Quarterly Report #7

Development of Hand-held Thermographic Inspection Technologies
RI06-038

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Summary of Accomplishments and Activities

Work this quarter included completing Task 2, *Controlled Testing of Concrete Test Specimen*. Task 3, *Operational Testing*, is ongoing, with each participating State currently testing cameras during normal operations. Work on Task 4, *Final Report*, has been initiated. A summary of progress on the project is included below.

Task 1 Preliminary Study Development

All elements of Task 1 have been completed.

Task 2 Controlled Testing of Concrete Test Specimen

The test block including targets at depths of 1, 2, 3 and 5 in. has been constructed and 3 months of data was collected on the south side of the block during the months of November, 2007 through January, 2008. The data acquisition house was moved to the North side of the block to collect data on the shady side of the block, where the embedded targets are not exposed to direct sunlight. Valid, continuous data was collected during the months of May, June and July. This data is being utilized to evaluate the trends for inspection of structures that are not exposed to direct sunlight. Data collection at the test block has been discontinued. The project is focusing on analysis of data.

The assembly of all data and analysis is ongoing in an effort to develop usable guidelines for infrared thermography. General guidelines related to the time of day that is optimum for inspection and the general effects of environmental variables such as wind speed and solar loading have been completed. Empirical data from the study supports general knowledge about the behavior of subsurface features in concrete and appropriate conditions for inspection. The data generally validates the training materials provided for the participating States, and some consideration of refining these materials for dissemination to other States may be appropriate for consideration as an implementation activity.

Analysis of shady-side data has been ongoing, with analysis focused on determining the effects of rate of change in ambient temperature on the thermal contrast apparent in the thermal images, both during the daytime and the nighttime. Analysis on the effects of stored heat in the block has also been conducted as a means of assessing the effects of the environment on the inspection of non-solar exposed surfaces. It has been observed through the data analysis that the peak negative contrast typically occurs early in the evening, followed by a long and relatively constant period of contrast at a somewhat lower level. This result indicates that the ambient temperature changes on the day preceding the nighttime inspection have a significant effect on the observed thermal contrast. This result is significant in identifying that a nighttime inspection is most effective when the ambient temperature change on the prior day has been large. This is due to the thermal inertia of the block, which is warming out-of-phase with the daily ambient temperature variations, such that the intact block continues to warm into the evening as the thermal wave propagates through the block. This analysis is ongoing, and will be presented more completely during the project conference call.

Another focus of research in this quarter has been an attempt to develop an empirical model that characterizes the quality of a given set of environmental conditions for the inspection of concrete structures. This model is being developed based on the data collected through the study. The goal of the model development is to provide a user with a calculation, formula or look-up chart that enables the user to determine the quality of a given day in real-time, such that the user can assess if that day is a good day for inspection using an IR camera.

To support this goal, various combinations of measurements from the study have been combined to develop a numerical factor that correlates with the quality of a given day for inspection. One model that has shown some progress combines the empirical measurements according to the following equations:

$$Thermal\ contrast = \frac{\left((Ambient\ Temperature\ Change+273)\times(Solar\ Loading+1)\right)}{(Wind\ Speed+1)\times\left(\frac{Humidity}{100}\right)^2} \qquad (1)$$

In the model, the ambient temperature change over 2 hours is calculated to include in the model the effects of rate of change analysis. The inclusion of a non-zero solar loading factor allows for the model to produce positive and negative contrast values, such that it could be effective for both daytime and nighttime inspections. Figure 1 shows the results of applying the model to the three months of data. This model development is in-progress, and firm conclusions or complete analysis have not yet been completed. However, the model does show potential for providing a tool for identifying optimum days for inspection based on a quantitative value depending on the existing (or recent) environmental conditions.

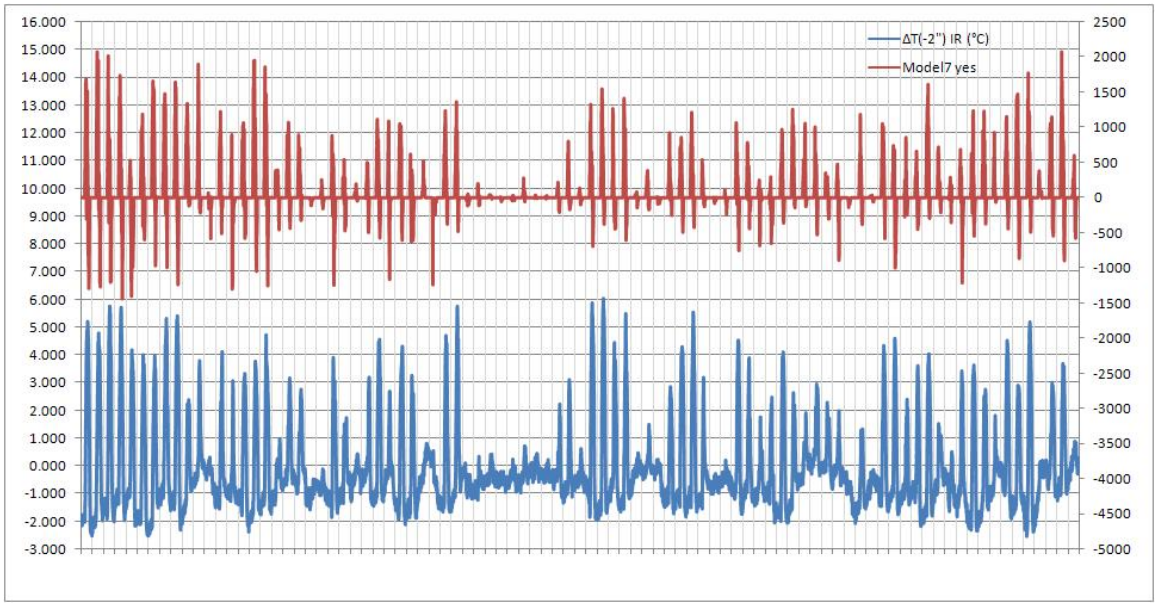

Figure 1. Results of empirical model output (top, right axis) and thermal contrasts for the 2" deep target (bottom, left axis).

As shown in the Figure, there is a strong correlation between this simple model and the thermal contrast for the sunny-side of the block. However, this correlation is driven largely by the solar loading for the daytime contrast, such that the general shape of the plot being similar is not necessarily significant. The correlation between the maximum contrast achieved and the maximum values for the model is being evaluated, along with the correlation between the area under the curve for the model and the thermal contrast, both for positive (daytime) and negative (nighttime) contrasts. Perturbations based on this initial model are being analyzed to develop on equations or factor that will apply to both the sunny and shady conditions.

Task 3. Operational Testing

Operational testing has been ongoing in the participating States. Collection of data based on field experiences has been limited. Further work to collect data from participating States is needed to identify problems that have emerged through field testing.

Task 4 Final Report

Efforts to develop the final report and associated guidelines have been initiated but are in the early phases. Processing and analysis of data is taking significantly longer than anticipated. Significant efforts to build an empirical model based on environmental variables have yielded positive results, but has been significantly more difficult than expected, slowing the progress toward completing a useable guideline.

4. Issues or Problems that need to be addressed.

There has been an impact on the overall budget as a result of procuring four hand-held cameras rather than the three originally planned. The impact on the overall budget is currently being analyzed.

Schedule

The project is currently behind schedule in terms of developing the final report, due the other tremendous amount of data generated during the study, and efforts to fully realize the potential value of that data. Additional data on the operational experiences of the States is also needed to make the final report as complete as possible. The project team believes adequate data has been collected to date to develop effective conclusions and provide necessary guidance on the implementation of research results, based on the test block data. However, the analysis of that data has taken longer than anticipated. Additional time may be requested to complete the final report such that data analysis can be as complete as possible. However, any additional requests for time to complete the report are not expected to be significant.

Table 1. Summary of project schedule.

	Months (Beginning February 1, 2007)																							
Tasks	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
1 Preliminary Study Development																									
2 Controlled Testing of Concrete Specimen																									
3 Operational Testing																									
4 Final Report																									

% of Budget Expended: Approximately 98% of the funding provided by the participating States has been expended. All of the University-provided funded has been expended. Approximately 95% of the University Transportation Center budget has been expended. The overall budget is being analyzed to determine if additional funds will be necessary to complete the project, as noted in (4) above.