

CONSTRUCTION ZONE DELINEATION
RAISED REFLECTIVE MARKERS

Final Report

Gordon Beecroft
Research Engineer

Project 1: 25th Street - Lancaster Drive
Interchange Section, Santiam Highway

Project 2: Chemawa Road - Hayesville
Interchange Section, Pacific Highway East

Project 3: Yachats Bridge Section
Oregon Coast Highway

Oregon Department of Transportation
Highway Division

August 1978

Acknowledgements

This study was sponsored by the Office of Development, Implementation Division, of the Federal Highway Administration. Mr. Charles Niesner, Office of Development, served as Project Manager for FHWA.

The interim reports for the projects on which the raised reflective markers were tested were authored by the resident engineers responsible for the respective projects. They are: Loren Weber, Resident Engineer for Project 1; Kenneth D. Wolfe, Resident Engineer for Project 2; and H. H. Patterson, Resident Engineer through the initial portion of Project 3. The final report for Project 3 was prepared by Charles W. Elroy, Resident Engineer, who completed the project. Their excellent evaluations are gratefully acknowledged.

Disclaimer

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

CONSTRUCTION ZONE DELINEATION -
RAISED REFLECTIVE MARKERS

Final Report

Gordon Beecroft
Research Engineer
Oregon Department of Transportation

The Oregon State Highway Division utilized raised reflective markers for temporary direction of traffic during stage construction on three different projects. Project 1 was the 25th Street - Lancaster Drive Interchange Section of the North Santiam Highway. Project 2 was the Chemawa Road - Hayesville Interchange Section of Pacific Highway East. Project 3 was the Yachats River Bridge Section of the Oregon Coast Highway. Funding for the raised reflective marker study was provided by the Office of Development, Implementation Division, of the Federal Highway Administration.

Details of the individual projects have been described in interim reports submitted previously. This final report will not duplicate the previous reports but will briefly summarize the findings. The use of raised reflective markers to direct traffic during construction offers several advantages, but their use does have some limitations. The night-time effectiveness of the raised markers is generally excellent. They provide good delineation and their brightness alerts the driver to the different conditions existing within the construction zone. Another advantage of the raised markers is that they are not susceptible to the night-time vandalism often encountered with plastic cones or candles. Frequently, the plastic cones are intentionally knocked out of place and, of course, they are occasionally struck accidentally.

During daylight, the markers are not adequate to guide traffic where sharp curvature exists or complex maneuvers are required of the motorist unless they are very closely spaced. The only condition in which the markers were totally effective in daylight was when the sun was shining behind the motorists so the reflective prisms were illuminated by sunlight. When traveling toward the sun or when the sunlight was coming from left or right, the markers would have to be at very close spacing to be effective. Although it was not done on these projects, it appears a combination of reflective and non-reflective markers would be preferable to provide adequate control both day and night.

Center-line spacing of the reflective markers ranged from 10 feet to 25 feet for the three projects. The 10 foot spacing was used on the Yachats Bridge project which included a $12^{\circ} 50'$ curve. The Chemawa

Road-Hayesville Interchange Section utilized a 12.5 foot spacing on center-line and a 25 foot spacing on shoulder line. The 25th Street - Lancaster Drive Interchange Section used a 12.5 foot interval on curves and a 25 foot interval on tangents for the center-line spacings. Shoulder spacings were at twice the center-line interval. On all of the projects, closer than normal spacings were used in areas requiring particular emphasis to guide traffic.

One objective of the study was to test the overall effectiveness of a self-adhesive type button that could be used on a final pavement surface for temporary traffic control and then removed without leaving tell-tale marks or lines that could lead drivers into a wrong traffic pattern. When the self-adhesive markers were used without primer they could be readily removed with a square nosed shovel or a small pry bar and hammer. When placed on warm asphalt concrete, the adhesion was very good and removal resulted in some particles sticking to the pad, leaving minor evidence on the pavement surface that the marker had been removed. After several weeks, some markers placed on new pavement without primer were displaced by traffic. When primer was used, the adhesion was better but removal included about 1/4" of the pavement surface under the marker. This left a distinct hole in the pavement surface. It was found the primer was needed in placing markers on old or existing pavements. When the pavement was wet or dirty, the markers would not adhere well. As an experiment, a propane torch was used to dry and warm the surface. This preparation was effective in making the markers stick, but the practice was time consuming. When the pavement was dirty, no amount of sweeping would clean it sufficiently to get the markers to adhere. On the Yachats Bridge project, the reflective markers were drilled and nailed to the surface where it was necessary to apply them to dirty pavement. Two concrete nails per marker held them securely and aligned properly. It is emphasized that this practice should be used only as a last resort because of the tire hazard. However, there were no tire punctures reported or witnessed on the project.

On the projects where the self-adhesive markers were utilized over an extended period of time, displacement by traffic and contractor equipment was prevalent. It was estimated 50 to 60 percent of the markers on the Yachats Bridge project were replaced over a two-month period.

Because of inadequate lead-time to obtain the self-adhesive markers for the Chemawa Road - Hayesville Interchange project, the conventional epoxy application was used on that project. The epoxy adhesive was effective in securing the buttons, but upon removal, a portion of the pavement adhered to the button, leaving a tell-tale impression in the pavement surface. For traffic control, the epoxy-applied markers were very effective but they did not provide the desired no-trace removal.

The cost of utilizing raised reflective markers for traffic control ~~during construction is appreciably higher than painted stripes, but~~ the markers do provide numerous advantages over paint. Where the markers were installed by engineering crews, one project estimated the

cost to install and remove a marker at \$0.35 and the other project estimated the cost to install and remove at \$0.46. Adding an average materials cost of \$1.32, the unit price including installation and removal ranged from \$1.67 to \$1.78. On the project on which the markers were placed by the contractor under an extra work order, the unit installed price was \$2.49. The cost of using the markers is, of course, sensitive to the spacing selected. On tangent, the cost for center-line and two shoulder lines was approximately \$750 per mile. The spacings on this project were 25 feet for center-line and 50 feet for shoulders. On the bridge project, where spacings were 10 feet for center-line and 20 feet for shoulder, the cost was \$1700 per mile for center-line and two shoulder lines. Although expensive, raised reflective markers can frequently fill a need not available from other marking devices. At times, and in some locations, it is difficult to obtain the services of a paint striping crew. In these cases, particularly on small jobs, the raised markers can be installed by the contractor or the engineering crew, thus avoiding delay and the need for obtaining a remote striping crew.

The Yachats Bridge project utilized two types of raised reflective markers; a 4" by 4" marker having a smooth beveled face and a 4" by 2" marker having a ribbed beveled face. The smooth face of the larger marker was much less susceptible to having the reflective surface obscured by debris than was the ribbed face of the smaller marker. Also, the larger marker was considered easier to see in the daylight and adhesion was better by virtue of a larger surface area. Little or no difference could be seen in the reflective characteristics of the two when clean. Neither type marker was considered adequate for daytime use where traffic control was difficult and construction caused the pavement surface to remain dirty much of the time. Although not tested on this project, a satisfactory alternative would probably have been to have several non-reflective markers spaced between the reflective markers which were placed at 10 foot intervals.

Following is a summary of the findings connected with the use of the raised reflective markers on the Chemawa Road - Hayesville Interchange section of Pacific Highway East. The summary is taken from the interim report on that project, but it applies very well to all projects.

Summarization of comments:

- Positive and complete obliteration of pre-existing traffic patterns is a must.
- Epoxy applied buttons not practical unless additional lift of pavement to be placed.
- Widespread use of buttons will lower material costs and create better and cheaper application procedures.
- Bright colors are necessary to enhance daytime visibility.
- Close spacing of buttons required for daytime visibility but every other one or less required to be reflectorized for nighttime visibility.

- Masking tape can be used to cover lenses at night prior to actual use.
- Many variations possible in use of buttons to highlight certain areas such as intersections, left-turn refuges, connections, "No Pass" areas, etc.

- Disadvantages

Close spacing required for daytime visibility.

One-time use product.

High initial cost.

Adhesion quality not good on rough or dirty pavement.

Reflective lenses subject to abrasion and coating from grading and surfacing materials spilled and tracked.

Tend to concentrate debris around them obliterating up to 75% of reflective area.

Paver and rollers completely destroy them.

Tack trucks overspray them.

Higher engineering costs due to critical layout requirements.

Longer actual application time.

- Advantages

No tell-tale marks left after removal with self-stick.

No problem with vandalism.

No problem with wind, truck or vehicle wind blasts.

In comparison to cones and barricades, they have a low daily maintenance cost.

Highly visible under adverse driving conditions especially at night, in the rain and in fog.

Less likelihood of delay in scheduling.

Eliminates worry.

~~CUTS DOWN ON ACCIDENTS.~~

Following, in Appendix A. is a final report on the Yachats Bridge project which provides somewhat more detail on the use of raised reflective markers for traffic control during construction on that project. The report also includes a photographic record of the day and night visibility aspects of the markers on the Yachats Bridge project.

To bring together all of the information on Oregon's use of raised reflective markers for traffic control during construction, the text portions of the previous interim reports are provided in Appendix B. The color photographs from the interim report for Project 2 are not included.

APPENDIX A

CONSTRUCTION ZONE DELINEATION -
RAISED REFLECTIVE MARKERS

Final Report

Project 3
Yachats River Bridge Section
Oregon Coast Highway
Lincoln County
Contract 8432

This is a final report on the raised reflective pavement markers for the Yachats River Bridge project. Please refer to the interim report submitted June 9, 1977 by Resident Engineer H.H. Patterson. Since that report there has been one more complete installation of the raised pavement markers due to a traffic pattern shift and asphalt overlay.

During the course of the project we experimented with the 2 types of reflective markers (see interim report), their application, adhesive primer, removal, reuse and spacing.

Marker adhesion presented some problems. The markers were applied under various weather and pavement conditions. When the pavement was wet and cold, a propane torch was used to dry and warm the surface. This worked well but required either more time or an extra man. When the pavement was dirty, no amount of sweeping would clean it sufficiently to get the markers to stick. Washing the pavement was considered to be impractical, and we resorted to drilling and nailing the markers to the pavement. This could be done rather quickly using previously removed markers with little or no adhesive remaining. Two concrete nails per marker held them securely and aligned properly. As stated in the interim report, this should be used only as a last resort because of the tire hazard. However, there were no tire punctures reported or witnessed. Another problem with adhesion was rough pavement. Again, nailing the markers in place was used at times. Beating the pavement smooth with a hammer was considered too time consuming.

The adhesive primer did help on the older, rougher surfaces by filling some of the gaps. On new or smooth and clean pavement there were no adhesion problems. Here we experimented with the primer and found it had little positive effect.

Throughout the project there were problems with marker displacement. The contractor's equipment was continually dislodging or destroying the markers in the work area and public traffic dislodged many more. No count was actually taken, but an educated guess would be 50% to 60% of the markers were replaced over a 2-month period. It became a weekly chore for the engineering crew to make the replacements. No accounting was kept of this maintenance work due to its short and sporadic nature.

Different spacings were tried and we found that 10' centerline and 20' fog line intervals were effective and not overly time consuming. This spacing was used throughout the project except in critical areas where a closer spacing was used.

Application of the markers in switching traffic to a new alignment was relatively fast. Through a project length of 1300 ft, three or four men could apply all new markers and remove conflicting old ones in about 2 hours. A complete installation required approximately 250 markers. At an average material cost of \$1.32 per series 88 markers and using the above stated labor (approximately \$0.35 for install and remove), the initial cost of a traffic shift on this project was approximately \$1.67 per marker or \$1700/mile. This does not allow for maintenance or required overtime.

Reuse of many (25% to 50%) of the markers was possible if care were taken in their removal with a shovel or small pry bar and hammer.

As to the markers daytime effectiveness in traffic lane delineation, the story is shown in the accompanying photographs. Cloudy or sunny, the markers were all but invisible on the 13-degree curve and only slightly better in the straighter sections. The traffic was constantly driving into the oncoming lane and/or missing the traffic detector loops for the temporary traffic signal. As one photo indicates, just a few pieces of reflective tape were required to keep the traffic in the right lane, at least in the stop bar area. As soon as the visibility problem was evident, the markers were supplemented with 1-ft strips of reflective tape. This helped to some extent, but eventually the striping crew was called upon to stripe the project.

At night the markers worked quite well, as the photos indicate. They provide excellent delineation and are an eye-catcher alerting the driver to hazards ahead. They can also be depended upon to be in place in the morning as opposed to plastic cones.

In most cases, the larger (88 series) markers performed better than the smaller (946 series) markers. We alternated their use throughout the project and found the smooth face of the larger markers did not catch debris which obscures the reflective surface as did the ridged face of the smaller marker; they were slightly easier to see in the daylight and adhesion was better by virtue of the larger surface area. Little or no difference could be seen in their reflective abilities when clean.

In conclusion, this office would recommend the use of the larger-sized raised reflective pavement markers in areas that could be confusing to night traffic, perhaps using the above mentioned spacing in tight areas. However, daytime effectiveness should be discounted and the markers should be supplemented with either striping or reflective tape.

Charles W. Elroy
Resident Engineer

Construction Zone Delineation-Raised Pavement Markers

DOT-FH-11-8876

Yachats River Bridge Section
Oregon Coast Highway
Lincoln County

Contract No. 8432

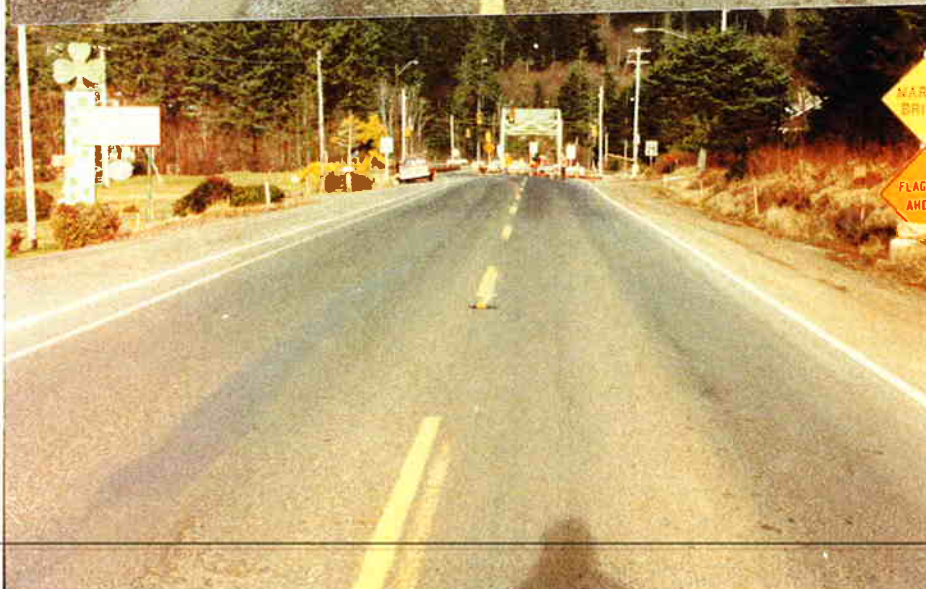
PHOTOGRAPHIC RECORD



4/7/77



3/23/77



2/3/77

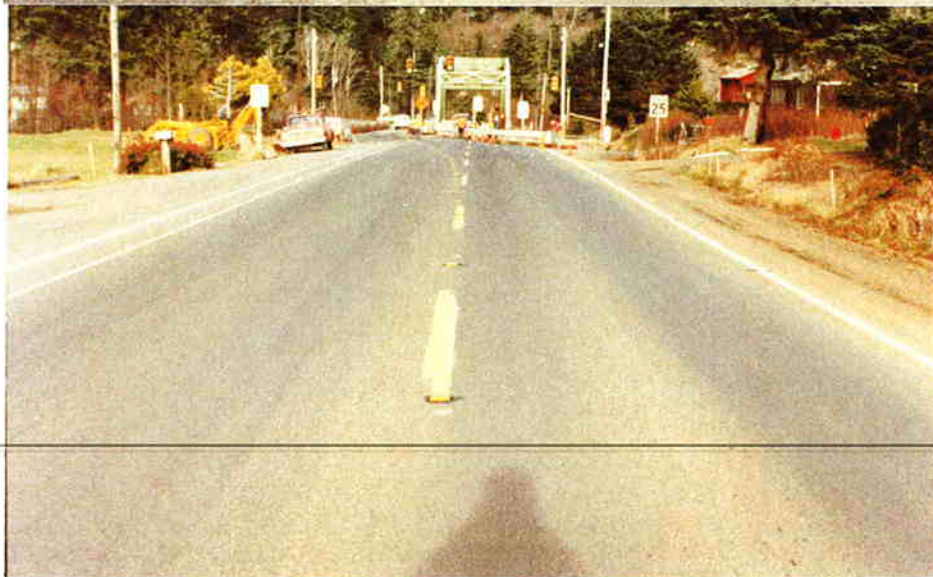
Northbound view, from station 146.



4/7/77



3/23/77



2/3/77

Northbound view, from station 147.



4/7/77



3/23/77



2/3/77

Southbound view, from about 50 feet northerly of the northbound stop bar.



4/7/77



3/23/77



2/3/77

Details of northbound stop bar. Signal detector loop is under the pavement patch. Bar is of metallic tape.



4/7/77



3/23/77



2/3/77

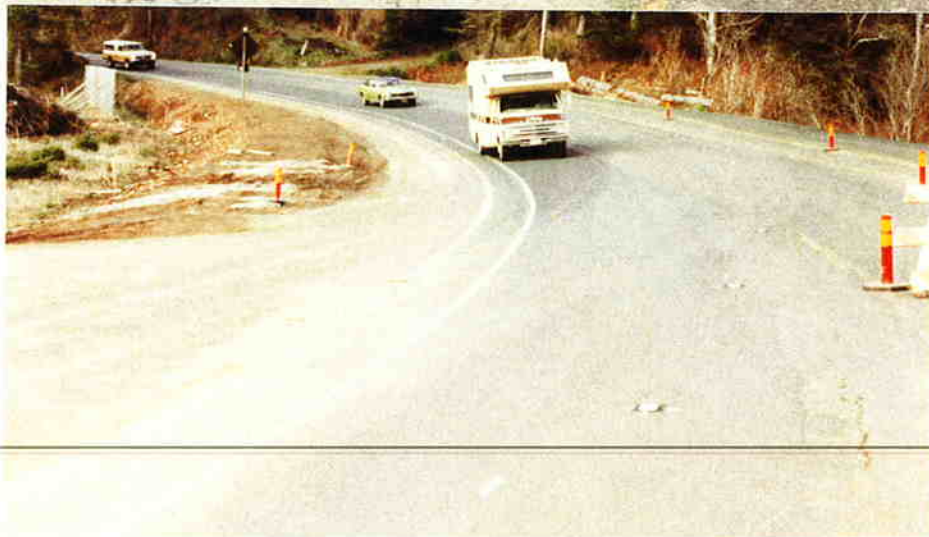
Southbound view of bridge, including southbound stop-bar area.



4/7/77



3/23/77



2/3/77

Looking northerly from near the southbound stop bar.



Looking southerly from station 1869+40.

3/23/77



As viewed by southbound traffic.

2/3/77



As viewed by southbound traffic.

2/3/77



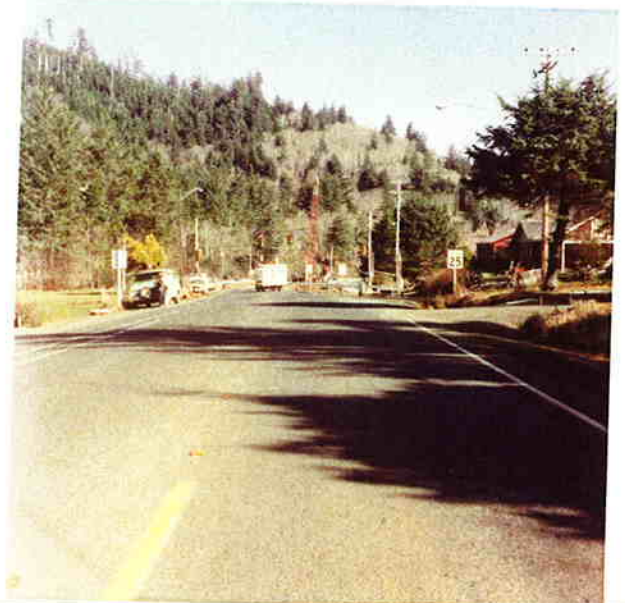
2/14/77 Looking south from 1869 at centerline reflectorized buttons on sunny day. Buttons barely visible.



2/14/77 Looking north from 1873 at reflectorized buttons. Very faint.



2/14/77 Looking south from 1875+50 Reflectorized buttons barely visible (weather sunny).



2/14/77 Looking north at centerline reflectorized buttons on sunny day from sta. 148.



3/22/77 Looking south from sta 1869 at reflectorized buttons (overcast day). Buttons barely visible.



3/22/77 Looking south at temporary striping (tape) at north traffic signal stop line near sta 1872. Note faintness of reflector buttons compared to striping. Prior to this stripe vehicles would pull into the oncoming lane to line up with structure and thereby miss the signal detector loops.



3/22/77 Temporary stripe to identify lanes more clearly at north traffic signal stop line near sta. 1872.

6/10/77
Northbound view from sta.
148. Note use of reflec-
tive tape alternating with
raised markers.

Day overcast--visibility
excellent.



6/10/77
Northbound view from
sta. 146.



6/10/77
Northbound view from sta.
145. Spacing on center-
line is 10 ft. \pm .





6/10/77
Southbound view from
near sta. 146. Note
use of reflective tape
and faintness of the
raised markers.



6/10/77
Southbound view from
sta. 148. Raised
markers and reflective
tape are being used
alternately.



6/10/77
Southbound view from
sta. 150.

6/10/77

Northbound view from
near sta. 1872.
Note use of reflective
tape. Nailed reflec-
tive markers are used
due to dirty pavement.



6/10/77

Northbound view from
northerly end of bridge.
Impact panel in
foreground.





6/10/77
Southbound view from
near sta. 1872. Note
nailed reflector in
foreground and use of
reflective tape.

Day is overcast.

Nailed reflectors used
in this area due to
dirty pavement.



6/10/77
Southbound view from
near sta. 1869.



6/10/77
Southbound view from
near sta. 1868.

APPENDIX B

CONSTRUCTION ZONE DELINEATION -
RAISED REFLECTIVE MARKINGS

Interim Report

Project 1
25th St. - Lancaster Drive Interchange Section
FAU 1560 & N. Santiam Highway
Marion County
Contract 8388

The above project is one of several projects that are conducting experiments with the raised pavement markers for temporary direction of traffic during stage construction.

The Stimsonite Model 88-SS Pressure-Sensitive Raised Reflective Marker with adhesive pad was used on this project.

The paving of this project called for multiple lifts of Class "B" and a wearing surface of Modified "C" which required traffic shifts daily. The contractor elected to return traffic to its normal pattern at the end of every day. This required the marking of the travel lanes each day either by paint or pavement markers. Several times the striping crew was not available and the pavement markers were used to delineate the travel lanes during darkness.

With the placing of the markers on warm asphalt it was not necessary to use the primer as a good bond was formed due to the adhesive backing and the heat. Removal of the markers the next day did not present a problem. The majority of the markers were lifted with a square shovel. The adhesive pad did retain some asphalt particles, leaving holes in the new AC mat. This did not present a problem as the mat was to have another overlay and the holes would be filled.

At this time we decided to salvage some of the old markers and try to reinstall them. It was found that they had too many AC particles on the pad to enable them to stick without being cleaned. Cleaning did present a problem by being very time consuming. Scraping the pad with a putty knife was not satisfactory. By soaking the marker in diesel the asphalt was removed but the adhesive action was gone. With the aid of the primer it was possible to reuse the marker. Due to the time element and the cost, we abandoned the idea of salvage.

The spacing intervals used were as follows: On tangents, centerline intervals were in 25' increments, while the shoulder spacings were 50'. On curves, centerline spacings were reduced to 12.5' and the shoulder to 25'. This spacing seemed to be very adequate for our volume of traffic.

After the major portion of the paving was completed it was necessary to reduce traffic from four lanes to two lanes for the winter months until the new structure is completed and the final paving can be completed. This has been accomplished very effectively with the use of the reflective markers. We placed the markers on new asphalt without the aid of primer as before. After several weeks we found that traffic was moving or shifting the markers. At this time we also noticed a few markers were being torn loose and being scattered. When replacing the markers the primer is being used. There is still some movement, but not nearly as much. When replacing a marker, it is imperative that the pavement be dry and clean. We have also noticed that the lower temperatures seem to reduce the bonding capability of the adhesive pad when used without the primer.

Removal of the traffic marker that has had primer applied is difficult as it tends to remove approximately 1/4" of asphalt before the bond is broken. This leaves a very distinct hole in the asphalt surface. Another method of removal was the application of heat to the marker. The marker suffered extensive damage due to the heat and was considered a total loss. Due to the heat, the surface around the marker "flushed" badly, leaving a fat spot that is visible and could be mistaken for traffic markings.

We found that in placing the markers on old or existing pavement that you need to use the primer. The raised markers if used for just one night could be used without primer on old pavement unless they were in an area where turning movements were over the markers. If used longer than one night traffic did move the markers badly.

The use of reflectorized pavement markers for temporary detours and semi-permanent lane marking is highly recommended over striping tape or a temporary stripe. The raised markers will pick up the lights from the vehicles, thus illuminating the travel lanes that are to be used. With a fog condition, the reflectorized markers were very effective compared to our present painted stripe.

Safety to the traveling public is our main concern when constructing roadways. Many traffic safety devices have been used in the past for the marking of travel lanes. The reflectorized pavement markers are far more effective than striping tape, painted stripes, and reflectorized cones during the non-daylight hours and should be considered for all future construction.

The actual time involved in the placing of the markers would be comparable to that of placing the striping tape. If it were possible to have the striping crew available, painting would be the quickest method of marking the travel lanes, but possibly not the most economical.

Our labor cost figures, from limited experience, are about \$0.23 per reflector installation, plus the cost of the materials (\$1.36 Double face, \$1.28 Single face), and when necessary, the removal which about equals the installation cost, \$0.23, totaling \$1.82 Double face, \$1.74 Single face, per marker. The removal probably would not be necessary if subsequent lifts of paving were to be placed over the markers. However, these lifts would need to be substantial such that the risk of the markers reflecting through would be eliminated.

Assuming that we would have to remove the markers due to shallow paving lifts, we arrive at the following costs per mile based upon the listed assumptions. The striping costs used for comparison are based upon overtime rates for the employees and some inefficiency due to the on-demand timing of the operation.

Thus, estimated costs are:

Centerline - One stripe - Skip:	
Labor	\$22.00/mile
Equipment rental	6.00/mile
Paint	36.00/mile
Total	<u>\$64.00/mile</u>

Shoulders - Two stripes - Solid:	
Labor	\$44.00/mile
Equipment rental	12.00/mile
Paint	102.00/mile
Total	<u>\$158.00/mile</u>

<u>Description</u>	<u>Reflectors</u>	<u>Striping</u>
Tangents - Centerline - 1 line - 25' spacing	211 x 1.82 = \$384.02	\$64.00
Shoulders - 50' spacing -	105 x 2 x 1.74 = \$365.40	\$158.00
Curves - Centerline - 1 line - 12.5' spacing	422 x 1.82 = \$768.04	\$64.00
Shoulders - 25' spacing -	211 x 2 x 1.74 = \$734.28	\$158.00

Summarizing, the markers are more expensive than the striping, especially in the curves where we used the 12.5' spacing. However,

they are entirely effective and can be available at any time as needed. The striping crew, in many instances, will not be readily available on command, especially in some of the outlying areas of the regions.

It would follow that a supply of the markers should be kept on hand to be used in those cases when it would be impractical to route the striping crew to the project. This would be especially true when the lines to be marked are short and in the current cases, where we are placing multiple lift paving.

Loren Weber
Resident Engineer

CONSTRUCTION ZONE DELINEATION -
RAISED REFLECTIVE MARKINGS

Interim Report

Project 2
Chemawa Road - Hayesville Interchange Section
Pacific Highway East
Marion County
Contract 8273
Federal Aid No. FF-19(6)

The Chemawa Road - Hayesville Interchange Section of Pacific Highway East was selected as one of three projects within the State for a trial use of raised reflective traffic markers in lieu of normal temporary painted traffic striping. It was intended that the markers be tested for their effectiveness under both daylight and nighttime conditions.

The project has a total length of 1.72 miles, with general alignment, typical section, and stage construction sequence as shown on the accompanying sheets. With the exception of minor curvature realignment, the new roadway section generally paralleled the existing highway with widening on both sides. New grade was generally flat with a maximum deviation from original pavement grade of about 6'. Stage construction required some temporary surfacing construction and traffic shifts. Part of this work was already done before we were notified of the raised marker study. We entered the program when Stage I was completed and we were just ready to shift traffic onto the new pavement. Part of the intent of the program was to test the overall effectiveness of a self-stick type button that could be used on final lift pavement for temporary traffic control after which it could hopefully be removed without the problem of leaving tell-tale marks or lines that could, especially under adverse weather conditions, lead drivers into a wrong traffic pattern. We were all ready to make the traffic switch and found there would be a long delay in ordering the self-stick type buttons. It was decided to use the conventional epoxy application type buttons as we had another final lift of asphaltic concrete pavement to go on yet which would cover the holes left after removal of the buttons. We would be testing primarily the traffic handling use of the buttons and not the effects of removal.

Several types of markers were experimented with and we found that the "bright yellow" and "appliance white" markers from Ray-O-Lite seemed to be much more visible in daylight on new asphalt pavement than some others. We also experimented (prior to actual use) with spacings on the buttons and found that with the sun to our backs, the spacing was not so critical but that when looking toward the sun, a spacing of 6' was not too frequent. As a compromise, we decided to space the yellow centerline buttons at 12.5', the white shoulder markers