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16. Abstract

During TxDOT Project 0-4385, a sliding profiler device was developed that has the capability to be attached to a concrete paver for determining the location of bumps on fresh concrete. This device has the potential to provide TxDOT and contractors an early identification of defects in newly poured concrete. Contractors could then fix the defects while the concrete is still fresh. During Project 5-4385-01, this device was implemented on several construction projects. This report describes the implementation of this device.

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PILOT IMPLEMENTATION OF BUMP DETECTION PROFILER

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ACKNOWLEDGMENTS

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INTRODUCTION

BACKGROUND

During Texas Department of Transportation (TxDOT) Project 0-4385 with the University of Texas at Arlington (UTA) and the Texas Transportation Institute (TTI) of Texas A&M University (See Report 0-4385-1), a sliding profiler device[1] was developed that has the capability to be attached to a concrete paver for determining the location of bumps on fresh concrete. If implemented and working properly, this device has the potential to provide TxDOT and contractors an early identification of defects in newly poured concrete. Contractors could then fix the defects while the concrete is still fresh and pliable. This device could potentially eliminate the need to use grinding operations in many cases to improve ride quality of CRC pavements thereby reducing contractor cost. During the end of Project 0-4385, the sliding profiler was taken on a project on I-20 near New Salem, Texas. The results of the device on this project for estimating profile and bump detection on wet concrete appeared promising. Following the tests a number of improvements were recommended as well as the need for further limited verification on several construction jobs. For example, runs before and after the finishers where defects are detected would help determine if improvements were made. Comparisons with bump profiles from the sliding profiler and reference profile would help tune the profile/bump calculation algorithm. Other recommended improvements included:

- Design and fabricate a production version
- Determine best target hardware and software platform
- Redesign and fabricate sliding profiler carriage
- Redesign and fabricate sliding profiler mounting system

Many of these recommendations were implemented in a follow on Project, 5-4385-01, described in this report. This report discusses the implementation project and results of using this device on several projects around the stat

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[1] Patent pending.

IMPLEMENTATION PROJECT 5-4385-01

In 2005, TxDOT initiated Project 5-4385-01, Pilot Implementation of Bump Detection Profilers for CRCP Construction, with The University of Texas at Arlington and the Texas Transportation Institute for a pilot implementation of this device and the construction of three units for TxDOT use. The implementation included the following tasks: fine-tuning, fabrication & testing of a production version of the device and the deployment of the units in three districts.

Implementation efforts first involved obtaining a working system. It was decided early on at the first project meeting with TxDOT personnel, to construct a simple and easy to use device, which did not require the computer, or inclusion of a battery. Instead, bumps would be detected and the operator simply notified by some type of a flashing light. Additionally, a marker was added to mark the exact spot that a bump was detected for quick location by the finishers.

In the summer of 2005 work began on building the production unit and at the same time, selecting a real-time operating system, and writing the real-time bump detection program. Windows CE was selected for the real-time operating system, primarily because, among other things, it was a true real-time system and supported by Microsoft. The initial bump detection method developed was somewhat similar to the one used in the current ride specifications (Special Specification 5880 and Item 585). Because this had to be done in real-time, a method was developed and tested on previous data collected during Project 0-4385.

PRODUCTION UNIT TESTING AT UTA AND SH 360

During the fall of 2005, the first version of the production unit was completed and tested in a sandbox constructed for the test at the Texas A&M Riverside Campus. The parts needed for the instrumentation were also obtained, wired and mounted within the sliding profiler unit. The system was then brought to UTA where the bump algorithm was tested by pulling the device down the hall outside the UTA Transportation Instrumentation Lab. Figure 1 illustrates the device being tested at UTA.

A number of problems in the circuitry and program were noted in these tests. These were subsequently addressed and fixed, and the device was then taken out on a construction project in December of 2005, on SH 360, west of the Dallas/Fort Worth (DFW) airport.
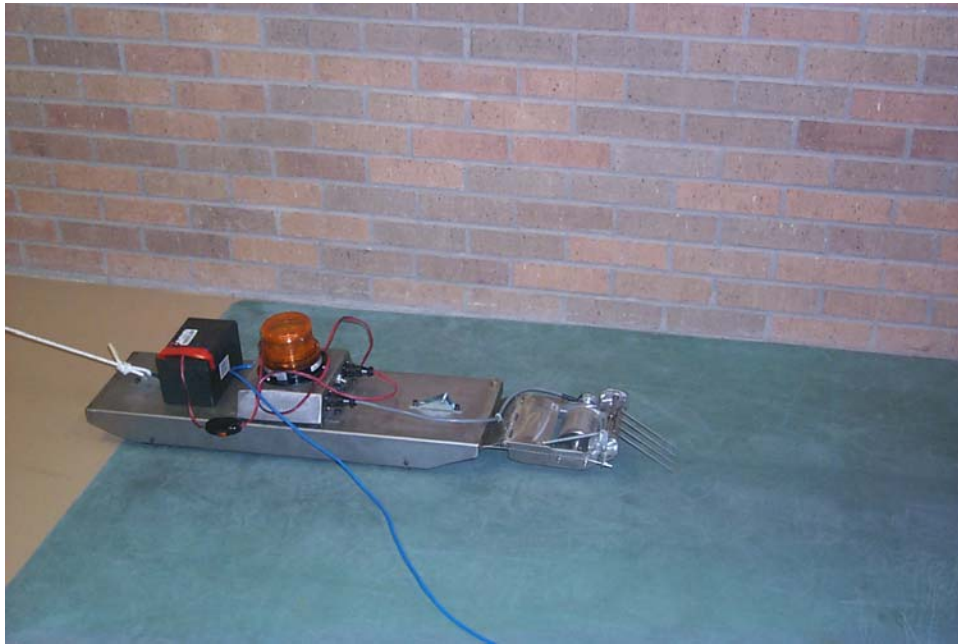

Figure 1 Testing Unit at UTA Lab

For these tests, the plan called for the sliding profiler to be attached to the work bridge following the paver for ease in installing and using the device. This configuration would also provide a means by which the area measured by the sliding profiler could easily be rerun to check the reworked pavement after a bump has been located. During the tests of the new production unit at this site, the marker mechanism, a new design for marking the pavement for the finishers when detecting a bump, was found to be too heavy to float on top of the wet pavement. This resulted in the back of the sliding profiler unit digging into the wet concrete and keeping the distance wheel from proper rotation. As a result of these tests, the unit was taken back to TTI for a redesign of the marker assembly.

EL PASO SLIDING PROFILER RUNS

As discussed above, following the test made on SH 360, the sliding profiler was redesigned reducing the weight and increasing the surface area of the sliding carriage. The unit was then taken to a construction job in El Paso on February 14th, 2006. The construction job was on a Dan Williams Co. paving project on Loop 375. The test involved mounting the sliding profiler on a work bridge and pushing it along on fresh concrete. Figure 2 illustrates the redesigned carriage. The heavier part of the marker assembly was removed and the marker portion was pushed back and not operative. The marker assembly was later completely removed.

Figure 2 Sliding Profiler on El Paso Tests after Hwy 360 Adjustments

Prior to data collection, researchers calibrated the distance wheel of the sliding profiler. For the first 525 feet, the sliding profiler traveled before the finishers worked on the concrete, and for the last 400 feet, the sliding profiler traveled after the finishers worked on the concrete.

A log was kept while the data were collected, and bumps were noted in the log when the light flashed. Initially the threshold was set at 150 mils and no bumps were noted. To show interested construction personnel that the sliding profiler would find more bumps if the threshold was set lower, the threshold was changed to 75 mils. Subsequently, there were a large number of bumps noted, primarily because of the low setting of the threshold (75 mils). The bump indicator was also more susceptible to false bumps caused by jerking of the work bridge as it was manually pushed along the pavement.

The data were recorded and then later processed with the bump threshold set to 150 mils as specified in the ride quality procedure. Figure 3 illustrates the bumps found for the 150 mils setting and the differences between points and the eight foot running average used in the sliding profiler's bump detection procedure.
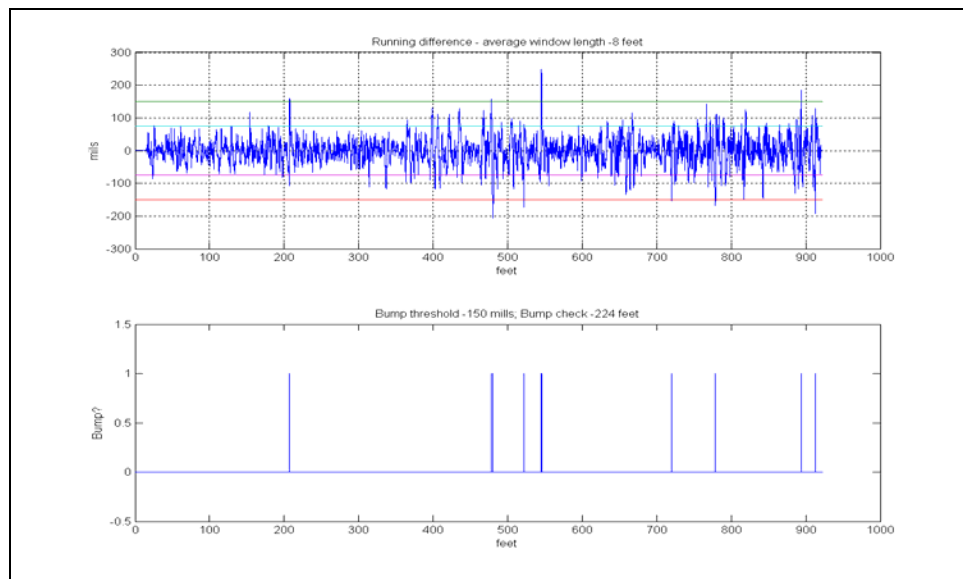

Figure 3 El Paso Points Differences between Running Average
(Bump Detection set to 150 mils)

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While watching the sliding profiler, it was suggested that the system be put in a latched box on a snowboard. This suggestion is more in line with the original ski shape design initially discussed during Project 0-4385.

The sliding profiler was calibrated after the data runs to see if the concrete had any effect upon the distance wheel. There was only a slight difference of about 0.21 inch between the first and second calibrations and after the sliding profiler was used to monitor the smoothness of the wet concrete (over 900 feet). Thus the distance wheel seemed to function properly on wet concrete.

THE SECOND VISIT TO EL PASO

The second El Paso test was to occur on the week of March 5th, on the same paving job. Unfortunately, a windstorm hit El Paso during that week, followed by a cold spell and paving was cancelled on both March 9th and March 10th. Between the first and second tests, researchers at UTA purchased a snow board and brought it to El Paso. The snowboard was given to TTI for modification so that it could be used as the carriage for the sliding profiler.

WALKING PROFILER

TTI researchers ran the Walking Profiler on the target section during the week of March 5th to obtain reference data to compare with the sliding profiler test results. Reference data were collected following TxDOT Test Method Tex-1001S, except that a sampling interval of 9.5 inches was used to collect the reference profile measurements. These measurements identified a bump in the dry concrete that was later shown consistent with one found by the sliding profiler.

The current method for detecting localized roughness in TxDOT's Ride Quality Program finds bumps in the profile data by comparing successive points with a 25-foot running average. A somewhat similar procedure is used by the sliding profiler, except an eight foot running average is used. Because of this average and the bump identification method used, bumps are not indicated by the sliding profiler until about six to eight feet from the actual location of the bump

or dip. Additionally, the sliding profiler takes one reading about every 0.05 inches, while the Walking Profiler reference data taken on the reference section takes a sample every 9.5 inches.

A comparison between the two detection methods is shown in the next figure. Because of the bump detection method used, the Sliding Profiler bump detection readings are always offset by about four feet. Note that the Walking Profiler detected a bump at 467 feet, and the Sliding Profiler detected a significant bump at 469 feet as illustrated in Figure 4.
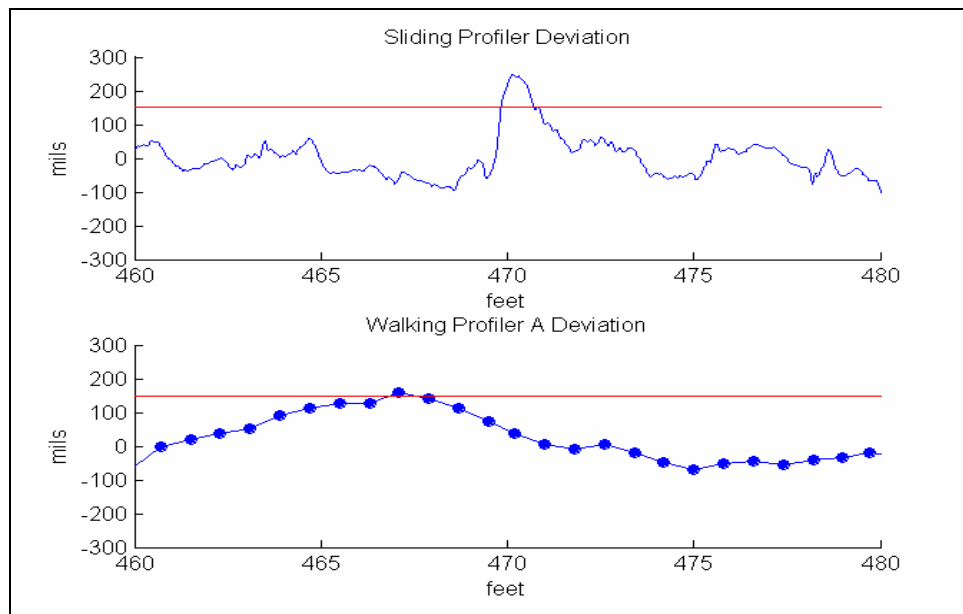

Figure 4 Comparison of El Paso 2 Bump Location and El Paso 1 Deviation at Same Point

DECATUR SLIDING PROFILER RUNS

Researchers next took the sliding profiler to a project along US 380 in Decatur, Texas on March24. Like the El Paso tests, the contractor, Site Concrete of Grand Prairie, provided a work bridge and crew for data collection. Researchers first went to the site and ran the sliding profiler on a patch of wet concrete that morning. The sliding profiler was then connected to the work bridge, and as in El Paso, was manually pushed over the wet concrete. The work bridge and sliding profiler were first placed directly behind the paver, in front of the finishers. After a section of about 200 feet was measured, the system was backed up to the beginning of the wet

pavement, which had now been worked by the finishers, and the profiler was run over the section a second time. In both cases, a large number of bumps were noted. It was unknown if this was due to actual bumps, the bump settings or because of jerking caused by pushing the work bridge. Two workers, one on either side of the bridge would push the bridge. Additionally, if one end started before the other, the work bridge would not only jerk, but also result in pulling the profiler unit slightly to the right or left. A bump would typically be noted soon (six to eight feet) after the bridge would start up again. The data from the two runs were later plotted for comparison. The approximately same starting location was obtained by using a combination of the GPS coordinates and the distance count. Once the same beginning and end were established, the linear trend was removed and plotted in Figure 5 below.
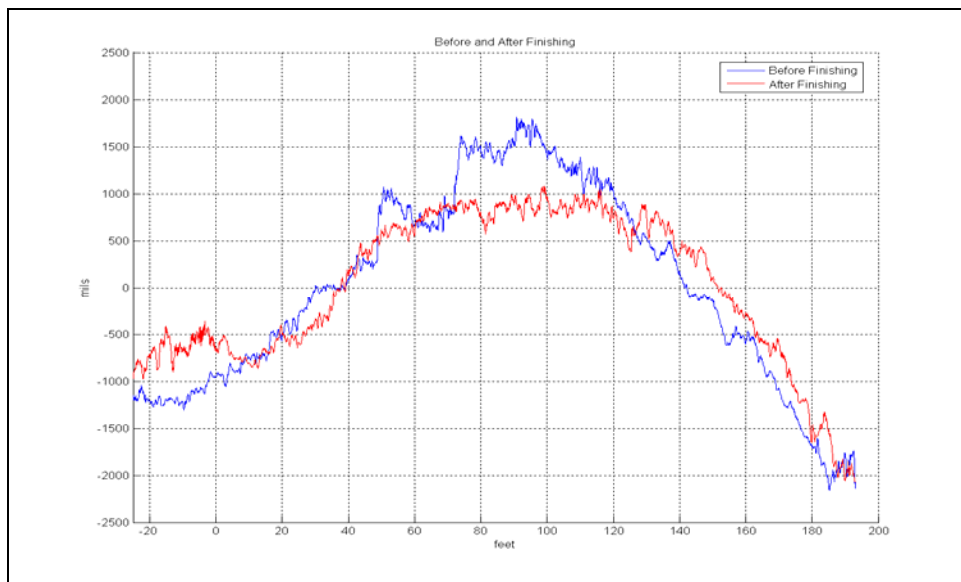

Figure 5 Decatur Section Before and After Finishing

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THE SNOWBOARD

As mentioned in the previous section, during the tests in El Paso, there was a concern on the markings left by the sliding profiler on the wet concrete from the wheel and carriage sides when it was used after the finishers. A snowboard was purchased to see if the profiling carriage could be changed from its current design to a snowboard in order to try and reduce these markings and increase the surface area supporting the electronics. Also planned was to place the measuring wheel inside the carriage. Thus, one objective of the Decatur project was to perform a test on the snowboard that was purchased during the second El Paso test. In order to flatten the surface area of the snowboard, it was fitted with stiffeners to remove the camber to make it flat. A hook and rope assembly was attached, and the modified snowboard was dragged across the lane width on the wet concrete during the Decatur runs. The modified snowboard left a wide, smooth track where it had crossed the pavement. Next, weights (approximately the weight of the sensor, distance wheel, and electronics) were added to the snowboard, and it was again pulled across the concrete. The snowboard seemed to float somewhat better than the carriage which had been used for the El Paso tests. The board however did not have a distance sensor wheel which had made some of the markings noted in El Paso.

The snowboard version was fitted with the electronics and distance wheel. This version was tested by once again pulling it across the lane width on the wet concrete on a project in Austin and found to float with minimal path markings. It was in hopes that the unit could be then actually used on the project, but this was not possible because of problems and delays in the construction project.

THE GRAND PRAIRIE DATA RUNS

The last set of tests was made on an Abrams's construction project on SH 161 in Grand Prairie in the Dallas District in August of 2006. For these runs, the sliding profiler was attached to a motorized work bridge in hopes there would be less jerking actions. The work bridge was positioned behind the finishers. The sliding profiler was pulled for about 300 feet where about six bumps were noted by the flashing light.

Figure 6 Sliding Profiler Attached to a Motorized Work Bridge

Three of the bumps detected seemed to be caused from the start up of the work bridge. After about 250 feet and after measuring one of the areas the paving operation had to stop and then restart because of the lack of concrete. A bump was detected by the sliding profiler that did not appear to be the result of the start up jerk. The finishers went back to rework this area of the section. The work bridge and sliding profiler were then repositioned back about 100 feet and the section rerun. At about the same spot, a bump was still detected. Measurements continued a bit longer before the paving machine was stopped because of delays at the concrete plant providing concrete for the paver.

Later during the month, after the concrete had dried, the walking profiler was brought to the site and a reference profile was taken over the entire section. Figure 7 illustrates an overlay of the reference profile and data collected by the sliding profiler. The blue plot illustrates the 100 foot section where the pavement was rerun after the bump was detected.
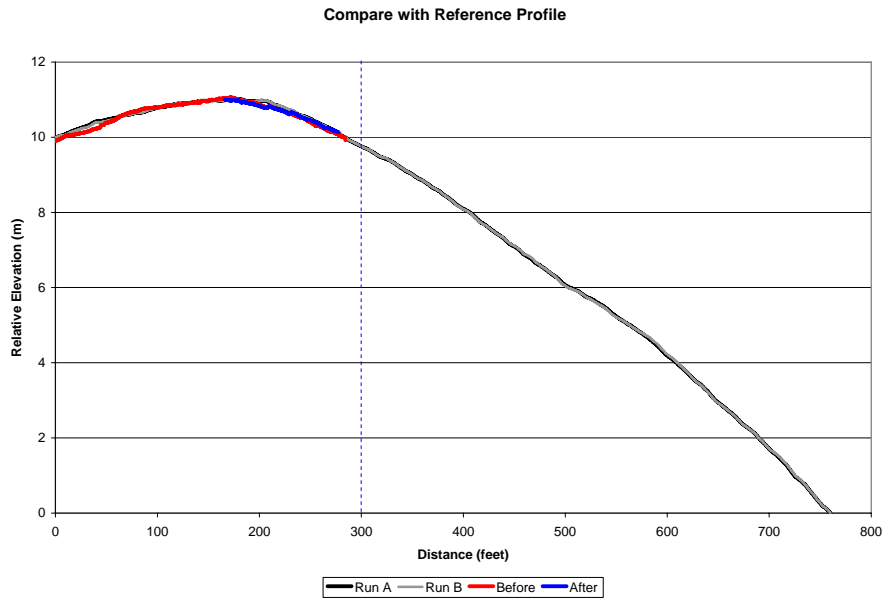
Compare with Reference Profile

Figure 7 Comparison of Sliding Profiler with Reference Profile

Figure 8 illustrates a bump found in the reference profile at approximately the same location as the bump noted by the sliding profiler during operations. Figure 9 illustrates a plot of the profile from the sliding profiler after reworking the bump area but still showing a bump in approximately the same area as found in the reference profile and during measurements.
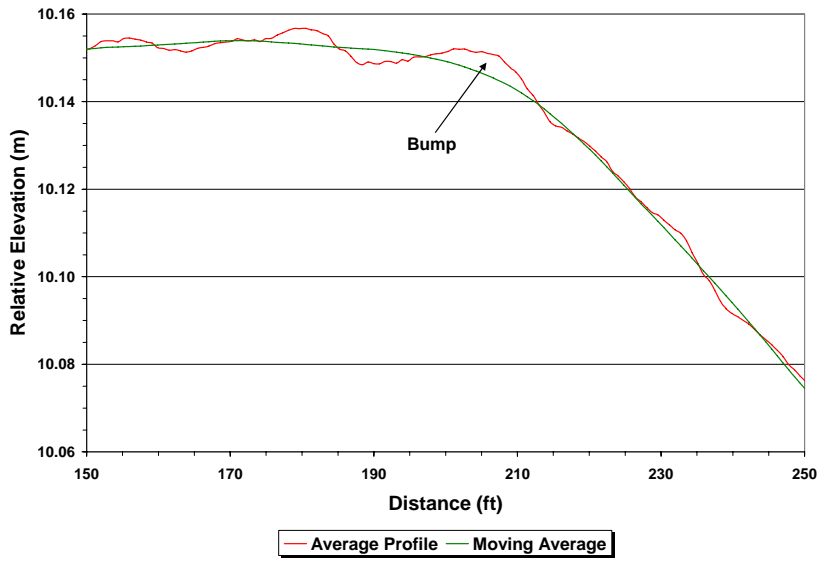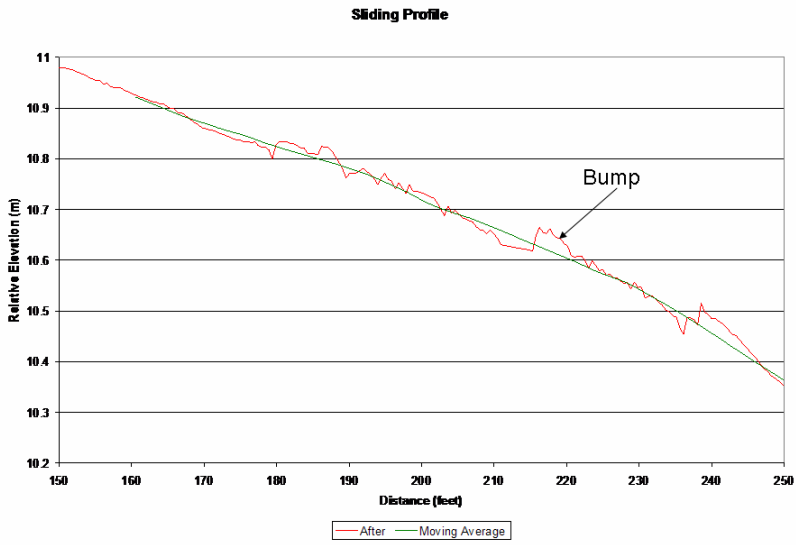
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Figure 8 Bump Illustrated on Pavement

Figure 9 Bump Found in Sliding Profiler Data

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5-4385-01 WRAP-UP MEETING DECEMBER 20, 2006

In a project wrap-up meeting on December 20, 2006, with David Head and other interested TxDOT personnel, the problems of introducing false bumps because of jerks when using the work bridge was discussed. UTA researchers developed a simple jerk removal procedure that was applied to the El Paso data. This procedure eliminated some of the false bump readings. Figure 14 shows that the number of bumps detected during the El Paso data runs changed from eight to three for the 150-mils bump setting (See Figure 3). In Figure 10, the first bump is the same one found in the reference profile taken by the Walking Profiler. The second bump indicated is at approximately the location where the work bridge was moved behind the finishers. Differences between the Walking Profiler and Sliding Profiler results may be due to changes in the concrete surface brought about by tining and curing. Note that the test with the Sliding Profiler was done on wet concrete while the test with the Walking Profiler was done after the concrete has hardened.
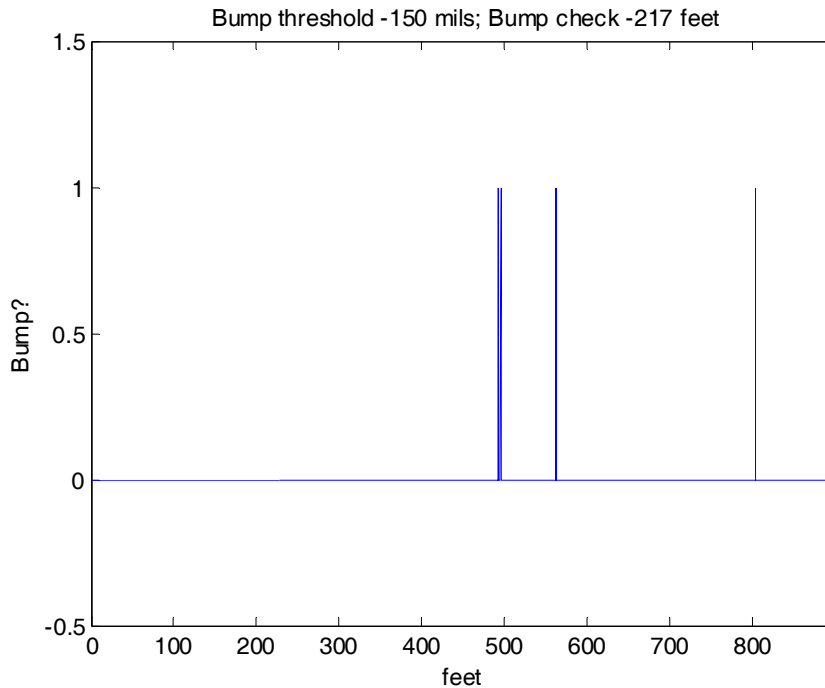

Figure 10 Bump Detected Using Jerk Procedure

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SUMMARY OF RESULTS, CONCLUSIONS
AND RECOMMENDATIONS

The efforts in developing a production version and pilot implementation of the sliding profiler device in Project 0-4385 are described in this project. A number of improvements were made to the profiler carriage. The electronics of the system used in Project 0-4385 included a sensor, distance encoder and embedded PC board with wireless Ethernet capability, which provided a means of acquiring data for sending to a notebook PC. During this project, a real-time profile computation and bump detection program was written to run on an embedded PC using a Windows CE platform. Although a method was included that could be used to capture sensor data for later analysis, the primary function of the device was to be an easy to use and stand-alone method for detecting bumps. Bumps detected are denoted by a flashing light as the device is pulled along the wet pavement behind the paver.

Three sliding profiler devices including hardware for attachments and an instruction manual were delivered to TxDOT. Figure 11 illustrates the sliding profiler delivered to TxDOT along with hardware used for attachment of the sliding profiler to an autofloat, work bridge or paver.

The system had problems with false bump detection, caused by jerking of the sliding profiler device as it was pulled behind the paver. This was not noticed during the tests made in Project 0-4385 on I-20, probably due to the fact that the profiler was attached to the paver. The paving machine starts up in a more constant motion than a work bridge. Thus it is recommended that the sliding profiler be attached to the paver behind the auto float when used in practice. The paver moves at a more consistent rate than a work bridge that has to be manually pushed or even one that is motorized. A procedure for minimizing jerk has been developed but was not implemented in the three versions delivered to TxDOT.

Other modifications that could aid the production version include a more user friendly means of collecting and storing sensor, profile and bump data computed by the device. Although the system can be run with two operating modes, both a stand-alone and a data acquisition mode, the

primary purpose of the project was a production unit that does not require the use of an external PC or other remote operations. Thus the PC data collection software only provided researchers a means for testing or modifying the unit. The system delivered is very easy to use and will start up automatically by simply turning on the power.
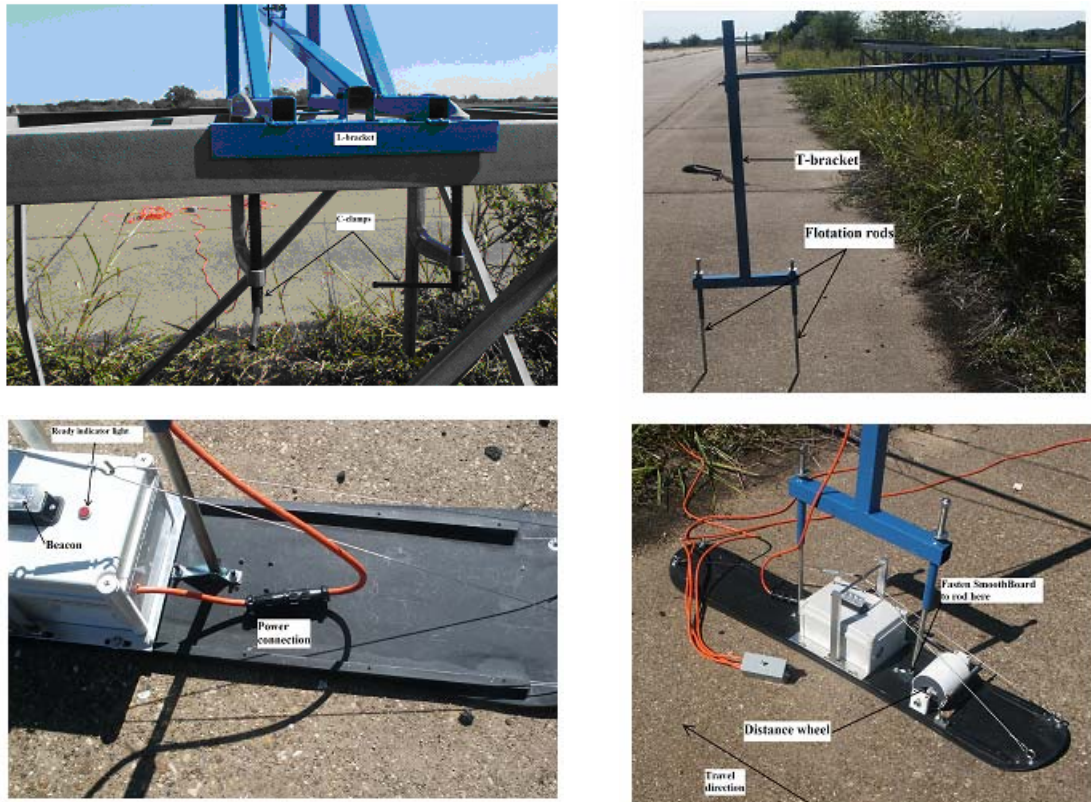

Figure 11 Sliding Profiler and Connection Hardware