MATERIALS AND RESEARCH

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INITIAL REPORT U 2006-3

Smart Stud In-Pavement Crosswalk Lighting System

REFERENCES:

WP – 2005-R-3

INTRODUCTION

In accordance with the Manual on Uniform Traffic Control (MUTCD), Section 3B.17, Crosswalk Markings, "Crosswalk markings provide guidance for pedestrians who are crossing roadways by defining and delineating paths and serve to alert road users of a pedestrian crossing point across roadways not controlled by highway traffic signals or STOP signs." However, recent studies have shown that many pedestrians feel overly secure when using a marked crosswalk often placing themselves in a hazardous situation. Additionally, the motorist's view of a crosswalk is greatly reduced when they are at a safe stopping sight distance due to the effects of foreshortening and distance diminishment as well as other variables such as roadway alignment, weather, dirty windshields, glare and adverse lighting conditions (ref. Mesa). In an effort to increase pedestrian safety and driver awareness, the Vermont Agency of Transportation, installed a series of in-pavement flashing warning lights to further delineate the limits of a preexisting crosswalk located in Quechee, an area with a high population of tourists and large traffic volume Quechee is an unincorporated village within the town of Hartford.

The following report provides initial observations about the installation of an experimental in-pavement lighting system in association with a heavily traveled roadway for both motorists and pedestrians. In addition, the report contains information pertaining to cost, maintenance and initial findings concerning the effectiveness at increasing driver awareness.

PROJECT DETAILS:

In accordance with the Category II workplan, WP 2005-R-3, the in-pavement lighting system was installed on US 4 at approximately MM 3.4 in the town of Hartford, near the Quechee Gorge Visitors Center. This area is characterized by a heavily traveled roadway consisting of local residents and tourists. The AADT, or Average Annual Daily Traffic, on this two lane roadway, is 12,500, a moderately high AADT for the State of Vermont. Although the posted speed limit along this roadway is 30 mph, visual observations indicate that many motorists travel above this speed. The setting for the reduced speed limit is similar to approaches posted at 50 mph from either direction. It is suspected that the observed rates of speed may be caused by unfamiliarity with the area as much of the demographic is composed of tourists. Figure 1, provided below, displays the crosswalk location in reference to US 4.

Figure 1 – Overall View

The installation of the in-pavement lighting system was performed in conjunction with the Quechee Gorge Visitor Center Project, Hartford PLH QGSP (2). This enhancement project included the construction of a new Visitor's Center and parking lot. Together, the improvements are supposed to allow pedestrians safe passage from the Visitor's Center to key vantage points of the gorge.

PRODUCT DETAILS:

SmartStud In-Pavement Crosswalk Lighting system is manufactured by Harding Electronic Systems of Otahuhu, Auckland, New Zealand, and is distributed by Econolite Control Products of West Mystic, CT. In accordance with the general description from the manufacturer, for crosswalk applications, the proprietary system is comprised of three major components: 1) the SmartCabinet, which houses the power supply and crosswalk control equipment, 2) the cable that transmits the power to the markers, and 3) the lighted markers. The markers, or Smartstuds, are not hard-wired to the cable. Instead, the markings are illuminated through inductive power transfer technology. The lighting system is available in a variety of colors including yellow, white, green, red and blue, and can be synchronized for slow and rapid flash modes. According to manufacturer, they can be seen from 500 meters away in all weather conditions

Several other accessories are available to enhance and increase the effectiveness of the operating system. SmartButton is a pedestrian push button containing a single, amber LED that acts as a visual indicator to crossing pedestrians. SmartPED is a pressure pad that is installed flush with the sidewalk surface and operates similarly to a traffic loop to detect pedestrians waiting to cross. Pedestrians must weight at least 30 pounds and stand on the pad for a minimum of 0 to 5 seconds. SmartSign is a modified "crosswalk" sign containing two amber LED clusters. These signs can replace existing MUTCD pedestrian signage, and will provide additional awareness and visibly to the crossing area.

For the application in association with the Quechee Gorge Visitor's Center, the operating system included a 24 volt SmartCabinet, inductive cable and 10 SmartStuds, five along each side of the crosswalk. In addition to the standard equipment, the assembly also included the installation of two SmartButtons and two SmartPEDs, one on each side of the road. Please refer to Appendix A for a layout of the entire assembly in reference to the roadway and Visitor's Center.

INSTALLATION

Installation by a private contractor began at approximately 9:00 A.M. on Wednesday, September 21, 2005, by marking out the layout of the cable installation with temporary paint. Once the site layout was properly marked, the pavement was saw cut to a minimum depth between 3.5" and 4" along the temporary paint markings. Please note that this procedure was carried out in two series as only one lane of traffic was left open to facilitate the flow of traffic coming from either direction. The surface of the pavement was then milled to generate a trench on either side of the future bi-directional SmartStud markers to provide for optimum visibility when operational. Please note that markers should never be installed within a wheel path. According to the manufacturer, the length and slope of the trench is directly correlated to the viewing distance of the lights as a longer trench will allow for a longer site distance. In this case, each trench was 24" in length on either side of the future lights creating a viewing distance of approximately 350 ft. Figure 2 and 3 demonstrate the saw cutting and milling efforts, respectively.


Figure 2 – Saw cutting


Figure 3 – Milling

Once the pavement was properly milled, a core drill with 5" bit was utilized to core the underlying pavement to a depth between 5/16" to 3/8" below the surface. This provided a clean and level surface for adhesion and a recessed area for the SmartStuds minimizing inherent damage from winter maintenance practices. Finally, to ensure proper installation, each marker was placed within the cored location to verify that the LEDs would not be obstructed from high spots in the adjacent pavement. Figure 4 displays the coring procedure.

Figure 4 – Coring

A pressure washer was used to remove any dust or debris from within the saw cut, or slot, and coring locations. In order for the sealant and adhesive to adhere, an air compressor was used to remove any excess water residing in the slot. Once sufficiently dry, the cable was inserted into the slot. At each cored area, the cable was cut using a utility knife. A node was then placed into the split section of the cable and inserted into the slot. Figure 5 shows the insertion of the cable and node. Upon verification that the cable and nodes were securely in place, a sealant applied into the slot, on top of the cable. Care was taken to ensure that the sealant did not overflow into the cored areas or trenches. When the cable sealant had cured, all of the SmartStuds were installed. This was performed by applying a special adhesive to each core location and inserting each SmartStud. Any excess adhesive was removed. Finally, the loose end of the cable was inserted into the SmartCabinet providing power supply and activating the system. The operation was completed by 6 PM. Please see Appendix B for a diagram of the SmartStud with cable and node.

Figure 5 – Inserting Node and Cable

COSTS:

The cost for the SmartStud in-pavement lighting system was $5,793.50 which included all of the installation components and equipment as well as labor. The price is certainly something to consider as the manufacturer claims that the typical life span of the system is approximately 5 to 7 years.

For consideration in other projects throughout the State of Vermont, the typical cost for a convention crosswalk comprised of standard waterborne paint is roughly $580. This includes all labor, equipment, material costs as well as the cost for maintaining a sign package during installation. Please note, however, that the pavement markings in Quechee are comprised of preformed thermoplastic, which have proven to be more expensive than standard waterborne paint.

SURVEILLANCE AND TESTING:

Materials and Research personnel returned to examine the experimental feature on Friday, September 30, 2005, nine days following installation, to examine the ease of operation of the system. As stated previously, both a SmartButton and SmartPED was installed on either side of the crosswalk activating the system either by pressing the button or pressure produced by standing on the SmartPED. Each activation element was examined and found to be in good working order. In addition, each SmartStud with LED lighting was assessed and appeared to be installed correctly with the bottom of each lens below grade Figure 6 and 7 display the SmartButton and SmartPED, respectively.

Figure 6 – SmartButton

Figure 8 – SmartPED

As per the work plan, the effect from potential damage due to winter maintenance practices was assessed during a site visit conducted in May of 2006. Upon inspection, there appeared to be no appreciable damage to any of the SmartStuds and the system was found to be in good condition. In addition during ?month? 2006, the District Operations staff was contacted to discuss any problems that may have occurred over the winter. General Supervisor, Tammy Ellis noted that there were no complaints from any maintenance personnel, despite the SmartStud sitting approximately 0.47" above grade.

It should be noted that on October 11, 2006 two SmartStuds were reported malfunctioning. There is no visible damage to the units and at this time it is unclear as to the cause of this failure however, the distributor's account manager, Scott Westervelt, has agreed to replace not only the malfunctioning units but also all ten SmartStuds. According to Scott there are two reasons for replacing all the units. The first is to test the failed SmartStuds to determine the cause of the problem and maintain continuous product improvement. Secondly, while there is nothing wrong with the remaining units, the manufacturer would like to keep the system uniform. This replacement will take place in the spring of 2007. Materials and Research personnel will be present to observe the removal of the preexisting in-pavement lighting system and installation of the new SmartStuds. The manufacturer has agreed report the causations of the failure, which will be published in the final report along with any additional observations.

BEFORE AND AFTER STUDY

In order to assess and document any changes in driver behavior, an observational study, known as a before and after study, was conducted in association with the in-pavement lighting system. For this examination, two scenarios were carried out prior to and following installation. The first situation involved an Agency member dressed in typical pedestrian clothing providing an impression that they were about to step into the crosswalk by looking in both directions. The second situation involved the same Agency member looking in both directions and then stepping into the crosswalk. Oncoming traffic was visually monitored during these events in order to assess driver behavior. Figure 9 and 10 below depict the two scenarios.

Figure 9 – Looking

Figure 10 – Looking and Stepping

The before study was conducted on Monday, July 18th, 2005, approximately two months prior to installation by personnel from the Local Transportation Facilities Section. In order to conduct the study, 400 feet was delineated on either side of the crosswalk at a distance between 100' to 500' from the crosswalk in both the eastbound and westbound direction. During each pedestrian event, a stopwatch was utilized to determine the amount of time it took to travel the known distance. In addition to travel time, the yielding behavior as to whether a driver stopped for the pedestrian was also recorded. Additionally, when possible, the state for registration of the vehicle was also noted in order to assess the impact of the crosswalk on local residents and tourists. The after study was carried out on Monday, June 12th, 2006, nine months after installation in a similar manner. In both case, the ambient air temperature was approximately 70°F and partly sunny.

All recorded observations were entered into a database for analysis. The average speed of the driver was calculated by dividing the travel distance by travel time and converting the units from feet per second into miles per hour. A summary of the change of speeds prior to and following installation are provided in Table 1 below. In addition, a summary of yielding behavior is contained in Table 2.

SmartStud In-Pavement Lighting System Recorded Speed (mph)								
	Before				After			
Summary	EB Looking	WB Looking	EB Walking	WB Walking	EB Looking	WB Looking	EB Walking	WB Walking
Average:	30.9	32.8	30.1	30.2	32.5	31.2	32.3	29.8
Std.:	5.3	7.1	8.0	8.3	5.2	7.0	4.9	6.2
Count:	50	50	30	50	50	50	50	50

Table 1 – Speed Summary

SmartStud In-Pavement Lighting System Traffic Yielding to Pedestrians				
Scenario	No	%	Yes	%
EB Looking Before	11	22%	39	78%
WB Looking Before	34	69%	15	31%
EB Stepping Before	11	37%	19	63%
WB Stepping Before	23	46%	27	54%
Total:	**79**	**44%**	**100**	**56%**
EB Looking After	20	40%	30	60%
WB Looking After	12	24%	38	76%
EB Stepping After	16	32%	34	68%
WB Stepping After	13	26%	37	74%
Total:	**61**	**31%**	**139**	**70%**

Table 2 – Yield Summary

In assessing the results from the speed study it is unclear as to how effective the in-pavement lights were in reducing the overall speed of oncoming traffic in either direction. Sample size may have influenced the results of this study. However, it is important to consider that the calculation provides an average speed, thus it is difficult to draw any conclusions as a driver may have been traveling well above the speed limit through the beginning of the identified section and slowed down significantly at the end. However, the SmartStuds did appear to have a larger impact on drivers traveling in the westbound direction. This theory is further supported by the observed yielding behavior. While the percentage of traveling public stopping for a pedestrian looking in both directions prior to walking into the crosswalk decreases by 18% in the eastbound direction following installation, the percentage increases by 41% in the westbound direction. The lights also appear to have an impact on the yielding behavior when pedestrians are stepping in the crosswalk with a calculated increase of 5% within the eastbound direction and 20% within the westbound direction.

At this time it is difficult to ascertain why the SmartStuds are more effective at increasing driver awareness within the westbound lane. It may be due to the location of the gorge in reference to the crosswalk. Travelers in the westbound traffic may be interested in examining the gorge as they drive by and slow down in anticipation. Conversely, drivers have already observed the gorge in the eastbound direction and may be distracted or increasing speed. As one other final aside, while the before study was conducted two months prior to installation, the after study was conducted nine months following installation. Over time local residents may become complacent as they become more familiar with the operating system. However, overall the in-pavement lighting system does appear to have an effect on driver awareness

INITIAL FINDINGS:

Although the operating system has greater cost than marking and maintaining a standard crosswalk, the in-pavement lighting system appears to be effective in increasing driver awareness and pedestrian safety. Installation of the system can be performed by any trained individual potentially reducing the overall cost. However, as with any power source, a licensed electrician must be onsite to connect the SmartCabinet to the cables and power supply. The life cycle cost of the system is an important parameter for consideration as an anticipated service life of 5 to 7 years results in a yearly cost of approximately $1200 to $800, respectively. The operating system should require very little maintenance although after just one year of service, two of ten SmartStuds are in need of repair. However, little is known at the present time what were the causations of the failure. Materials and Research personnel will be onsite to observe the removal of the failed lights and will include the reasons within final report.

The results from the before and after study are quite promising. In each case, driver awareness increased following in the installation of the lights with the exception drivers traveling in the eastbound lane when the pedestrian was looking in both directions. Overall, there was an increase of 14% in yielding behavior. However, the discrepancy in effectiveness within the east and westbound lanes requires additional attention. In addition, it is recommended that another after study is conducted three years following installation in order to examine effectiveness over time or during inclement weather which may obstruct the view of oncoming traffic.

APPLICABILTY:

The main objective of a recent initiative by the Federal Highway Administration, known as the Safe Routes to School Program, is to encourage children to walk and bike to school instead of taking the bus or being driven by parents. This is accomplished by increasing the number of appealing transportation alternatives such as the construction of sidewalks and crosswalks. However, recent studies have shown that many pedestrians feel overly secure when using a marked crosswalk often placing themselves in a hazardous situation. Even the MUTCD, Section 7C.01, Traffic Control for School Areas, states that "Pavement markings have limitations. They might be obliterated by snow, might not be clearly visible when wet, and might not be durable when subjected to heavy traffic." The MUTCD further asserts under Section 4L.-01, Application of In-Roadway Lights, that the use of in-roadway lights are to warn roadway users to slow down and/or come to a stop in reference to marked school crosswalks. However, they do stress that engineering judgment must be utilized to determine if a particular traffic control signal is justified at a particular location.

FOLLOWUP:

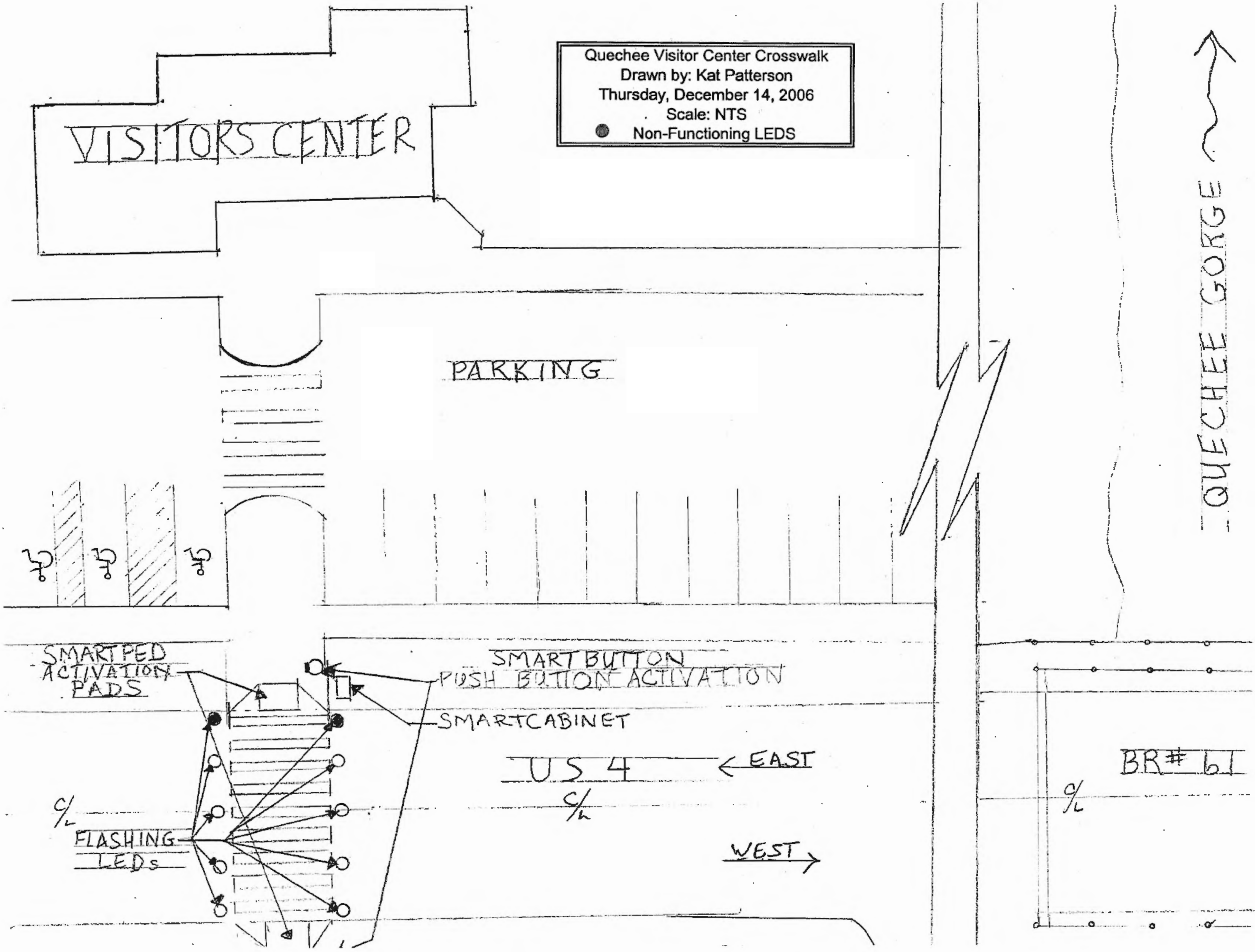
The in-pavement lighting system will be assessed on an annual basis for a minimum duration of three years. The SmartStuds will be examined for any damage due to vehicles or winter maintenance practices. In additional the entire operating system will be assessed to note all malfunctions. In addition, another after study should be conducted three years following installation to evaluate driver complacency. Materials and Research personnel will be present to observe the removal of the preexisting in-pavement lights and determine the causations for the failure of the two SmartStuds. A final report will be published outlining the above referenced topics and recommendation regarding applicability.

References:

Pedestrian Crosswalks – How Safe are They?. 27 Nov. 2006. The City of Mesa. 15 December 2006 <http://www.cityofmesa.org/transportation/ped_cross.asp>.

Federal Highway Administration. *Manual on Uniform Traffic Control.* 2003.

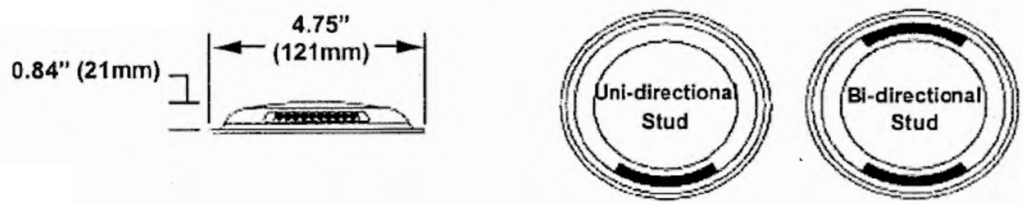
Appendix A


Quechee Visitor Center Crosswalk
Drawn by: Kat Patterson
Thursday, December 14, 2006
Scale: NTS
Non-Functioning LEDS
VISITORS CENTER
PARKING
QUECHEE GORGE
SMARTPED ACTIVATION PADS
SMART BUTTON PUSH BUTTON ACTIVATION
SMARTCABINET
US 4
EAST
WEST
FLASHING LEDs
BR# 61
C/L

Appendix B

SMARTSTUD™

- Inductively powered LED road stud.
- No physical connection to buried cable.
- Uni-directional: 10 high intensity LED's facing one direction.
- Bi-directional: 20 (10&10), high intensity LED's facing both directions.
- Available LED colors: Yellow, White, Green, Red, and Blue.
- Available stud colors: Yellow and White are standard. Other colors available.
- Visible up to 1.2 Miles (2Km) away.
- Light divergence - 9.5° vertical, 30° Horizontal
- Bayer™ Mackrolon® Hi Impact Polycarbonate housing.
- Can withstand an impact of over 9000kg compressive load (20,000lbs).
- Can withstand a maximum temperature of 100 degrees Celsius (212 degrees Fahrenheit).
- Two orientations: Lengthways (long line) and crossways (cross walk).
- The Node is used to help amplify the inductive field under each stud.



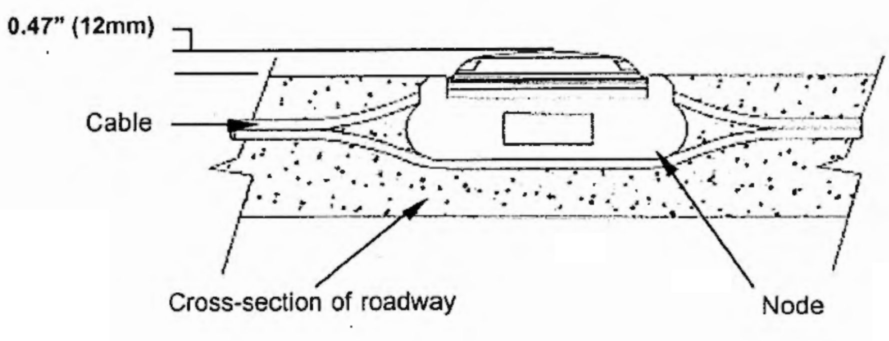


FIGURE 1: Orientation of SmartStud