This report documents research conducted in the evaluation of flashing arrowboards when located in advance of lane closure work zones. The effects of advance arrowboard placement were compared to the effectiveness of the arrowboard placement normally used by District 14 of the SDHPT.

The research indicates that arrowboard placement in advance of the beginning of a taper can be extremely effective if the sight distance to the arrowboard improves the effective sight distance to the work zone. This improvement is dependent on the horizontal and vertical alignment of each work zone. From the distances evaluated, 2000 ft. in advance of the taper appears to be the maximum advance placement. Distances greater than 2000 ft. may result in drivers moving back into the blocked lane.
DISCLAIMER

The contents of this paper reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas State Department of Highways and Public Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.
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SUMMARY

Background

Flashing arrowboards have become an important traffic control device in work zone traffic management over the past several years. Because of this, arrowboards have been the subject of many research reports which cover a wide range of topics including design, human factors considerations and application guidelines. The results have been very positive indicating that arrowboards do have a very high target value and that motorists respond positively to the arrowboards' indications.

Two reports, however, differ concerning the placement of a flashing arrowboard for the most effective use. One report (1) recommended the placement of the arrowboard at the beginning of the taper; another (2) recommended that the most effective arrowboard placement is 100 ft. to 500 ft. in advance of the beginning of the taper. A study was therefore conducted on I-35 in Austin, Texas to further evaluate arrowboard placement.

Recommendation

The research documented in this report indicates that the placement of an arrowboard in advance of the beginning of a taper is beneficial only when the sight distance to the work zone is improved. For the maximum benefit in arrowboard usage, a minimum sight distance must be maintained. The minimum allowable sight distance for urban freeway operations, as developed in a related study (4), is 1000 ft. [as supported in related studies (3,4)]. The desired sight distance is 1500 ft.

Locating an arrowboard in advance of the beginning of the taper does not necessarily increase the sight distance. The vertical and/or horizontal
geometrics at each work site would control the sight distance and the resulting placement of a flashing arrowboard. Figure 1 represents an example of when sight distance is not improved. Figure 2 represents a situation where moving the arrowboard in advance of the taper can be of great benefit.

Figure 1. Typical Work Zone Where Critical Arrowboard Sight Distance is not Improved (Controlled by Geometrics)

Figure 2. Typical Work Zone Where Critical Arrowboard Sight Distance is Improved

Work zones on a tangent section of roadway would not require advance arrowboard placement because, again, sight distance to the work zone is not critical (less than 1500 ft.). Figure 3 represents this situation.
The limitations of the study prohibited the determination of the distance in advance of the beginning of the taper at which the arrowboard becomes ineffective. From the two sites studied, the arrowboard when placed 2000 ft. in advance of the beginning of the taper was most effective in shifting traffic from the blocked lane. Little improvement in shifting traffic was observed after locating an arrowboard 2500 ft. in advance of the beginning of the taper at one of the sites. However, it appears that positioning an arrowboard too far in advance of the beginning of the taper does not improve the effectiveness of the advance arrowboard. Shifted traffic was observed returning to the closed lane when an arrowboard was placed 4000 ft. in advance of the beginning of the cone taper.

In conclusion, when the sight distance to the work zone is less than 1500 ft., an arrowboard should be placed on the shoulder in advance of the beginning of the taper. When the sight distance to the work zone is between 1500 and 2500 ft., the use of a flashing arrowboard may be used to increase the advance warning (effective sight distance) to motorists. However, if the sight distance to the work zone is greater than 2500 ft., a flashing arrowboard in advance of the beginning of the cone taper is not needed.
STUDY APPROACH

Controlled field studies were conducted by TTI on I-35 in Austin, Texas. These studies were conducted in order to evaluate the effectiveness of flashing arrowboards when used in advance of work zones requiring a lane closure. The Texas State Department of Highways and Public Transportation (SDHPT), Austin District, used flashing arrowboards to supplement the standard traffic control devices as suggested in the Texas MUTCD (5). Figures 4 and 5 are schematics of the two worksites and show the relative location of all traffic control devices used at each work zone. Thirteen controlled field studies were conducted at the two worksites. Seven arrowboard arrangements were studied at Site I and six at Site II.

The SDHPT required one arrowboard to be located and operating in each of the closed lanes at the end of the taper. This requirement restricted the capability of the study to isolate the effects of only the arrowboard in advance of the beginning of the taper. Data collected at each site while the arrowboards were in this required arrangement represented the base data or the normal driver response to the arrowboards. These data included the effects of the advance signing and permitted a comparison to be made of arrowboards when positioned in advance of the beginning of the taper to the base (or normal) placement.

The data collected during each of the studies consisted of freeway volume counts, lane distributions, and sight distances to the arrowboards. The volume counts and the lane distribution data were collected at count stations located upstream from the first taper. Stations were also located at all freeway access points in order to record entering and exiting vehicles, thus providing a closed system for data analysis. The lane distribution data
Figure 4. Site I Schematic (Base Condition)
Figure 5. Site II Schematic (Base Condition)
provided information concerning the lane occupancy at each station so that
the effects of the arrowboards could be determined. The sight distances to
the arrowboards were determined by an observer traveling in a vehicle equipped
with a distance measuring instrument (DMI). These data, when compared to each
arrowboard arrangement studied, reflected the relationships of lane distribu-
tion with the arrowboard locations and relative sight distances in advance of
the work zone.

The data for each arrowboard arrangement were collected during sixty
minute periods. After each set of data was collected, a new arrowboard
arrangement was positioned. A fifteen minute gap between arrowboard position-
ing and data collection was provided in order for the data to represent
normal traffic flow.

The data representing the effectiveness of an advanced arrowboard place-
ment were collected when an arrowboard was positioned at distances ranging
from 250 ft. to 4000 ft. in advance of the beginning of the taper. An addi-
tional study was conducted to evaluate the positioning of an arrowboard at the
beginning of the taper versus the normal placement at the end of the taper.
STUDY RESULTS

Vertical and/or horizontal alinement control the sight distance to the arrowboard or the work zone. The results from both sites indicated that the sight distance to an arrowboard and thus the driver's perception of a lane closure influence the lane changing behavior of approaching motorists.

Both worksites were located downstream from varying geometric alinements. The actual work at Site I was located downstream from a vertical crest and on a downgrade. Site II was downstream from a short crest and a long, relatively flat section. The work area, however, began in a sag and the closure extended along an upgrade. The results of all the data collected during the different arrowboard arrangements are shown on Figures 6 and 7.

From these Figures, it can be seen that the advance signing and arrowboard placement normally used by the Austin District reduced the traffic in the closed lane 40% at Site I (Figure 6) and approximately 30% at Site II (Figure 7). With these percentages representing the base signing effectiveness measured at 2000 ft. in advance of the beginning of the taper, a comparison on the effects of advance arrowboard placement was made for each site. One such comparison is shown on each figure. At Site I, when placing an arrowboard 2000 ft. in advance of the beginning of the taper, a 60% reduction in traffic (20% fewer from normal) was evidenced. At Site II, a 65% reduction (35% fewer than normal) was experienced when placing an arrowboard 2000 ft. in advance of the beginning of the taper. This reduction of traffic in the blocked lane was caused by the advanced arrowboard placement and the increased effective sight distance. The effective sight distance in this case is that sight distance to the arrowboard which communicates an oncoming hazard to the motorist.
Figure 6. Arrowboard Placement Effectiveness at Site I
Figure 7. Arrowboard Placement Effectiveness at Site II
Figures 8 and 9 represent the comparison of traffic remaining in the blocked lane with effective sight distances to the arrowboard at 2000 ft. upstream from the beginning taper for the advance arrowboard placements studied. From these figures, it can be observed that the improved effective sight distance reduced the amount of traffic in the closed lane. Conversely, as the advance arrowboard's sight distance approached that of the normal arrowboard placement (base sight distance) the amount of traffic in the blocked lane increased.
Figure 8. Site I Arrowboard Placement and the Effect of Lane Distribution and Sight Distances
Figure 9. Site II Arrowboard Placement and the Effect on Lane Distribution and Sight Distance
FINDINGS

The Texas and National MUTCDs (6,7) each contain a section on flashing arrowboards. These sections, however, deal primarily with minimum design standards. The need for and the location of an arrowboard are optional. The need of an arrowboard upstream from the beginning of a cone taper should be dependent primarily on the horizontal and vertical alinement upstream from a work zone and should be determined during the preparation of the Traffic Control Plan (TCP).

The results from the sites studied indicate that the use of a flashing arrowboard in advance of the beginning of a cone taper can be effective in shifting approaching traffic out of a blocked lane. This improved effectiveness is, however, based on an increased effective sight distance to the work zone.

An arrowboard should be located in advance of the beginning of the cone taper when the sight distance to the work zone or arrowboard is less than 1500 ft. However, since the sight distance to each work zone varies with vertical and/or horizontal alinement, a standard location for an arrowboard in advance of the beginning of the cone taper for all work zones is impractical.

In one study when an arrowboard was positioned at 4000 ft. in advance of the beginning of the taper, traffic which had vacated the blocked lane returned to the blocked lane. Therefore, whenever an arrowboard is placed in advance of the beginning of the taper, a field evaluation should be conducted to ensure that a minimum sight distance (1500 ft.) is maintained and to determine if traffic is moving back into the blocked lane. If vehicles are returning to the blocked lane, the distance from the beginning of the taper to the arrowboard is excessive and the arrowboard should be relocated closer to the beginning of
taper. If the vertical and/or horizontal alignment is such that the advance location is needed, an additional arrowboard may be required to confirm the closure ahead.
REFERENCES


4. Richards, S. H. and Dudek, C. L. "Sight Distance Requirements at Freeway Work Zones," Texas Transportation Institute, Unpublished.


The results of each of the advance placement arrowboard studies for both Sites I and II are contained in the following pages. The graphs illustrate the percentage of traffic in the blocked lane upstream of the beginning of the taper and the relative sight distances to each arrowboard used.

The plan and profile views below each graph illustrates the location of each arrowboard in relation to the cone tapers and the relative vertical alinement at each site.
Sight Distance (S.D.) to A.B. 1

Sight Distance (S.D.) to A.B. 2

Beginning of Taper

DISTANCE in FEET

% of TRAFFIC on SHOULDER LANE

Site I - Base Condition
Site 1 - Arrowboard at the Beginning of the 1st Cone Taper and Base
Site I - Arrowboard 1000 ft. in Advance of the 1st Cone Taper and Base
Site I - Arrowboard 2000 ft. in Advance of the 1st Cone Taper and Base
Site I - Arrowboard 2500 ft. in Advance of the 1st Cone Taper and Base
Site I - Arrowboard 4000 ft. in Advance of the 1st Cone Taper and Base
Site II - Base Condition
Site II - Arrowboard at the Beginning of the 1st Cone Taper and Base
Site II - Arrowboard 450 ft. inAdvance of the 1st Cone Taper and Base
Site II - Arrowboard 550 ft. in Advance of the 1st Cone Taper and Base
Site II - Arrowboard 2000 ft. in Advance of the 1st Cone Taper and Base
APPENDIX B
ARROWBOARD CASE STUDY –
Placement at End of Taper vs. Placement at Beginning of Taper

The effect of arrowboard placement within the closure, either at the beginning or end of taper, is documented in this appendix. The base arrowboard position is at the end of the taper or at the closure.

The plan and profile view illustrate the relative arrowboard placement and the vertical alinement of each work zone.
Site I - Base Condition vs. Arrowboard Placement at the Beginning of the 1st Taper and at the End of the 2nd Taper
Site II - Base Condition vs. Arrowboard Placement at the Beginning of the 1st Taper and at the End of the 2nd Taper
# APPENDIX C

## METRIC CONVERSION FACTORS

### Approximate Conversions to Metric Measures

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### LENGTH

- **in** to **cm**: 2.5
- **ft** to **cm**: 30
- **yd** to **m**: 0.9
- **mi** to **km**: 1.6

### AREA

- **in²** to **cm²**: 6.5
- **ft²** to **m²**: 0.09
- **yd²** to **m²**: 0.8
- **mi²** to **km²**: 2.6

### MASS (weight)

- **oz** to **g**: 28
- **lb** to **kg**: 0.45
- **short tons** (2000 lb) to **t**: 0.9

### VOLUME

- **tsp** to **ml**: 5
- **Tbsp** to **ml**: 15
- **fl oz** to **ml**: 30
- **c** to **l**: 0.24
- **pt** to **l**: 0.47
- **qt** to **l**: 0.95
- **gal** to **l**: 3.8
- **ft³** to **m³**: 0.03
- **yd³** to **m³**: 0.76

### TEMPERATURE (exact)

- **°F** to **Celsius** temperature
- **Celsius** temperature to **°F** temperature

\[ °C = \frac{°F - 32}{9/5} \]

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25, SD Catalog No. C13.10:286.*