Trial and Evaluation of Internally Illuminated Pavement Markers

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Biography

Tanya Styles joined the Road Safety and Traffic group at ARRB Transport Research in 2002. She holds an Honours Degree in Psychology from Deakin University and will graduate with a Doctorate in Health Psychology later this year. During her studies Tanya developed expertise in evaluation research, models of health behaviour, and the measurement of attitudes and behaviours. While at ARRB Tanya has been involved in a range of projects including a review of the administrative arrangements of Community Road Safety Councils, a scoping study of Indigenous road safety in Australia, and the evaluation of internally illuminated pavement markers that is described in this paper.

Abstract

Pavement markers which self-activate in response to environmental conditions are one of the newer technologies being applied in efforts to promote the safety of road users. Self-activated pavement markers are designed to provide enhanced road delineation in the event of wet weather, fading light, or ice formation by means of a solar powered LED. VicRoads undertook to trial self-activated pavement markers at various sites around Victoria, and commissioned ARRB Transport Research to conduct an evaluation study to proceed along with the trial. Three aspects of the performance of the self-activated pavement markers were assessed. First, laboratory tests were used to determine the consistency of the markers' on-off thresholds in response to fading light, fog, and low temperatures. Second, the "in service" performance of the markers was assessed via inspection of several trial installation sites. Third, the impact of the pavement markers on driver behaviour was measured by means of a "before and after" observational study. A number of conclusions were drawn based upon the results of the study. The on/off threshold of the pavement markers is accurate enough for their purpose and they do appear to encourage drivers to travel more slowly and to place their vehicles further from the centre of the road in some circumstances. Nonetheless, the self-activated pavement markers do not appear to be sufficiently robust, being susceptible to theft, vandalism, and damage by traffic.

1. INTRODUCTION

One of the more recent technologies available for improving road delineation are solar powered LED illuminated pavement markers that activate in response to environmental conditions such as rain, ice, or fading light. Self-illuminated pavement markers offer certain advantages over conventional retroreflective markers, the most obvious being their visibility. Conventional retroreflective pavement markers function by returning light in the direction from which they are illuminated. To a driver, conventional retroreflective markers appear bright only when headlights are shining directly onto them. As such, there are limits to the extent to which effective delineation around a curve can be maintained using conventional retroreflective markers. Internally illuminated markers are designed to provide drivers with consistent light output from a wide range of viewing angles, thus giving a clear indication of road curvature throughout a curve. As part of a trial of internally illuminated pavement markers VicRoads commissioned ARRB Transport Research to conduct an evaluation study.

2. ACTIVATION CONSISTENCY

2.1 Method

Each of the tested markers responded to either fading light (for delineation during darkness), low temperatures (for alerting drivers to the presence of ice on the road), or moisture (for delineation during rain and fog). Thirteen light sensitive pavement markers of a combination of four colours (red, green, amber, and white) and three housing types (surface mounted, flush mounted, and inset) were tested. Five blue surface mounted temperature sensitive markers and seven amber surface mounted moisture sensitive markers were also tested.

The University of Sydney tested the triggering consistency of the temperature sensitive and moisture sensitive pavement markers in their climatic chamber. This allowed the atmosphere surrounding the markers to be controlled and monitored.

During the testing of the moisture sensitive markers, humidity within the chamber was kept at 70%. The temperature in the chamber was lowered gradually and an injection of steam used to create fog. The response of all seven moisture sensitive markers was recorded.

During the testing of each of the five temperature sensitive pavement markers, a dish of water was placed near the markers to allow checking for ice formation. The temperature in the climatic chamber was lowered gradually until the marker was activated, at which point the temperature was increased again and the process repeated. The temperature of the pavement markers was monitored using a thermocouple.

Optometric and Photometric Technology (OPT) assessed the triggering consistency of the 13 light sensitive markers. The light sensitive pavement markers were arranged with sensors facing toward a light source and were illuminated from a distance of 25 metres. Initially the laboratory was dark and all of the units were on, then the illuminance was increased in steps and the illuminance level at which each marker turned off was noted. When all of the pavement markers had turned themselves off, the illuminance was decreased in steps and the illuminance at which each marker turned on was noted.

2.2 Results

The moisture sensitive pavement markers activated before fog formed in the chamber. Within two minutes of the steam injection, and all within a narrow time frame, the seven moisture-sensitive pavement markers had activated. It appeared that the slight rise in ambient temperature caused by the steam injection resulted in the formation of moisture on the markers and this small amount of moisture was sufficient to activate the studs. The only circumstance in which fog would not activate the markers in the field would be when they were hot enough to remain above the 'dew point,' (at which moisture would form on their surface). Given that the self-illuminated pavement markers activated consistently in response to the formation of dew on their surface there is little reason to suspect that even light rainfall would fail to activate them.

Figure 1 presents a representative sample of the activation consistency data obtained by the University of Sydney for the temperature sensitive pavement markers. An upward spike indicates that the test pavement marker has commenced flashing and a downward spike indicates the cessation of flashing. In accordance with the manufacturer's specifications, activation tended to occur when the pavement markers reached a temperature between 0.5°C and 1.0°C. At no point during the tests did ice form.

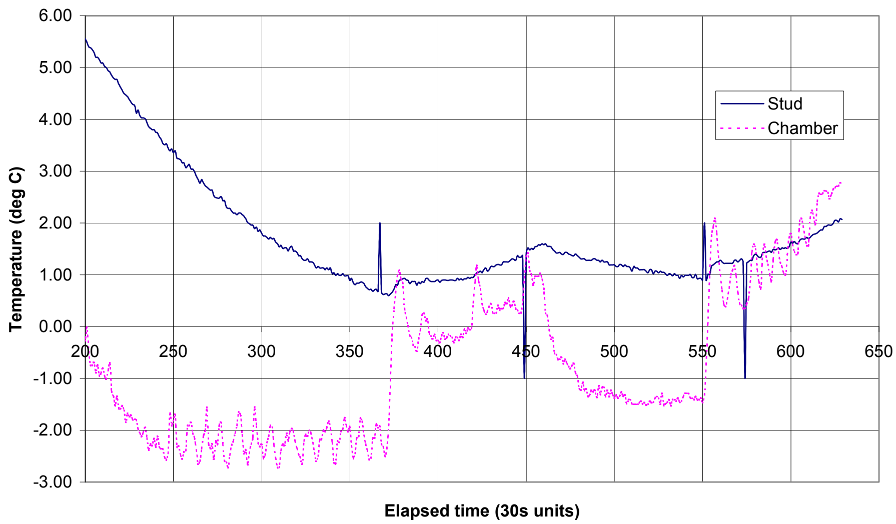

Figure 1: Activation performance of temperature sensitive markers

The markers were more sensitive to reduced ambient lighting conditions than specified by the manufacturers, who suggest that the pavement markers will activate at lighting levels below 15 lux. Four of the markers tested activated at illuminance levels over 100 lux. The pavement markers tested also tended to switch off at higher illuminance levels than specified by the manufacturer, who indicates that the markers should turn off when illuminance levels climb above 30 lux. Table 1 shows the illuminance trigger levels for the tested pavement markers.

Table 1: Illuminance Trigger Levels for Tested Markers

Colour	Housing Type	Illuminance trigger level (lux)	
		On	Off
Red	Surface	25	35
	Flush	142	170
	Inset	85	>245
Amber	Surface	85	203
	Flush	121	138
	Inset	85	118
Green	Surface	39	49
	Flush	142	150
	Inset	77	203
White	Surface	62	82
	Flush	112	130

	Inset	54	82
	Bi-Directional	32	56

Note. The red inset marker did not turn off at the highest illuminance level possible during testing but did turn off when placed in sunlight.

Ambient light levels on a dull day are approximately 3,300 lux, a full moon during the evening will produce ambient lighting levels of approximately 0.03 lux, and good street lighting will produce ambient lighting levels of about 44 lux (Testo, 2003). The trigger levels identified by OPT would seem to suggest that the internally illuminated pavement markers will activate before ambient lighting falls much below levels that would be offered by good street lighting, and will switch off long before full daylight, even on overcast days.

3. SITE INSPECTIONS

A road safety auditor visited eleven test installation sites in five regions throughout Victoria. Inspection of the sites and reports from VicRoads personnel indicated that the trialled pavement markers are prone to traffic damage, theft and vandalism. The markers do appear to fare reasonably well in some locations however. For example, no pavement markers appeared to have been stolen from an installation site near the regional town of Harcourt, a site that was particularly inaccessible to pedestrians. At locations where pedestrian access is easier, the pavement markers are prone to theft and vandalism. For example, along the one stretch of road in Suburban Olinda, the internally illuminated markers had been replaced with conventional retroreflective pavement markers due to theft of the former.

As well as being prone to intentional removal and breakage, traffic appears to damage some of the internally illuminated markers. Pavement markers in surface-mounted housings, which are similar in appearance to conventional retroreflective pavement markers, appear to be especially vulnerable. Nonetheless, even the surface of the flush mounted units, which are embedded into the road surface, was found to be susceptible to scuffing.

4. DRIVER BEHAVIOUR

4.1 Method

To determine the effect of the installation of internally illuminated pavement markers on the behaviour of drivers, observations of traffic movement through a stretch of road between two bends, both before and after internally illuminated pavement markers had been installed, were conducted. ARRB's video trailer was used to collect the data. Using footage of 400 vehicles (200 in both the before and after periods) taken during darkness, data was collected in relation to five variables; Lateral placement, speed, brake use, high beam headlight use and travel on or over the centerline.

4.2 Results

Table 2 shows average speed through the observation site before and after pavement markers were installed and the associated *t*-tests.

Table 2: Mean Speed through Test Site Before and After Installation of Markers

Direction	Before		After		Change	t-test
Headed	Mean	SD	Mean	SD		
North	63.3 km/h	7.8	62.1	8.7	-1.2 km/h	$t(220) = 1.03$, p

			km/h			=.31
South	62.8 km/h	7.7	59.7 km/h	7.9	-3.1 km/h	*t*(176) = 2.68, p =.008

To determine whether or not the lateral placement of vehicles travelling through the observation site changed following installation of the pavement markers, four *t*-tests were conducted, one for each point at which lateral placement was measured. All four measurement points were near to bends in the road. The lateral placement data and *t*-tests are presented in Table 3.

Table 3: Lateral Placement of Vehicles Before and After Installation of Markers

Direction Headed	Location	Before		After		Change	t-tests
		Mean	SD	Mean	SD		
North	1	35.7 cm	25.8	30.7 cm	20.1	-5.05 cm	*t*(220) = 1.62, p = .11
	2	60.2 cm	24.6	66.4 cm	23.7	+6.21 cm	*t*(220) = -1.92, p = .06
South	3	62.1 cm	23.6	55.9 cm	22.9	-6.25 cm	*t*(175) = 1.79, p = .08
	4	46.2 cm	23.0	54.0 cm	22.7	+7.79 cm	*t*(175) = -2.26, p = .03

Using an alpha level of 0.1, the *t*-tests reveal that in two locations distance from the centerline was increased, a favorable outcome that may result in decreased risk of head-on collisions. In a third location however, distance from the centerline decreased after the pavement markers were installed. Perhaps in some circumstances clearer delineation of the centerline makes travel close to the centre of the road more comfortable than travel nearer to what may be a poorly delineated road-edge.

Chi-square analyses were used to determine whether there were any changes in the incidence of high-beam use, brake use and encroachment upon centerline markings following installation of the pavement markers. Table 4 presents the results of these tests.

Table 4: High Beam Use, Brake Use and Centerline Encroachment Before and After Installation of Pavement Markers

	Before	After	Change	Chi-square test
Crossed Centerline	10.0%	5.0%	-5.0%	χ^2 (1, n = 200) = 2.78, p<.10
Used Brakes	17.5%	14.8%	-2.7%	χ^2 (1, n = 108) = 1.29, p>.10
Used High-Beams	22.2%	23.9%	+1.7%	χ^2 (1, n = 121) = 0.40, p>.10

Brake use and high beam use were not significantly reduced as a result of the presence of the internally illuminated pavement markers. Travel on and over the centerline was reduced following the installation of the markers however. This is a favorable finding as travel on or over the centerline may increase the risk of head-on collision.

5. CONCLUSIONS

Based on the information gathered from the laboratory-based tests it appears that internally illuminated pavement markers perform the tasks they were designed to perform. The tested pavement markers activated in response to the environmental conditions to which they are designed to activate. They illuminated before ice formed, in response to the presence of moisture on their surface, and before light levels fell below that afforded by good street lighting. There is also little to indicate that the markers will not turn themselves off within an appropriate interval. Although they perform in the lab as specified, the performance of the tested pavement markers in the field is detracted from by their proneness to theft and damage.

At least some of the internally illuminated markers in nearly all of the inspected installation sites had been removed before the time of inspection. For some sites inspection occurred within three months of initial installation. Field inspections also revealed that many of the internally illuminated markers that remained in the installation sites were damaged. In some cases the damage appeared to have occurred during efforts to remove the markers from the road surface, in other cases markers appeared to have been damaged by traffic.

Observation of driver behaviour revealed that some behaviours, such as high-beam headlight use and brake use were largely unaffected by the presence of the markers. The markers did seem to facilitate some reduction in the speed at which vehicles traveled through the installation site however, and this was a favorable finding, as was the apparent reduction in the tendency of vehicles to travel on or over the centerline. Findings in relation to changes in lateral placement associated with the installation of the pavement markers were mixed. In some circumstances installation of the pavement markers may facilitate travel closer to the centerline. Based on the evaluation study presented, the following conclusions were reached:

- The response of the tested pavement markers to environmental conditions is accurate enough for their purpose;
- The installation of internally illuminated pavement markers has an impact upon *some* aspects of driver behaviour; and
- The tested pavement markers are not sufficiently robust in service.

References

Testo (2003). *Light measurement technology*. Accessed April 4, 2003 at http://www.testo.de/US/lig/upload/mwmlus_1034594176500_1.pdf

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