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DEVELOPMENT OF A SYSTEM TO VALIDATE AND CERTIFY EQUIPMENT AND TECHNICIANS FOR UNDERGROUND PIPE INSPECTION

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Storm water delivery systems are an integral part of transportation construction projects. Pipe placement is costly and time consuming, and when a system fails, the costs associated with repairing and replacing the system are significantly greater because of the existing infrastructure often built above the pipe. Several state departments of transportation in the U.S. have standard specifications for the inspection of newly-installed pipe, but no Department of Transportation has standardized operator training for laser profiling or closed-circuit television (CCTV) pipe inspection. This is significant because state-of-the-art systems for underground pipe inspection currently utilizes these two technologies. Likewise, standards do not exist for the certification of systems or operators for CCTV, laser profiling, or other technologies. Within this report are the findings of an ongoing project funded by the Florida Department of Transportation. This paper reports on pipe inspection in the U.S., the development of a field test for laser- and CCTV-based inspection systems, and practical exams for prospective operators of certified systems used in the inspection of underground pipe construction.

Keywords: Underground pipe, Storm water, Pipe inspection, Laser profiling, Closed-circuit television (CCTV), Equipment certification.

1 INTRODUCTION

Ensuring the longevity of a nation’s roadways is tantamount to sustaining national livelihood; improperly installed storm water pipe culverts damage those roadways and result in expensive repairs, which often further damage the roadway. In order to remedy poorly-placed pipe, infrastructure already in place often must be cleared. Depending on the production schedule, this may entail removal of the topmost pavement layer (Hovland and Najafi 2009). However, the accrued costs associated with repairing newly-installed pipe culverts pale in comparison with the costs resulting from future system failures.

Advancements in modern technology have introduced efficient methods of locating and identifying deficiencies in pipeline systems. However, issues have surfaced regarding the accuracy and the consistency of operation of these complex pieces of equipment. The Florida Department of Transportation (FDOT), for example, has expressed concern over the lack of a standardized testing procedure for laser profiling equipment operators. This project, therefore, endeavors to establish a certifiable examination that will demonstrate an operator's competency with regards to both equipment use and knowledge of inspection procedures.

This project additionally seeks to develop a validation method for laser profiling equipment used in pipe culvert inspections (which is concurrent with the FDOT's employment of an "approved vendors list"). Any system selected for use in inspecting pipelines must display proper laser function and calibration. Moreover, the method of calibration must be such that the specific type of laser does not influence results. In other words, a calibration test must be developed that will objectively authenticate the laser profiling equipment. This calibration test must address the natural discrepancy in accuracy readings between laboratory conditions and field-testing conditions.

It is necessary to investigate the methods employed by all DOT offices in post-installation pipe inspection, and compare the findings with Florida's current practice. To that end, each state DOT was contacted and interviewed on the subject.

2 LITERATURE REVIEW

Laser profiling was originally developed as a means to inspect the placement of liners in cured-in-place pipe systems (Hancor 2007), and to investigate inflow conditions of existing pipe systems (Wirahadikusumah et al. 1998). With laser technology in pipe-culvert installation inspections came a more efficient means of locating and identifying defects in reinforced concrete pipe (RCP) systems. The National Association of Sewer Service Companies (NASSCO), however, recently expressed the concern that modern profiling technologies fail to provide the required, and repeatable, level of precision (Holdener 2011).

2.1 Culvert and Pipe-Installation Inspections

The criteria for inspecting newly installed storm water pipe can be found in FDOT's Standard Specifications for Road and Bridge Construction. Observable defects must be properly identified and located, the severity of these defects must be evaluated, and considerations for remediation must be made (as per the engineer's recommendation).

In 2004, before laser-scanning technology was put into practice, inspection consisted of a CCTV unit affixed to a mobile unit. The portable unit travelled along the pipe invert transmitting footage to an operator that would subsequently measure joint gaps and classify defects. This method of visual investigation was deemed subjective, and the operators were prone to fatigue and inexperience (Iyer and Sinha 2005). Bennett and Logan (2005) also articulated that CCTV cameras were limited in their accuracy to measure pipe defects, and in some circumstances failed to detect the defects at all.

2.2 FDOT Specification Requirements

In a series of meetings between FDOT, members of the Pipe Advisory Group (PAG), and members of the Pipe Installation Task Group, there is an account of laser profiling's early involvement in the state's pipe culvert inspection process. Discussions concerning the use of deflectometers and mandrels in detecting and testing pipe deflections began on June 6, 2005; by September 28, the committees were already considering the potential benefits surrounding implementation of a "laser ring" inspection method. By late 2005, the American Association of State Highway and

Transportation Officials (AASHTO) had been introduced to the laser profiling and sought its use in Florida. As of PAG's April 26, 2007 meeting, laser ring inspections had been implemented and were being used to inspect pipe culvert installation projects.

2.3 Impediments to Laser Profiling

While readily embraced and steadily growing in use, laser profiling as a means of inspecting system defects is not without issues (Sutton 2009). Although it presents data objectively, poor configuration and faulty positioning can create erroneous data (Dettmer et al. 2005).

2.3.1 *Equipment limitations*

Buonadonna et al. (2011) identified the most recurrent issues with laser profiling as: only data above a waterline will be collected (as water will refract the laser light); there is no distinguishing between material densities (e.g., spalling and corrosion may be falsely labeled as debris); and aligning the laser "cross-section" with the center of the pipe is an extremely difficult task.

2.3.2 *Operator limitations*

Profiling manufacturers and individuals in the inspection industry agreed that problems exist regarding inspectors (not) following FDOT pipeline inspection procedures (FDOT et al. 2011). Both groups mentioned the necessity for improving operator familiarity with and implementation of existing specification guidelines. For example, it was noted how operators often fail to observe the maximum allowable system speed (30 feet/minute). Other examples of operator error include the omission of gap reports for all pipe joints (*ibid*). Failure to properly clean and dewater a pipe prior to inspection was also a major concern of the industry members, as the resulting data may be skewed and require additional investigation (Motahari and Forteza date unknown).

Aside from operator error, there is also the potential for error in data analysis. Profiling manufacturers may provide either proprietary software and training, or access to an analysis center (Griffin 2008). In cases where a third party analyzes the data, there may exist a lack of sufficient information and input/output familiarity (FDOT et al. 2011). It is vital to have an operator that can fully comprehend the limitations of the equipment, recognize and remedy any common problems, and understand the analytical procedures involved in evaluating the information.

3 RESEARCH METHODS

There were three main objectives for this research. First, a synthesis of the industry was needed. Second, an approval process was developed for the various types of equipment utilized in pipe culvert installation inspections. Third, an investigation was conducted to establish a qualification program that would certify prospective equipment operators.

3.1 Data Acquisition

The synthesis of the industry required a series of three different interviews. The primary interview was conducted over the telephone and directed towards state DOT officials. The secondary interview was conducted via email and was directed towards DOTs that had demonstrated in their first interview that they had experience with CCTV and/or laser profiling testing methods. A third interview was also conducted via email surveying specific responders from the primary interview, inspection operators, and equipment manufacturers.

The testing of potential equipment and the certification of potential operators also required data gathering, and the questions that made up the written portion of the operator certification were taken directly from the 2013 FDOT specifications and the supplementary page in equipment calibration criteria.

4 RESULTS

4.1 Synthesis of the Industry

Thirty-two state agencies noted that their specifications required the inspection of pipe culvert installations. These agencies required either initial or final inspections, but in several cases neither was explicitly stated – so long as the inspection process occurred before final road opening. In a few instances, the process of "inspection" included pre-construction material/product quality assurance and/or control, and did not entail assembly process inspection. The number of states that made specific mention of the inspection methods required for pipe culvert installations are listed in Table 1. For the agencies whose specifications denoted permissible methods of inspection, a larger number of states listed mandrel testing (18 states). In decreasing order of popularity were CCTV (16 states), laser profiling (8 states), and video micrometer (5 states).

Table 1. Inspection Methods for Pipe Culvert Installations.

	States	
Inspection Method	**Number**	**Percentage**
Mandrel Testing	18	35%
CCTV	16	31%
Laser Profiling	8	16%
Video Micrometer	5	10%

Among investigating agencies that indicated more than one method of inspection, the combinations of technologies are noted in Table 2. These combinations were distinguished as either those including laser profiling or those not including laser profiling. The states that included laser profiling also all included the use of CCTV. A greater number of agencies also permitted both mandrel testing and laser profiling (6 agencies) than agencies permitting both laser profiling and video micrometer (3 states). Agencies that did not include the use of laser profiling used either mandrel testing or CCTV, or a combination of the two. And all methods were permitted except for laser profiling in only two states.

Table 2. Combinations of Technologies with Respect to the Use of Laser Profiling.

Category	Technology Combination	Number of States
Combinations Including Laser Profiling	Mandrel, CCTV, Laser Profiling	4
	Mandrel, CCTV, Laser Profiling, Video Micrometer	2
	CCTV, Laser Profiling	1
	CCTV, Laser Profiling, Video Micrometer	1
Combinations Omitting Laser Profiling	Mandrel	6
	CCTV	2
	Mandrel, CCTV	4
	Mandrel, CCTV, Video Micrometer	2

4.2 Written Exam and Field Test

After the equipment and testing methods were approved, the research team produced two written examinations of 40 questions each to test the understanding of specifications, inspection procedures, and equipment criteria. The field test was designed and constructed to test proficiency in using approved methods of inspection. The course was comprised of one run each of varying pipe material: high-density polyethylene (HDPE), polyvinyl chloride (PVC), reinforced concrete pipe (RCP), and corrugated metal pipe (CMP) (Figure 1). The pipe run contained a variety of defect types, including cracks, deflections, excessive joint gaps, debris, and misalignments. Techniques for scoring the field test, grading the results, and recertifying the operators would be established.

Figure 1. Field Course Comprised of HDPE, PVC, RCP, and CMP.

5 FINDINGS AND CONCLUSION

Although several states did not explicitly identify specific inspection procedures or methods, in a few cases there was an implied technique. Some states incorporated certain aspects of specific methods into other requirements.

It is also apparent that there are few laser profiling equipment manufacturers nationwide, and there is a software overlap among the individual manufacturers. This can provide a solid foundation for the expansion of the laser profiling industry as the companies expand their support base. It bodes well for the future of the industry that laser profiling manufacturers provide data analysis services to their customers, and that some of these manufacturers have been around for years (if not in the U.S., then elsewhere in the world), showing a longevity to the inspection equipment and an acceptance by public agencies. A gradual increase in the number of agencies that include laser profiling in their specifications can be expected. So can improvements in the technology and decreased costs in the subcontracting of these services.

This research revealed a growing awareness on the part of DOTs of the need for more efficient and effective pipe construction inspection, and state-of-the-art methods for accomplishing this. Once FDOT gets its operator and equipment testing and certification processes in place, other DOTs will soon follow, and this will result in more effective and uniform inspection of pipe construction nationwide.

References

Bennett, N. H. and Logan, G. I., Laser profiling – A necessary tool for pipeline assessment, *Proceedings,* NASTT No-Dig 2005 Conference, Orlando, Florida, April 24-27, 2005.

Buonadonna, D., McKim, R., and Wade, M., Uses and limitations of special sewer inspection technologies for large-diameter gravity pipeline trenchless rehabilitation design, *Proceedings*, North American Society for Trenchless Technology (NASTT) No-Dig Show 2011, Washington, D.C., March 27-31, 2011.

Dettmer, A., Hall, D., Hegab, H., and Swanbom, M., Refining laser profiling methods used for pipeline assessment, *Proceedings,* NASTT No-Dig 2005 Conference, Orlando, Florida. April 24-27, 2005.

FDOT et al., Laser profiling and video inspection industry meeting minutes, *Florida Department of Transportation*, Tallahassee, Florida, August 9, 2011.

Griffin, J., Growth of laser profiling technology enhances CCTV inspections, *Underground Construction* (63) 9, September 2008.

Hancor, Laser profiling of flexible pipe, *Hancor Technical Note,* TN 5.08, October 2007.

Holdener, D., What is the practical accuracy of crack measurement in concrete pipes? *NASSCO Times*, Spring 2011 Edition, 14 & 16, 2011.

Hovland, T. J. and Najafi, M., Inspecting pipeline installation (ASCE manual and reports on engineering practice), *American Society of Civil Engineers*, Virginia, 2009.

Iyer, S., and Sinha, S. K., Improving condition assessment of buried pipes using non-contact ultrasound based 3-D crack map generation, *Proceedings,* NASTT No-Dig 2005 Conference, Orlando, Florida, April 24-27, 2005.

Motahari, A., and Forteza, J. G., Accuracy of Laser Profiling of Flexible Pipes using CUES system, *University of Texas at Arlington*, date unknown.

Sutton, M., Getting a closer look: A practical guide to available pipeline inspection technologies, Trenchless Technology, June 2009.

Wirahadikusumah, R., Abraham, D. M., Iseley, T., and Prasanth, R. K., Assessment technologies for sewer system rehabilitation, *Automation in Construction* 7, 259-270, 1998.