MICHIGAN DEPARTMENT OF TRANSPORTATION
M•DOT

ADVANCE WARNING ARROW PANEL EVALUATION

MICHIGAN DEPARTMENT OF TRANSPORTATION

MATERIALS and TECHNOLOGY DIVISION

MICHIGAN DEPARTMENT OF TRANSPORTATION
M•DOT

ADVANCE WARNING ARROW PANEL EVALUATION

D. J. Rogers
V. C. Andrews
R. E. Nordlund

Research and Technology Section
Materials and Technology Division
Research Project 93 TI-1698
Research Report No. R-1331

Lansing, February 1995

This report, authorized by the transportation director, has been prepared to provide technical information and guidance for personnel in the Michigan Department of Transportation, the FHWA, and other reciprocating agencies. The cost of publishing 60 copies of this report at $.75 per copy is $45.00 and it is printed in accordance with Executive Directive 1991-6.

Action Plan

1. Engineering Operations Committee

   A. Approve this report.

2. Construction Zone Advisory Committee (CZAC)

   A. Determine specific application potential and requirements.

   B. Develop guidelines for use and evaluation criteria.

3. R. A. Welke, Deputy Director, Bureau of Highways

   A. Transmit report to FHWA.

4. Materials and Technology Division

   A. Send copies of this report to all districts, the CZAC, and participating arrowboard manufacturers.

Executive Summary

This study evaluated and compared several models of Type C solar-powered advance warning arrow panels, hereafter called arrowboards[1], as well as a motor-operated and a battery-operated arrowboard. Federal specifications (Manual on Uniform Traffic Control Devices, Section VI) specify Type C arrowboards be used on high-speed, high volume construction projects and have a minimum legibility distance of one mile. Because initial testing indicated that solar arrowboards did not meet federal legibility requirements, investigators did not test for such characteristics as lamp color, glare and solar efficiency.

The research investigations recommend solar arrowboards not be approved for use in Michigan on high-speed, high volume construction projects. If the department, through the Construction Zone Advisory Committee and the Engineering Operations Committee, determines that solar arrowboards are desirable in certain applications, specific guidelines and performance criteria shall be developed prior to establishing their use in Michigan. Pending results from the National Cooperative Highway Research Program (NCHRP), further evaluation may also be warranted.

[1]The results and recommendations in this report pertain only to the specific arrowboards tested in the study.

BACKGROUND

This study resulted from several manufacturer requests to the department for evaluation of solar arrowboards. The current 1990 Michigan Standard Specifications for Construction specify that arrowboards be motor operated, fueled by diesel, gas or LP gas; in addition they require a standard Phillips lamp, number 4412A. The Michigan Department of Transportation (MDOT) evaluated the solar arrowboards to determine whether to write a new specification that would permit their use on Michigan roads.

According to solar arrowboard manufacturers, solar arrowboards are approved for use in several states, including California, Florida, Georgia, Illinois, Massachusetts, Minnesota, Ohio, and Pennsylvania. They are actually "solar-assisted" arrowboards, because they operate from a battery source charged by solar energy. A review of the literature indicates that solar arrowboards offer ease of maintenance and less noise and air pollution, but they also have a decreased field of view (angularity) in comparison to motor-operated arrowboards. This decreased field of view results from the use of low-power lamps, which consume less energy. These are not standard industry lamps; each manufacturer has devised a lamp that is unique to its arrowboard.

Federal Specifications for arrowboards require that a Type C arrowboard have a minimum size of 48" x 96", a minimum of 15 lamps, and a minimum legibility distance of one mile. Legibility distance is the greatest distance at which the driver can comprehend the arrow panel message. Michigan uses Type C arrowboards for traffic control maintenance.

EVALUATION PROCEDURE

MDOT ensured that all arrowboards in this study complied with the federal legibility specification prior to evaluating such factors as lamp color, glare, and solar efficiency. We did not evaluate arrowboards for maximum legibility distance, but rather chose one mile as the beginning point of the evaluation. Because the MUTCD does not define conditions under which this maximum legibility specification must be met, investigators established the conditions: Researchers must view arrowboards in dry conditions during the day. Arrowboards had to be legible at one mile by at least 50 percent of the total observers to meet the legibility specification. We also evaluated the field of view (angularity), because we were interested in comparing data from motor and solar arrowboards. All arrowboards were Type C production models supplied by contractors.

We evaluated the following arrowboard models.

Manufacturer	Model	Power Source
Bemis	1500	Motor (Gas)
---	---	Battery*
Amida	DSLB	Solar
Bemis (Allmand Brothers)	Eclipse 2200 SE	Solar
Flex-O-Lite	Sun Up 2004-S	Solar
Solar Technology	Silent Sentinel AB-1515	Solar
Trafcon	TC1-15S	Solar
Work Area Protection	Arrowmaster III	Solar

* The battery operated arrowboard was tested at the request of MDOT Maintenance to evaluate compliance with the federal legibility specification. Maintenance uses the battery arrowboard on projects of short-term duration. Their specification requires a standard Phillips 4037A lamp. This particular unit was a diesel unit converted to battery with a conversion kit from Renco, Inc.

A one mile straight stretch of road marked in 1/10 mile increments was the test site. Batteries for the solar and battery arrowboards operated at optimum capacity, 12-14 volts, during field testing. We tested arrowboard models a minimum of two times, using four observers, ages 32 to 48 with normal or corrected normal vision. Although the initial intent was to have several observers, we deemed results from the first four observers conclusive for the purposes of this study.

All evaluations took place between the hours of 10:00 a.m. and 3:00 p.m. during the months of late February, March, and early April 1994, under sunny, partly cloudy, or cloudy conditions. Cloudy and partly cloudy weather conditions may have resulted in slightly longer viewing distances than sunny conditions, because bright sun tends to decrease the legibility distance.

Legibility at One Mile

MDOT evaluated the arrowboards two at a time, side by side, with one arrowboard in the left driving lane and one in the right driving lane. We aligned the two boards vertically and aimed them directly down the roadway (0 degrees) at a point one mile away. The arrowboards showed right flashing arrow, left flashing arrow, double flashing arrow, or caution pattern. We did not inform observers of the arrow panel message setting, but drove them to the one mile distance point, and asked them to view and record the arrowboard message. If observers were incorrect or uncertain of their

observation we drove them forward at 1/10 mile increments until they deciphered the arrowboard(s) message correctly.

Field of View

We repeated the evaluation process from the one mile point with the arrowboards turned 5 degrees to the left of center. Evaluation at 5 degrees equates to a total horizontal lamp beam spread of 10 degrees. We also evaluated the arrowboards at angles of 7.5, 10, 12.5, and 15 degrees.

RESULTS

Results of the study are in Table 1, which contains raw data from the evaluations, and Table 2, which shows averages of the raw data.

Legibility at One Mile

Since researchers did not evaluate the arrowboards for maximum legibility distance, the average legibility distances for the motor and battery arrowboards are not true averages; they may have been legible at a distance greater than one mile.

The motor arrowboard was legible (at 0 degrees) at one mile by two of the four observers. The 0.7 mile reading was from an observer who commented that the brightness of the lamps made the message difficult to read. The battery arrowboard was legible at one mile during all six comparative evaluations. None of the solar arrowboards were legible at one mile, though they appeared to be comparable at the initial legibility distance, which ranged from 0.5 to 0.8 miles.

Additionally, a participating arrowboard manufacturer, Work Area Protection, demonstrated its solar arrowboard outside of this study, using a different arrowboard of the same model as in this study. At 0 degrees, this particular solar arrowboard was legible at one mile, raising the investigators' concern over potential solar arrowboard variance within a manufacturer, and also the present lack of a practical, quick procedure that will evaluate field performance of each solar arrowboard.

Field of View

The legibility distance of the motor arrowboard, turned 15 degrees from center, decreased by approximately 25 percent, while that of the battery arrowboard decreased by 40 percent. Motor and battery arrowboards were still readable at 0.7 miles and 0.6 miles, respectively, when turned 15 degrees. The results for the solar arrowboards varied widely, with Amida/DSLB maintaining the highest legibility distance (0.6 miles) at a 15 degree offset. Work Area Protection/Arrowmaster III and Trafcon/TC1-15S showed an

approximate 85 percent decrease in legibility distance, with legibility at a minimal 0.1 miles at a 15 degree offset.

We are not aware of any federal specifications regarding angularity requirements for arrowboards. The department's specification of a 4412A lamp, based on our field evaluation, provides for legibility at 0.7 miles when the motor arrowboard is turned 15 degrees from center. Therefore, this serves as a benchmark for evaluation of solar arrowboard angularity.

Although lamp color measurement was not a part of this study, observer comments noted that the color of the solar arrowboards varied, with lamp colors ranging from white to amber to green-yellow.

CONCLUSIONS AND RECOMMENDATIONS

The motor arrowboard was legible at a distance of one mile and met federal specifications, based on conditions established by the investigators.

The battery arrowboard was legible at a distance of one mile. MDOT's Maintenance Division uses this arrowboard solely for short-term projects. We do not recommend it for long-term projects on Michigan highways.

We do not recommend the solar arrowboards for use in Michigan on high-speed, high volume construction projects at this time because they do not meet federal legibility requirements for Type C arrowboards. If the department determines there is a potential need for solar arrowboards in certain circumstances, guidelines for their use and performance criteria should be developed.

The NCHRP is currently conducting an extensive study of various aspects of arrowboards, including legibility, field of view, lamp intensity, glare and color. The investigators will await the NCHRP recommendation and development of performance criteria by the department before conducting any further evaluation of solar arrowboards.

TABLE 1 - ARROWBOARD LEGIBILITY DISTANCE - RAW DATA (MILES)							
	Degrees						Date Evaluated/ Conditions*
	0	5	7.5	10	12.5	15	
Motor	≥1	0.9	0.9	0.9	0.8	0.8	2/28 C
	0.9	0.9	0.9	0.8	0.7	0.5	3/1 S
	≥1	0.6	0.9	0.8	0.8	0.6	3/1 S
	0.7**	0.9	0.9	0.9	0.7	0.8	2/28 C
Battery	≥1	0.6	0.6	0.5	0.8	0.6	4/11 PC
	≥1	0.9	0.6	0.4	0.7	0.4	3/11 S
	≥1	0.5	0.5	0.6	0.4	0.5	4/11 PC
	≥1	0.9	0.7	0.6	0.7	0.6	4/11 PC
	≥1	0.8	0.5	0.6	0.5	0.8	4/11 PC
	≥1	1.0	0.5	0.5	0.6	0.4	3/11 S
Amida	0.6	0.9	0.8	0.6	0.4	0.6	4/11 PC
	0.6	0.6	0.5	0.6	0.4	0.5	4/11 PC
	0.7	0.9	0.5	0.6	0.5	0.5	4/11 PC
	0.6	0.8	0.7	0.6	0.5	0.6	4/11 PC
Bemis	0.7	0.6	0.5	0.6	0.4	0.3	3/1 S
	0.6	0.6	0.6	0.6	0.4	0.2	3/1 S
Flex-O -Lite	0.5	0.5	0.5	0.4	0.4	0.3	3/1 S
	0.5	0.5	0.6	0.5	0.4	0.3	3/1 S
Solar Tech.	0.5	0.4	0.5	0.5	0.4	0.4	2/28 C
	0.5	0.5	0.5	0.5	0.5	0.4	2/28 C
Trafcon	0.6	0.4	0.4	0.3	0.1	0.1	3/11 S
	0.7	0.5	0.4	0.4	0.1	0.1	3/11 S
W.A.P.	0.5	0.6	0.5	0.3	0.1	0.1	3/11 S
	0.6	0.6	0.5	0.3	0.1	0.0	3/11 S
	0.8	0.5	0.4	0.2	0.1	0.0	3/11 S
	0.6	0.5	0.3	0.3	0.1	0.1	3/11 S

* S - Sunny, C - Cloudy, PC - Partly Cloudy

** Observer comment during evaluation was that brightness of lamps made message difficult to read until .7 miles.

TABLE 2 - ARROWBOARD LEGIBILITY DISTANCE - AVERAGES (MILES)						
	Degrees					
	0	5	7.5	10	12.5	15
Motor	≥0.9*	0.8	0.9	0.8	0.8	0.7
Battery	≥1*	0.8	0.6	0.5	0.6	0.6
Amida	0.6	0.8	0.6	0.6	0.4	0.6
Bemis	0.6	0.6	0.6	0.6	0.4	0.2
Flex-O-Lite	0.5	0.5	0.6	0.4	0.4	0.3
Solar Tech.	0.5	0.4	0.5	0.5	0.4	0.4
Trafcon	0.6	0.4	0.4	0.4	0.1	0.1
W.A.P.	0.6	0.6	0.4	0.3	0.1	0.1

* Not a true average, since maximum legibility distance of the motor and battery arrowboards was not determined.