires engineering judgment regarding the truck traffic expected on a bridge. Information about the heavy truck traffic on particular stretches of state routes can be a valuable supplement to the structural data used in establishing load limits. A system that

collects and analyzes data about the heavy trucks that cross a bridge would be a useful supplement the equipment currently available to the BRLT Section.

ALDOT is interested in obtaining a portable, easy-to-install system that can determine the number of axles, the gross vehicle weight, and the traffic lane of each heavy vehicle that crosses a bridge. The system should store this data and transmit a copy of the data every two hours to an ALDOT computer. Software must be available that permits a user to view graphical representations of the data such as a histogram of gross vehicle weights for any two hour period or any combination of two hour periods.

Special Condition Monitoring

ALDOT's BRLT Section is responsible for performing a forensic investigation and monitoring the performance of a bridge when a special condition such as damage or deterioration is found that causes a safety concern. If the special condition is an immediate threat to the safety of the bridge, the bridge is closed. If the special condition is not an immediate threat, but has the potential to quickly become a threat, then a monitoring program is started to provide the information needed to ensure the safety of the bridge.

Forensic investigation is used to identify the cause and to more accurately assess the threat to the safety of a structure. Monitoring is used to identify changes in the condition and to assess the rate of change. Instrumentation and field data collection are important parts of both a forensic investigation and performance monitoring. ALDOTs BRLT Section must be equipped and ready to address a wide range of possibilities since the occurrence of special conditions cannot be predicted. The role of the BRLT Section in monitoring special conditions is short-term. Monitoring only continues until repairs are made or it is concluded that the special condition does not pose a threat to the safety of the bridge.

ALDOT is committed to maintaining the readiness of the BRLT Section through periodic purchases of monitoring equipment and training of personnel. The BRLT Section is a very hands-on group that needs rugged, durable, portable equipment that can be quickly installed and configured to make measurements with one to 30 sensors.

APPLICATIONS FOR THE FUTURE

Descriptions are provided above for bridge monitoring applications and systems that are currently of interest to ALDOT. These systems provide information recognized to be of value to ALDOT. None of these systems are essential for continued safe operation of Alabama's transportation network, but each will be useful and desirable if appropriately priced.

ALDOT is interested in bridge monitoring systems that will appropriately be referred to in the future as bridge health monitoring systems. A robust bridge health monitoring system will continuously assess the condition, or state-of-health, of a bridge and provide ALDOT with action items when there is a significant change in condition. Systems available today do not provide this level of health monitoring and in most cases provide the user with only raw data that must be interpreted. This is inefficient when applied to typical bridges where there is no special condition, damage, or deterioration toward which a monitoring program can be targeted.

Bridge health monitoring systems of the future will have the capability of predicting the remaining life of bridges and bridge components based on continuous monitoring of structural integrity, environmental factors, and traffic loading. Accurate predictions of remaining life require accurate modeling of the relationship between the deterioration of bridge components and the environmental factors and traffic loading that cause deterioration. Bridge deterioration modeling is not sufficiently developed today to make the monitoring of a bridge's "health" possible. The Federal Highway Administration has a twenty-year Long-Term Bridge Performance research program underway. One of FHWA's goals is the development of the bridge deterioration models that are needed for the advancement of bridge health monitoring.

INSTRUCTIONS FOR VENDORS

ALDOT welcomes proposals from vendors for bridge monitoring technologies and equipment, but those technologies must meet a high standard to earn serious consideration for purchase. For example, nonspecific claims of improved safety and extended bridge life alone do not meet that standard. ALDOT engineers continually weigh maintenance and operational alternatives to establish which will have the greatest impact on safety and longevity. Alabama's bridges meet the standards for safety established by FHWA and AASHTO and expected by the public. Expenditures for additional safety and longevity at one bridge decrease the funds available to maintain another part of the transportation system. All expenditures must add corresponding value to ALDOTs transportation system.

Vendors are responsible for identifying and communicating scenarios where their systems provide a cost-effective way to meet a real need. Vendors should not expect ALDOT to expend significant man-hours and resources identifying applications for their systems beyond those listed in this document. And, ALDOT is not responsible for costs incurred by a vendor in their marketing efforts.

Initial contact should be made through Eric Christie, the Bridge Maintenance Engineer. His contact information is provided below. To facilitate discussion upon initial contact, each vendor should provide a written executive

summary not exceeding three pages that addresses the following questions as a minimum.

- What specific bridge monitoring application(s) are you proposing to address?
- What fundamental scientific or engineering principle is the basis for your system?
- What standard output does your system report to the bridge owner and how?
- Does your company provide equipment for use by bridge owners? Or, does your company design the sensor array, install, and operate the monitoring system?
- How should ALDOT screen its bridge inventory to identify bridges where your system can be used cost-effectively? What are the characteristics of the best candidate bridges?
- Is your system cost-effective for use at a single bridge, or are you proposing the development of a monitoring network?
- What is the approximate cost per bridge of your system?
- What factors affect the cost of your system and how sensitive is the cost to those factors?

In addition to the executive summary, vendors may wish to provide standard marketing information that addresses typical questions such as the following.

- Overall, how does your system operate? Is it self-contained, portable, programmable, computer controlled, and/or adaptable to a wide range of bridge types?
- What is the expected service life of your system and how was that established?
- What warrantees does your company provide?
- What other states are currently using your system?
- Who may ALDOT contact in those states for additional information about your system and company?

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