DEVELOPMENT OF LOUVERED SIGNS TO REDUCE WIND LOAD

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

DEVELOPMENT OF LOUVERED SIGNS TO REDUCE WIND LOAD

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Final Report on a Highway Planning and Research Investigation
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Federal Highway Administration

Michigan State Highway Commission
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Lansing, January 1973

SUMMARY

This study has developed a louvered sign background of light gage aluminum sheet, fabricated by standard sheet metal techniques. The finished sign background weighs 3.2 lb/sq ft. Louvers are curved, about 4 in. wide, 1-1/2 ft long and are assembled into sign "planks," 1-1/2 ft wide, the height of the sign. A louvered sign 8 ft high and 12 ft wide was built and tested in comparison with a standard sign. Wind load reductions of approximately 50 percent were attained in the direction normal to the sign face with a typical legend in place. Lateral wind resistance was approximately equal to normal wind resistance. Photometric and observer evaluation of the louvered background showed adequate legibility and contrast between painted louvered background and reflectorized embossed letters. Reflectorized sheeting applied to the louvered surfaces gave poor results because of the angles involved, and is not deemed worth the investment. It is concluded that louvered sign panels would be quite expensive when compared to standard signs. Although normal wind loads are reduced, lateral forces and dead-load are increased. Also, the effect of ice load on the larger surface area, along with constriction of the louver passages by ice and snow, are not determined. While it appears that there may be special applications where louvered signs would be applicable, they are not recommended in general.

CONTENTS

INTRODUCTION

This report covers developmental work on louvered sign backgrounds and mounting devices for the background and legend. The work was carried out by the Research Laboratory Section of the Michigan Department of State Highways as a Highway Planning and Research study in cooperation with the Federal Highways Administration.

The project was proposed as an extension of earlier experiments on non-solid sign backgrounds by Tidwell and Samson at the Texas Transportation Institute (1). At about the time that this project was to begin, TTI published results of further experimentation (2). The later work at TTI completed some of the experiments that had been proposed for the initial stages of this study; namely, evaluation of various louver shapes, sizes, and orientations, with regard to wind resistance. Therefore, the emphasis of this project was altered to make use of the new data. The louvered sections constructed for the TTI tests were made by fillet welding the individual louvers to the side plates. While this type of fabrication is adequate for experimental models, it does not lend itself well to production because of its relatively low speed and high cost. The basic aim of this project was the development of a louvered background design that would be modular, weigh no more than absolutely necessary, be sufficiently strong and stiff for handling and mounting, and could be manufactured using standard sheet-metal shop practices.

Objectives

The objectives of the project were stated in the Proposal as follows:

1. To develop a louvered sign background that has a "solid" appearance when viewed by motorists, suitable strength and stiffness, and can be readily manufactured and mounted on the support structures.

2. To develop suitable mounting devices for the signs and legends.

3. To develop proper legend size and brightness, based on legibility considerations.

4. To construct prototypes for wind tunnel testing and determination of applicable load reduction factors.

DESIGN DEVELOPMENT

On the basis of work performed by the Texas Transportation Institute the shape, size, spacing and orientation of the louvers to most effectively reduce wind resistance were determined. Therefore, our development work was limited to experiments with fabrication methods to obtain a louvered sign that could be manufactured by standard sheet metal procedures and also be comparable in weight to our present extruded aluminum plank signs.

There are many possible ways to build a louvered sign. However, to build one that is comparable in weight, as easy to handle and as simple to assemble as an aluminum sign made of planks, or one made of plywood, is a difficult task. The standard sign in Michigan for overhead mounting and for large roadside signs is made of extruded aluminum planks 6 or 12 in. wide. The planks are shaped in the form of a channel. The legs are 2 in. long and at the free end a T-slot is located on the inside of the legs. The 12-in. plank has an additional stiffening rib in its center. On the 6-in. plank, only one of the legs has a T-slot at its end.

Signs of this material are made by cutting the individual planks to the desired length and then bolting them together to obtain the height required. Aluminum bolts 3/8 in. in diameter, spaced at 1-ft centers are used to fasten the planks together. For mounting purposes, aluminum angles are fastened to the sign back in a vertical position by bolts inserted in the horizontal T-slots of the planks.

Prior to assembling the planks, green reflective material is applied to the front of the planks. Then, after the planks are assembled the message and border are mounted on the sign face. Both the message and border are of silver reflectorized sheeting.

Although there are no Federal Standards governing the structural design of signs, Michigan has had specifications for several years limiting the deflection of aluminum panel signs. The maximum allowed deflection for a sign supported at L/5 from each end, and subjected to a design wind load of 35 lb per sq ft, is L/85, where L is length of sign. The deflection limitation prescribed is an arbitrarily selected value and its reasonableness may be disputed. However, the specification has provided satisfactory signs with respect to both stiffness and handling.

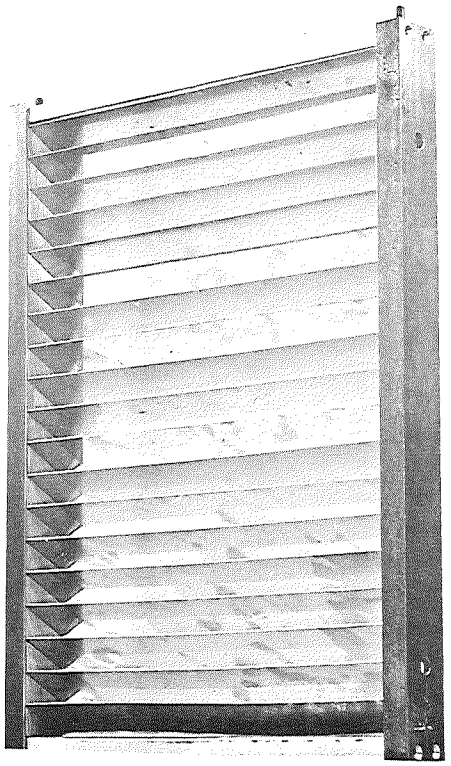
As previously noted, a basic aim of this project was to make the louvered background as light as possible. It was generally agreed among the staff that from a practical point of view, 0.040 in. was about the minimum

thickness of aluminum sheet that should be used in the experiments. It soon became obvious that if plain flat louvers were used, stiffness requirements for the individual louvers would dictate the use of heavy gage materials, and the final weight of the section would be high. In the tradition of sheet metal fabrication, light gage materials can be given considerable stiffness by forming the cross section, to increase effective moment of inertia. However, the more complicated the shape of the cross-section becomes, the more expensive it is to produce. Experimentation with various flat and Z-shaped louvers led to the conclusion that the modified S-shaped curved louver evaluated by TTI, was probably as practical as any, even though it would have to be produced by sheet metal dies.

In order to determine a reasonable fabrication method for a louvered sign, several small models were made for evaluation purposes as shown in Figures 1 through 5. The first model made was fabricated by inserting spacers between the louvers and bolting through the spacers and louvers (Fig. 1). The louvers were straight, 2-3/16 in. wide, 18 in. long, and 0.040 in. thick. Louver spacing was 1-1/8 in. and their slant was 30° from horizontal. For this type of design the various parts could readily be manufactured. However, assembly of the many parts when building a large sign would appear to be very cumbersome. For this reason no further development on this type of fabrication was carried out. Elimination of this mode of assembly also eliminated the use of long horizontal sections of louver, and subsequent work was directed toward development of louvered subassemblies that would be built to the height of the sign and assembled vertically, side by side, to form the required width of the sign.

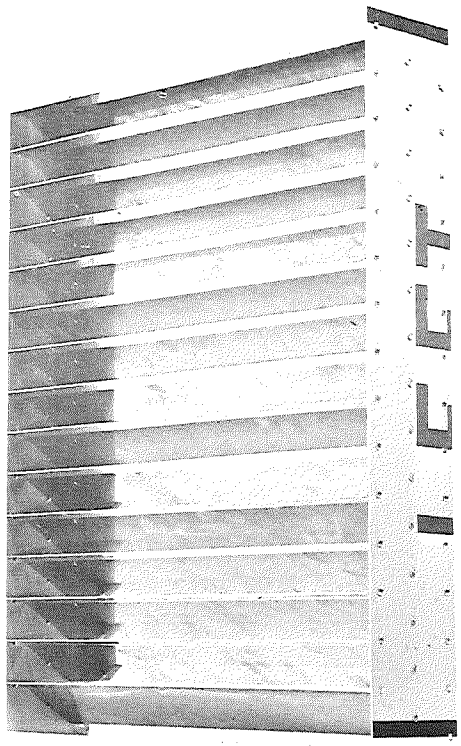
The remaining models were fabricated by fastening the louvers to the side plates with tabs. These tabs are an extension of the louver that protrude through corresponding slots in the side plate where they are clinched over. In a design of this type the two basic features that need to be determined are the number of tabs required to fasten the louvers to the side plates and the allowable length of the louvers so that they will not be destroyed by wind-induced vibrations.

Since no wind tunnel was readily available for testing the vibration susceptibility of the louvers as mounted, a fixture was built to secure the models on the front of a truck (Fig. 6). Two curved-louver models were prepared for testing, with louver lengths of 18 and 24-in. The models were mounted on the truck and driven down the highway. The test revealed that the 24-in. louvers vibrated severely and broke loose from their side plates at speeds less than 45 mph. Subsequently, 18-in. louvers, mounted with four and five tabs at each end, were mounted and run up to 70 mph into a headwind of approximately 30 mph, with no visible vibration and no damage.



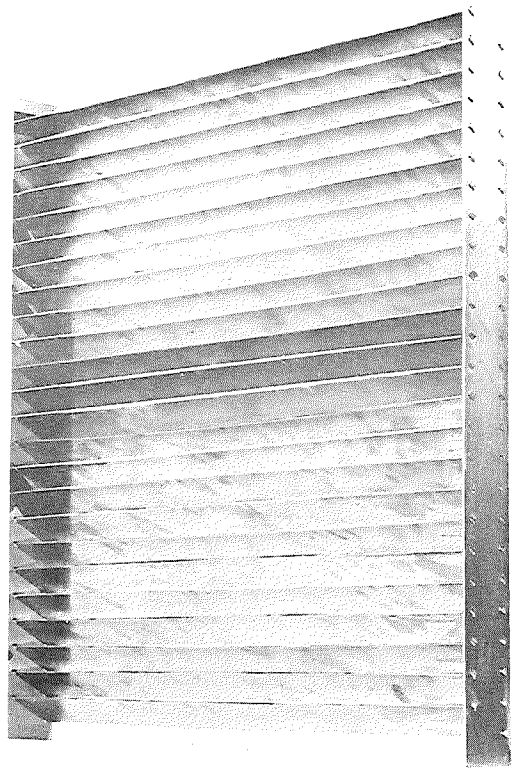
Dimensions: 18 by 24 in.
Louver Type: Straight
Louver Dimensions: 2-3/16 by 18 by 0.040 in.
Louver Spacing: 1-1/8 in.
Side Plate: Machined 2-in. channel
Assembly: Channel and sheet metal frame with spacers between louvers. Bolt-through spacers to hold assembly together. Top and bottom plates formed from 0.040 sheet metal.

Figure 1. Initial louvered sign model.



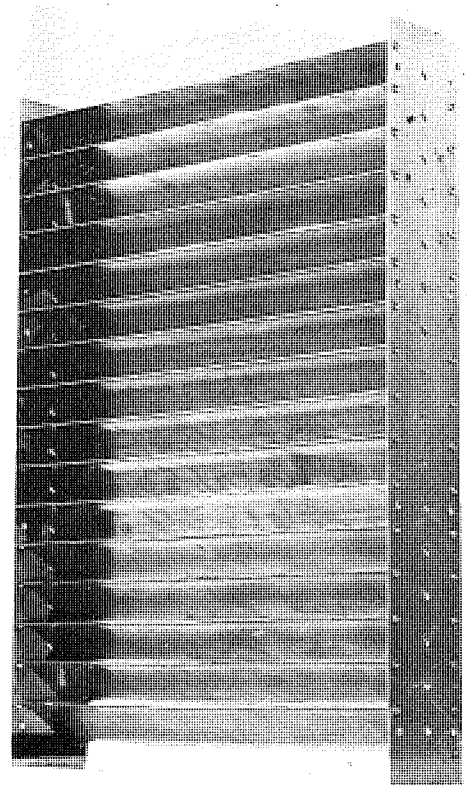
Dimensions: 18 by 24 in.
Louver Type: Straight with a 7/8-in. bend at each edge.
Louver Dimensions: 4-3/8 by 17-1/2 by 0.040 in.
Louver Spacing: 1-1/2 in.
Side Plate: 4 by 24 by 0.082 in.
Assembly: 3, 3/16-in. tabs, 5/16 in. from each edge and on center.

Figure 2. Louvered Sign Type II



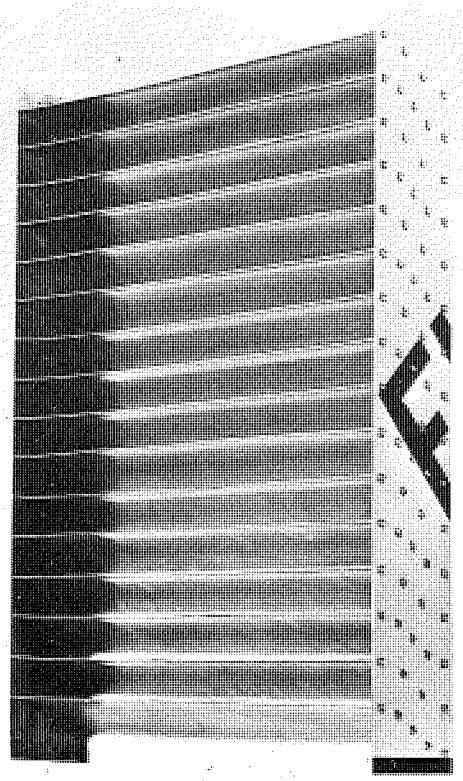
Dimensions: 24 by 24 in.
Louver Type: Straight with a 1/4-in. bend at each edge.
Louver Dimensions: 2-1/2 by 24 by 0.040 in.
Louver Spacing: 1 in.
Side Plate: 2-1/4 by 26 by 0.082 in.
Assembly: 2, 1/4-in. tabs, 1/4 in. from each edge.

Figure 3. Louvered Sign Type III



Dimensions: 18 by 24 in.
Louver Type: S-curve
Louver Dimensions: 4-3/8 by 18 by 0.040 in.
Louver Spacing: 1-1/2 in.
Side Plate: 4 by 26 by 0.082 in.
Assembly: 3, 1/4-in. tabs, 1/4 in. from each edge and on center.

Figure 4. Louvered Sign Type IV



Dimensions: 18 by 24 in.
Louver Type: S-curve
Louver Dimensions: 4-3/8 by 18 by 0.040 in.
Louver Spacing: 1-1/2 in.
Side Plate: 4 by 26 by 0.082 in.
Assembly: Alternating 4 and 5 tab louvers. 1/4-in. tabs symmetrically spaced. Outside tabs 1/4 in. from edge.

Figure 5. Louvered Sign Type V

Figure 6. Truck-mounted louvered sign models for determining dynamic instability. Speed attained, 70 mph.

On the basis of the experience with these sign models, and the results published by TTI, curved louvers, 18 in. long, fastened to side plates with four tabs on each end, were selected for use in a full-scale sign. The louver spacing was set at 1-1/2 in. and the louver angle at approximately 20°. The side plates were 4 in. wide and 0.080 in. thick. A full-scale sign of this design would be made up of 18-in. wide louvered panels cut to the height of the sign.

After the design of the louvered bakcground had been determined the methods for attaching the legend and mounting of the sign were selected. To avoid drilling holes for mounting the message and for mounting the sign itself, an extrusion 4-1/8-in. wide, 0.10 in. thick with a T-slot on each side, was designed to fit between the louvered panel side plates. The panels with the extrusion inserted between them were bolted together with 3/8 in. stainless steel bolts spaced at 2-ft 6-in. centers. The attachment for mounting the legend consisted of bolting 3/4 by 3/8-in. aluminum channel extrusions to the front T-slots of the vertical extrusions. The channels were positioned in accordance with the location of the message lines. Reflectorized embossed cut-out letters were fastened to the channels with sheet metal screws. Mounting of the sign was accomplished by bolting angles to the T-slotted extrusions on the back of the sign. In order to show a border on the sign and for appearance and handling purposes the sign was

enclosed in a casing or frame. In the case of the experimental sign built for this project, the casing was made from available sign plank extrusions. It was made in two parts; the front portion consisting of an angle 2 by 2-5/8 in. and the back consisting of a piece 2 in. wide with a T-slot on one side. The casing was fastened to the sign with sheet metal screws.

A bid from a local manufacturer for building a 10 by 10-1/2-ft louvered sign background was $1,800 for the sign, plus approximately $1,600 for tooling. This was rejected by the Research Laboratory staff because of limitations in funds available for the study. Instead, the Laboratory's machine shop was asked to build a 8 by 12-ft sign including mounting angles and post for outdoor testing and observer evaluation. Plans for the 8 by 12-ft experimental sign background, casing, mounting angles and post are shown in Figure 7. For any future production, the casing should be extruded in a single unit, rather than using a two-piece casing.

The louvered panels, T-slotted extrusions, casing, and channels were painted with Interstate green color prior to assembly. The paint was not reflectorized. The border was 2 in. wide and was made by applying a pressure sensitive reflectorized tape.

The completed sign, including casing, but not the legend and the mounting angles, weighed 3.2 lb per sq ft. The aluminum panel sign currently used in Michigan weighs 2.8 lb per sq ft. On the basis of a static load deflection test, the equivalent moment of inertia per ft width of sign was determined to be 0.35 $in.^4$. The moment of inertia per ft width of the same size sign made of currently used material is on the average 0.94 $in.^4$. A smaller moment of inertia could be used for a sign of this size, but the manufacturers of aluminum plank make only one size. Consequently, signs less than 30 ft in length are stiffer than required by the specifications.

By comparing the stiffness of the two signs it follows that the louvered sign would require more care in handling because it is not so stiff. Its bulkiness also tends to make handling more difficult and the louvers can be damaged by careless handling. Therefore, it appears that the sign developed is about as light as it can be made from a practical point of view when handling, hauling, erecting, and probable durability are considered. Obviously there will be considerable fabrication and assembly costs in any louvered sign. Since the quantity of aluminum required for even this light-gage sign is greater than the amount used in standard signs, where assembly and handling are far easier, it is equally obvious that any louvered sign will be quite expensive. At present, it seems highly questionable whether such additional costs can be justified.

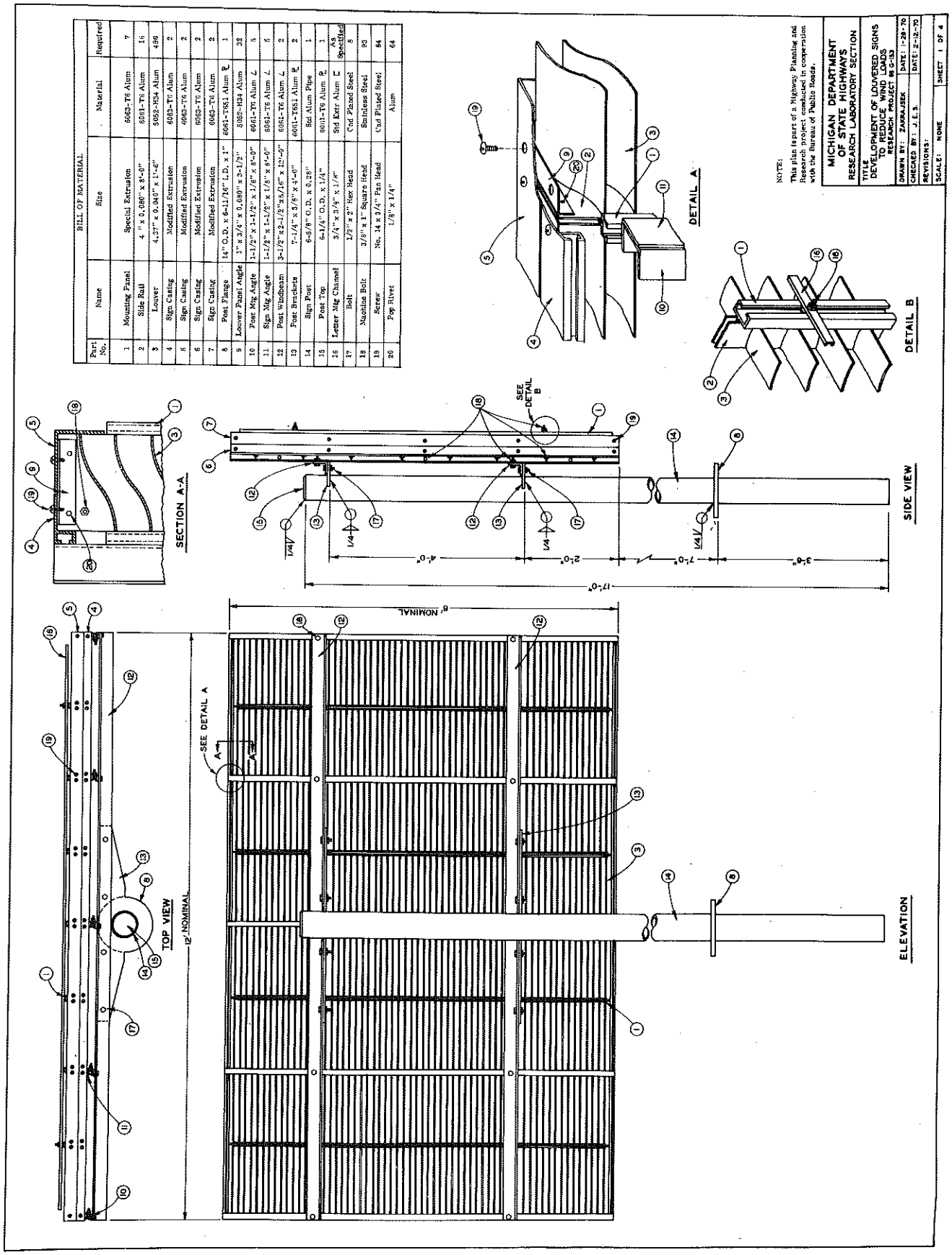


Figure 7. Plans for full-size louvered sign model.

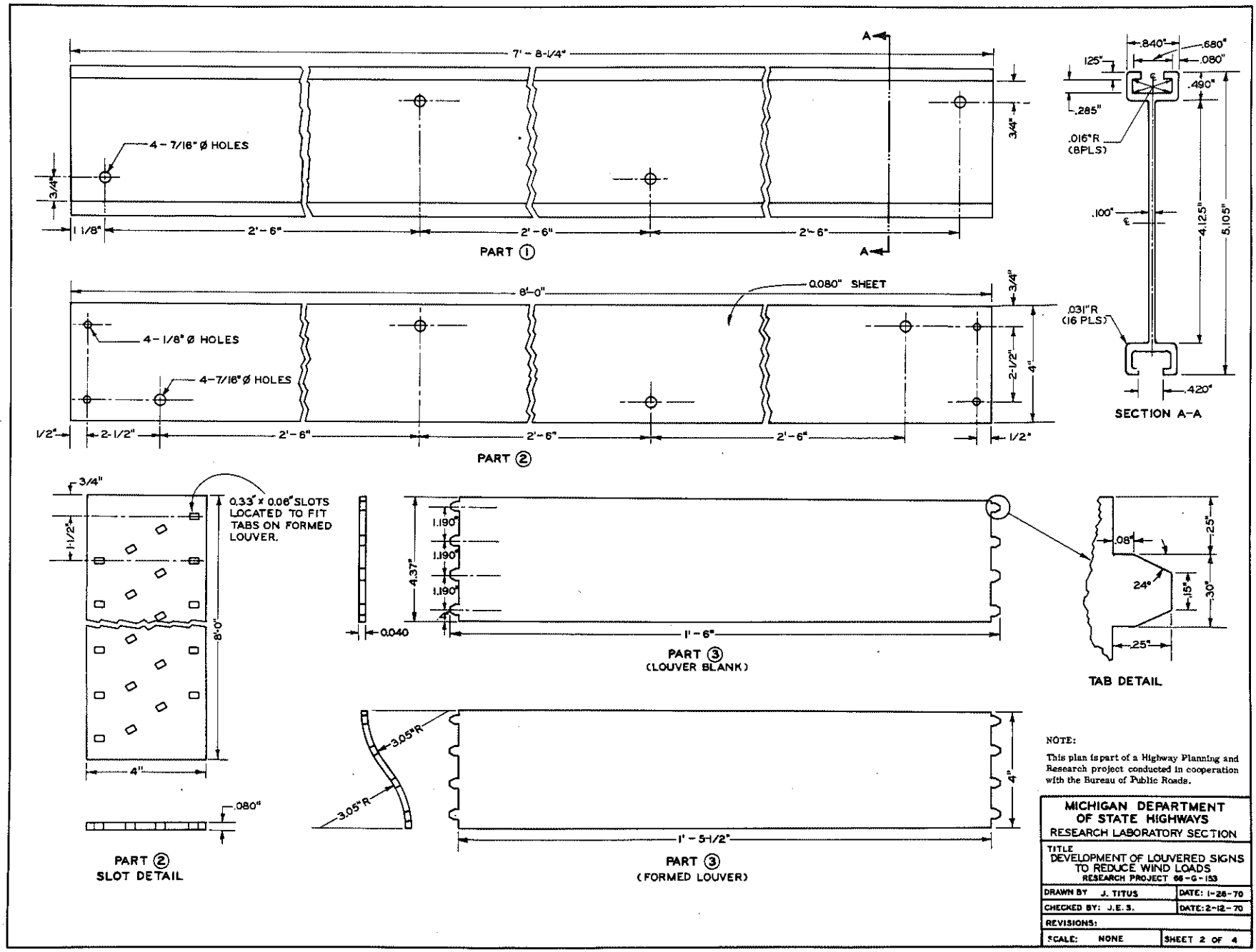


Figure 7 (Cont.). Plans for full-size louvered sign model.

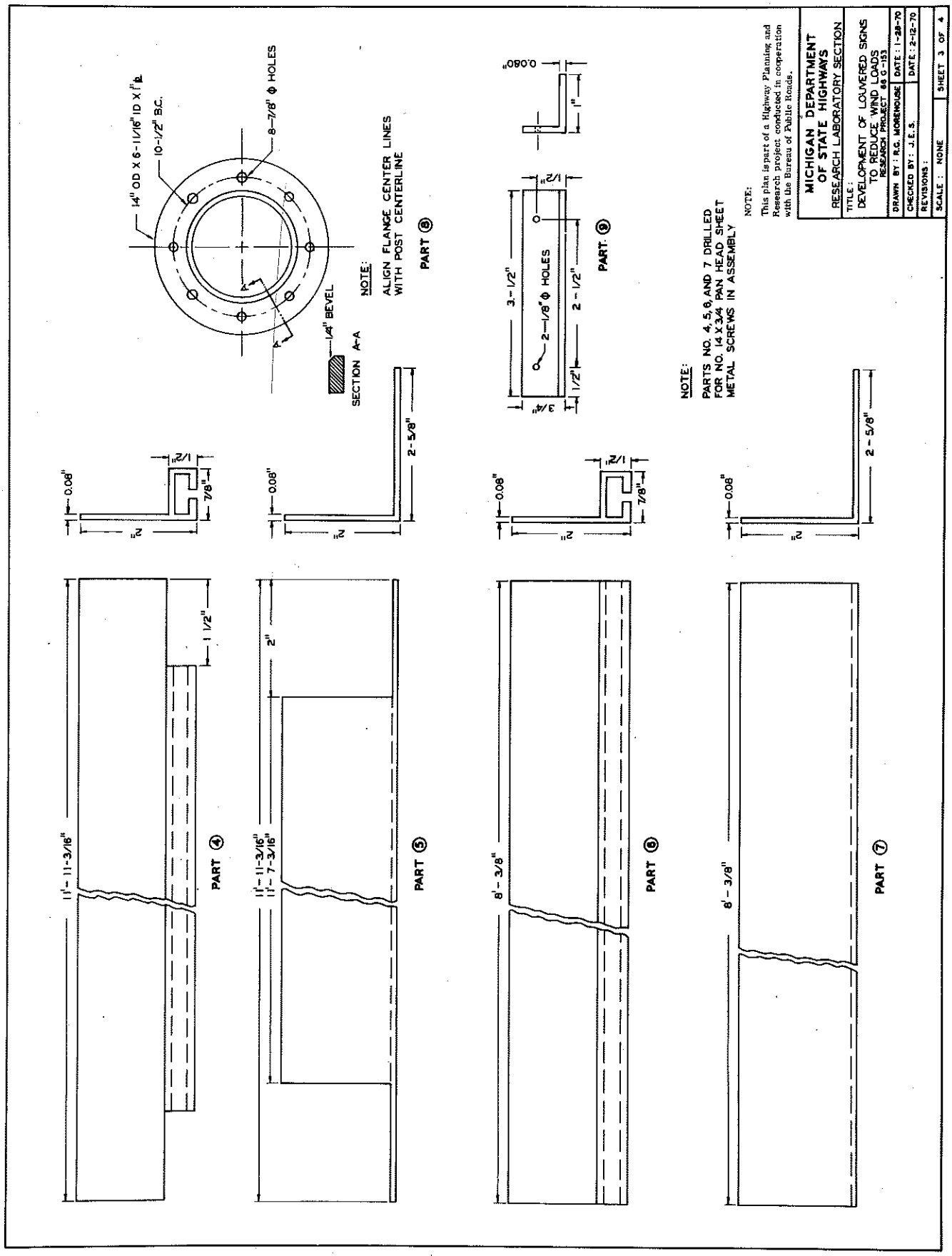


Figure 7 (Cont.). Plans for full-size louvered sign model.

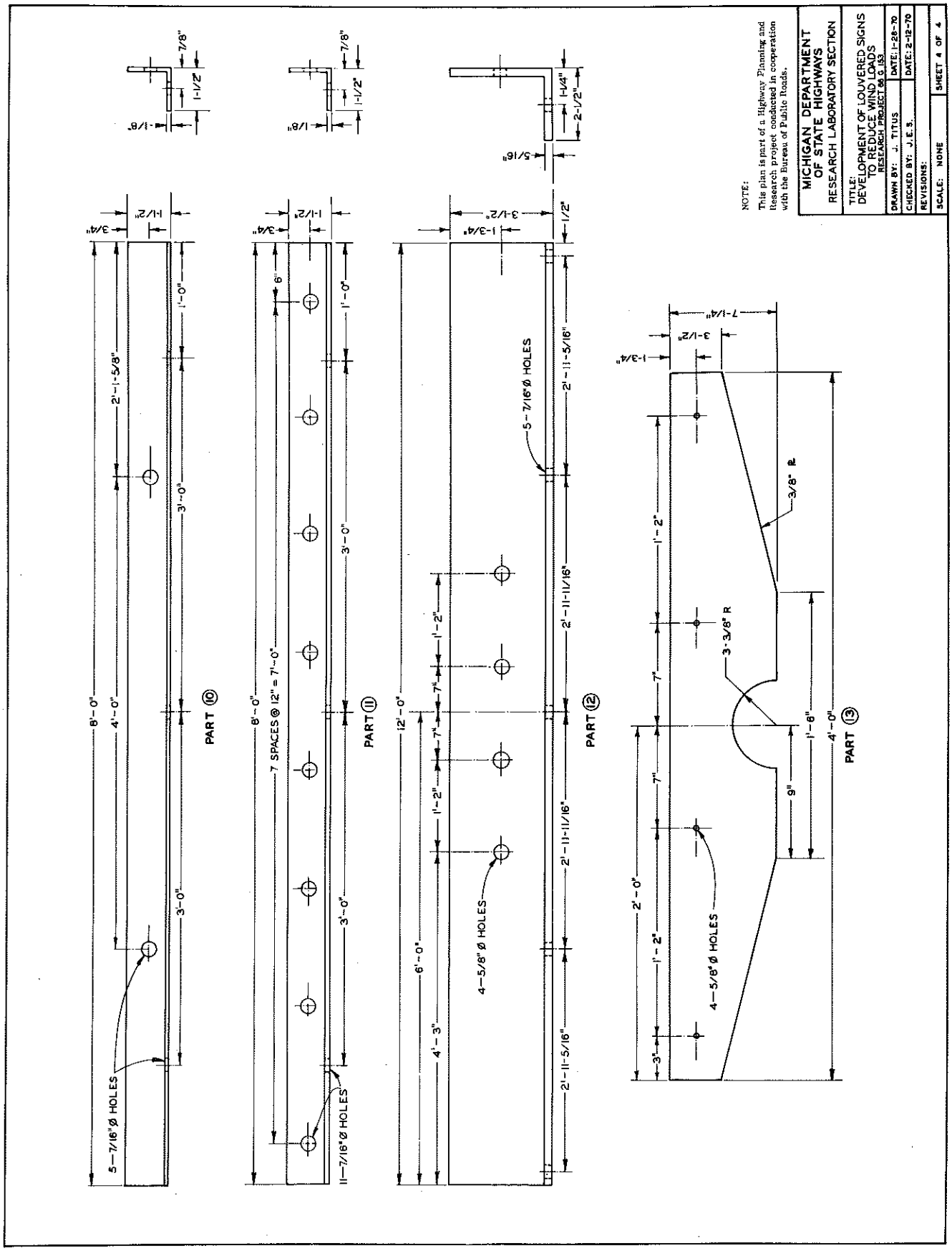


Figure 7 (Cont.). Plans for full-size louvered sign model.

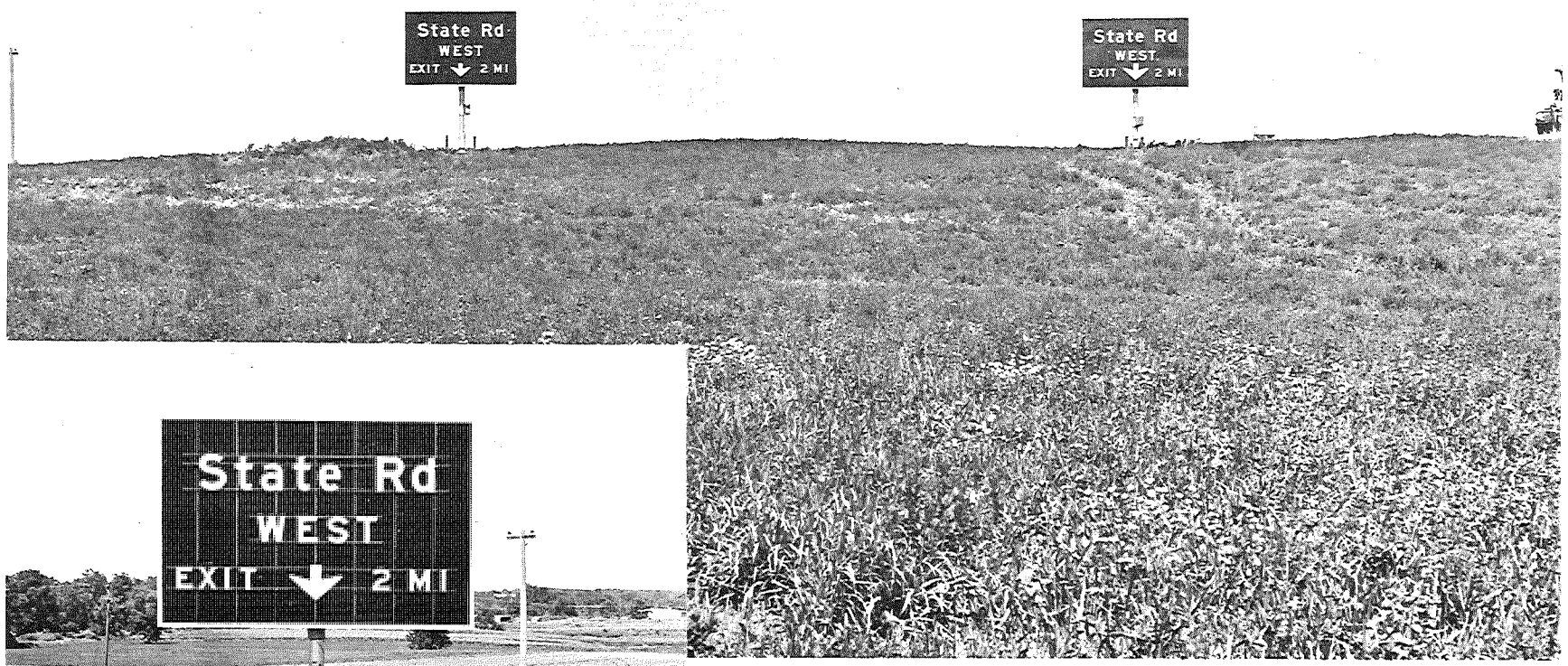


Figure 8. Field-mounted louvered sign (left) and standard reflectorized sign; overall sign dimensions and legend size are the same on the two signs. Distance from signs approximately equal. Close-up shows the 8 by 12-ft louvered sign with typical legend attached.

FIELD TESTING

Since the developmental phase of the project ultimately resulted in a full-size louvered sign, and since the sign had to be mounted for observer evaluation, a decision was made to mount the sign on an instrumented support for wind resistance evaluation. The TTI had made field tests on a solid sign, but had not constructed or tested a full-size louvered sign. Our louvered sign was slightly different in detail than the louvered segment that was wind-tunnel tested by TTI, and we wished to determine if similar reductions in wind load were obtained. Instrumented sign supports were built on the same order as those used in the Texas experiments, with strain gage bridges positioned to measure normal, transverse, and torsional loadings. The base flanges had 16 holes, so that the orientation of the signs could be varied in 22-1/2° increments. The supports were calibrated by dead weight.

Electronic instrumentation for the study included a seven-channel analog magnetic tape recorder, a two-channel oscillograph, and a digital volt meter; with associated power supplies, amplifiers, and signal conditioners. The same equipment was used in calibration of the supports and in the actual test runs. Shunt resistors were used as calibration checks in the field. "Cross-talk" between strain gage bridges was less than 2-1/2 percent. A review of the Texas report indicated that they had trouble in accurately determining instantaneous wind speed at the sign face, since they used standard rotating-cup type anemometers that have inherent lag when subjected to gusts. Hot-wire anemometers were obtained for this study in an attempt to eliminate the problems associated with the rotating anemometers.

A field test site was selected on high ground, with no trees or other obstructions projecting into the path of the wind. The louvered sign and a solid sign were mounted on the instrumented supports with the bottom of the signs approximately 7 ft above the ground. Wind velocity probes were placed on either side of the sign, and immediately above the sign, to determine the variation of wind velocity with time--and also to indicate whether velocity gradients existed at any given time--in the immediate vicinity of the sign. The field installation is shown in Figure 8.

Several attempts were made to obtain comparative wind resistance data from the field installation, but several problems prevented the collection of adequate information. Remarks concerning these problems are included here as information for future investigators who may wish to try similar experiments.

1) Wind velocity measurement--Instruments for wind velocity measurement that are suitable for this type of study are not plentiful. Reportedly, there are instruments available that measure velocity and provide linear output. However, the instruments used for this study provided outputs that were non-linear, and were not sufficiently sensitive to changes in velocity in the range of interest. Moreover, hot wire anemometers are moisture sensitive and cannot be used during inclement weather.

2) The collection of reliable strain information under field conditions requires that the instruments and gages be zeroed and calibrated. This cannot be done accurately while the support is being subjected to violent vibrations. Therefore, the sign must be dismounted from the support if a reasonable assurance of proper zero adjustment and scaling is to be attained. The signs were dismounted for such checks by using a frame with legs bolted to the wind beams, outside the post bracket ends. These legs were made to pivot at ground level. Once the angle posts were fastened to the windbeam the sign was unbolted from the post brackets and swung away from the post. The movement of the sign was controlled by struts fastened to the angle posts at one end and to the bed of a truck at the other end. By driving the truck backward or forward, dismounting and remounting of the sign was accomplished. However, the operation is time consuming and uncomfortable for workmen during cold weather.

3) Wind variability--It is necessary to have wind velocities of approximately 20 to 30 mph to generate sufficient forces for measurement with the type of gear used in this study. Although such velocities may not be unusual in some parts of the country, it was found that winds of 30 mph or higher were quite rare at the test site. The higher velocities usually were associated with storms of rain or snow, which prevented the use of the anemometers. Gusting and turbulence caused dynamic actions of the sign and support to an extent that desirable steady state information was nearly obscured. Significant gradients in velocity existed within the dimensions of the sign, and turbulence caused obvious temporary differences in wind direction from one edge of the sign to the other. Since the gusts occur in random fashion, and the range of velocity and direction is considerable, average values are not useful.

Due to the above mentioned problems, it became obvious that useful data would not be obtainable at the field site, within reasonable limits of expenditures of time in the field and for data analysis.

Fortunately, a nearby U. S. Army facility, the Tank-Automotive Command at Warren, Michigan, has a large indoor testing cell where winds up to 40 mph can be generated. Due to recent changes in priorities within the Federal Government, it became possible during 1971 to utilize the TACOM cell for evaluation of the louvered sign.

There are obvious drawbacks to testing in a facility of this type as well; such as the existence of some turbulence, lack of absolutely uniform flow conditions across the test area, etc. However, there are many advantages. The wind can be shut off, to zero and calibrate strain gage instrumentation; the wind speed can be varied at will; and because fan conditions can be maintained at a given level, time averaging of signal can be performed to remove the effects of vibration and turbulence. Both the louvered and solid signs could be mounted in turn at the same location and subjected to very similar wind conditions.

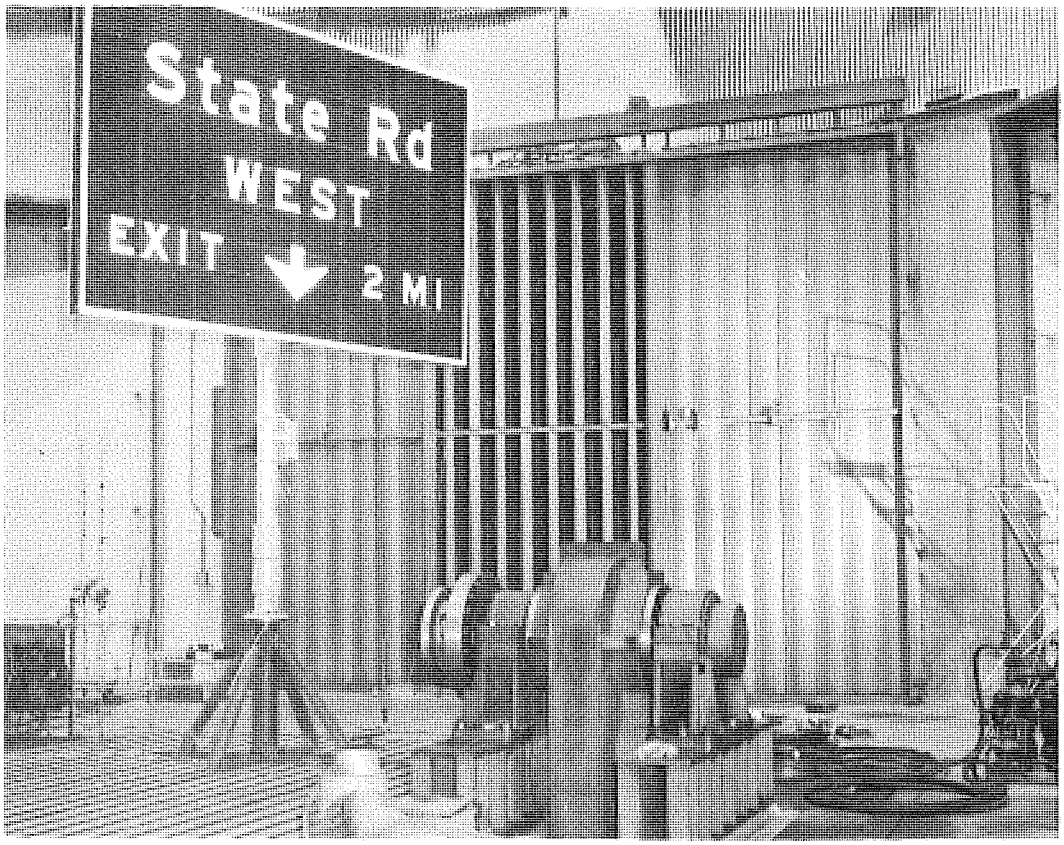


Figure 9. Full-size louvered sign mounted in test cell at U. S. Army Tank-Automotive Command.

Since we had seen no reference to previous testing of full-size louvered signs, and because there was no nearby wind tunnel facility for testing smaller sections of our sign, a decision was made to go ahead with comparative testing of the signs at the TACOM facility. The tests were conducted during the week of September 13, 1971. Both signs were subjected to nominal 20, 30, and 40 mph winds. The sign support was set up in front of the inlet louvers in the test cell as shown in Figure 9. The inlet opening was approximately the same width as the sign, so that there was a slight

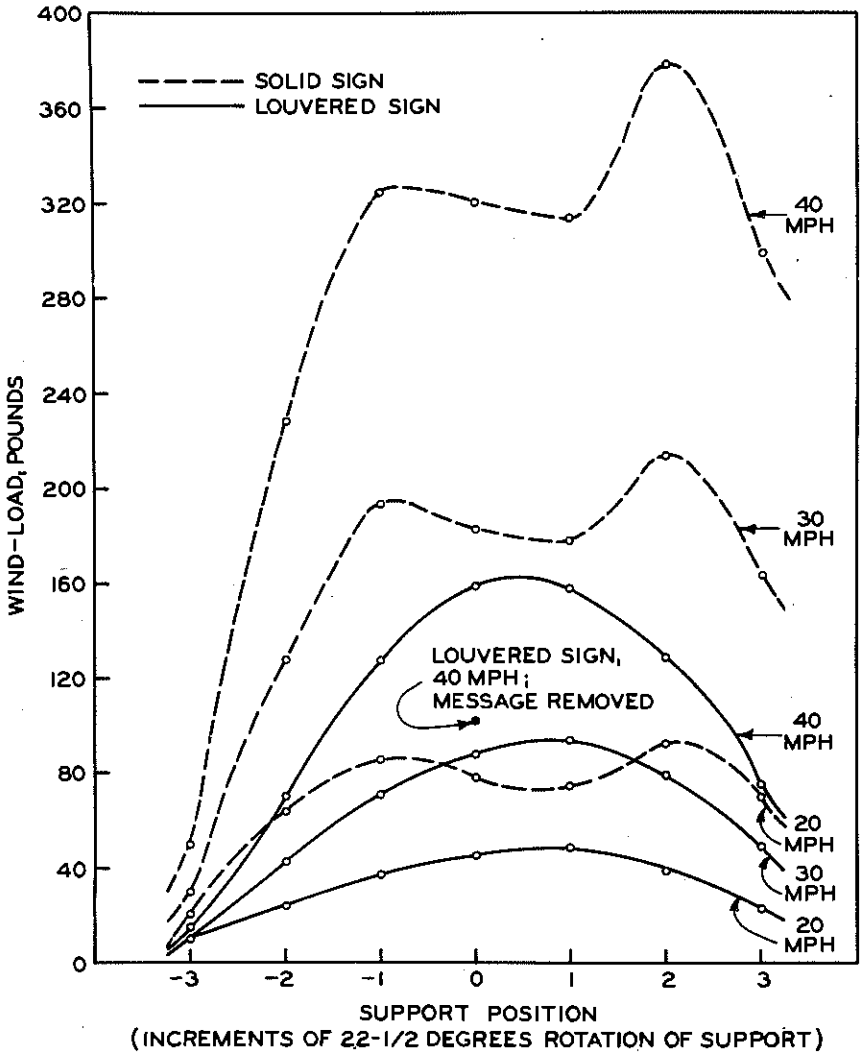
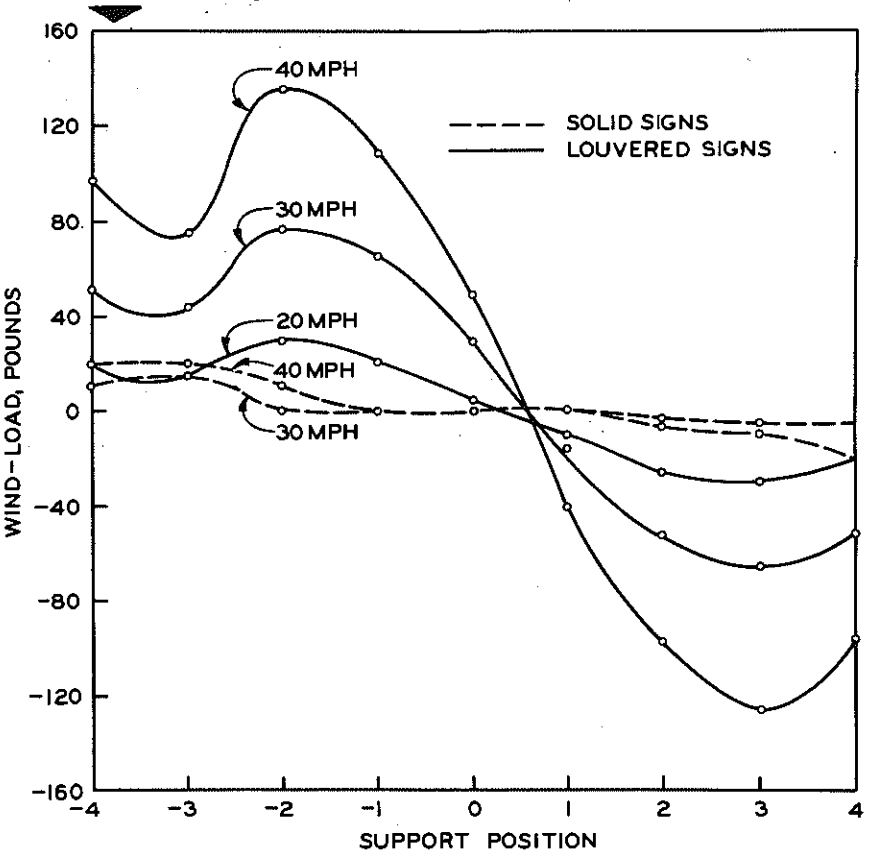


Figure 10. Variation in normal force on louvered and conventional signs.

Figure 11. Side force variation for louvered and conventional signs.



reduction in wind velocity near the edges of the sign when it was faced into the wind. Also, because of the concentric cylindrical layout of the cell, with wind approaching through the outside annular space and then traversing the interior area diametrically, the windstream swung slightly to one side as it entered the test area. The anchorage system was positioned so as to center the sign in the airstream as much as possible, but it was not possible to align the support to face the sign squarely into the wind stream at any index position. There were also some effects of the non-uniform velocity distribution across the sign. Therefore, as the sign was rotated in 22-1/2° increments both ways from center, the resulting data points did not result in symmetrical plots as readily can be seen in the figures. The indicated positions relate to the orientation of the support structure in the cell, and are the number of 22-1/2° increments of rotation of the support.

Figure 10 shows the variation in normal force for the louvered and conventional signs as the orientation of the sign in the test cell is changed. Since there was a decrease in velocity near the outside edges of the sign, rotation of the sign face exposed a larger proportion of the sign face to the higher velocity central portion of the stream. The louvered sign allowed the wind stream to pass through and was not as greatly affected by this action. However, the solid sign directed the higher velocity air along the face of the entire sign, increasing the net normal force. The asymmetry of the data points for the solid sign reflect this effect, along with the angle of wind approach that was mentioned previously. The net effect of the louvered background was a reduction of about 50 percent in wind resistance when the signs were oriented approximately normal to the wind.

The message was removed from the louvered sign and the wind resistance was measured in the "0" support condition only. The result is plotted as a single point on Figure 10, and shows that the legend caused more than 1/3 of the wind resistance, even though the letters and mounting channels represent only about 1/8 of the gross frontal area of the sign.

Figure 11 shows the variation in side force on the two signs for various orientations in the test cell. Again the non-symmetrical distribution of the data is due to wind direction being slightly skewed with respect to the sign support. Comparison of Figures 10 and 11 shows that the maximum side force developed by the louvered sign is nearly equal to the maximum normal force. Therefore, support structures for this type of sign would require approximately equal sectional properties in both the normal and transverse directions. Tubular sections would then be preferable to the rolled shapes normally specified for such use.

Figure 12 demonstrates the well known fact that considerable moments are developed by flat plates when the wind blows at oblique angles. Forces normal to the sign face also remain high at such angles of approach. In a roadside sign installation subjected to similar wind conditions, the induced moment tends to unbalance the amount of load distributed to the various supports. This effect is also mentioned in the TTI report but, since it is not considered in normal design practice, it bears repeating here. Traditional design of roadside sign supports considers the most critical condition to exist when the wind blows normal to the sign face. Experimental and theoretical results do not warrant such a conclusion. Figure 12 also indicates that such moments developed by the louvered sign are of very small magnitude, as is to be expected because of the air flow through the sign background.

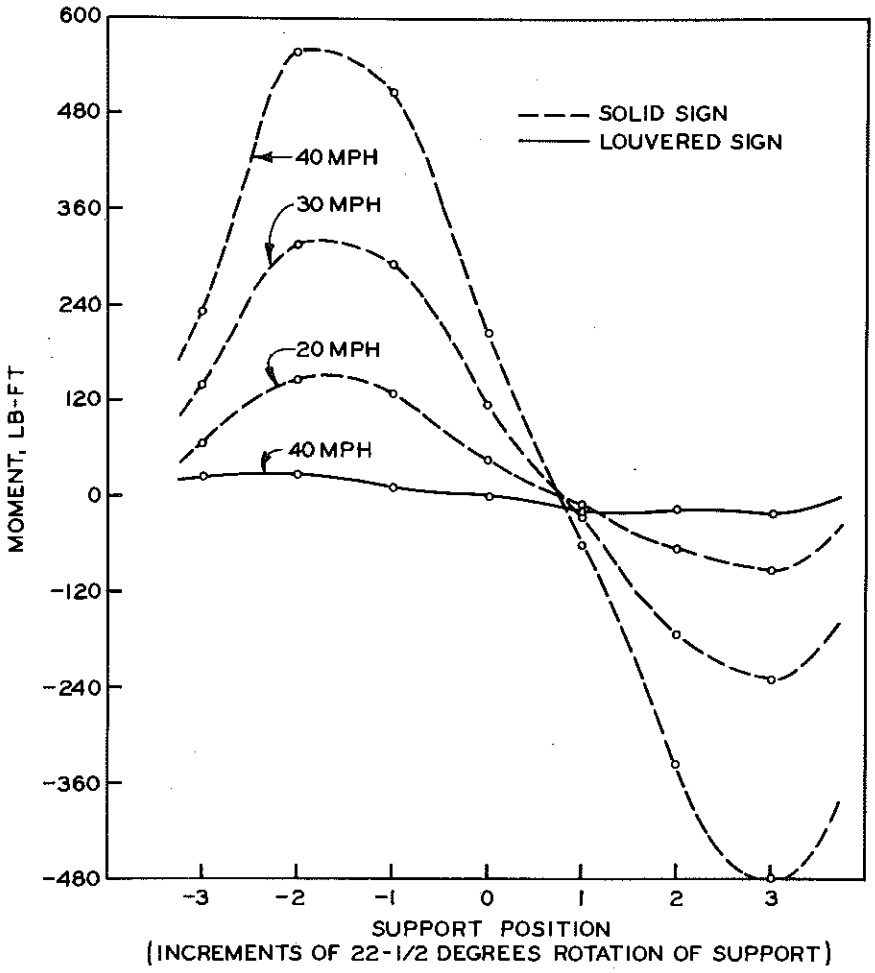


Figure 12. Resultant moment about the vertical support.

In summary, the tests conducted for this study indicate that the Michigan louvered sign design is capable of reducing normal wind resistance by approximately a factor of two, when a typical message is attached to the sign. Side load is increased to approximately equal the normal load. These results are in general agreement with the model tests run at TTI, on their curved louver model with louver angle of 20.6°.

Wind passing through the curved louvers causes a net moment to occur about a horizontal axis through the face of the sign. This moment is commonly called a pitching moment, and can be additive to the moment caused in the support by the normal force on the sign. Pitching moments were not measured in this experiment. However, such measurements were made in the TTI wind tunnel testing of similar louvers (2). Since these tests have shown the load reduction factors for the Michigan design to be comparable to the TTI design, and the louver configuration is the same, it would seem reasonable to assume that air flow through the sign is similar also, and that pitching moment measurements made in that experiment to be of the same order of magnitude as for the Michigan sign. A typical design calculation in the TTI report indicated that the pitching moment added approximately 18 percent to the bending load in a typical roadside support. It is obvious that such factors must be included in the design of supports for this type of sign. The reader is referred to the above referenced TTI report for further information.

VISUAL CONSIDERATIONS

Legibility

Various letter types and backgrounds were evaluated photometrically under standardized conditions of illumination. The results of the test in terms of specific luminance or brightness are summarized in Table 1. The specific luminances given have little significance as absolute values, but the values in relation to the other values in the table represent, in general, the relative brightness of the reflective materials as the driver views them from 200 to 600 ft away.

The materials were measured in a 100-ft indoor photometric range at an observation angle of 1/2°. In unpublished research by the Laboratory (Research Project 65 G-140, October 1967) it was determined that the 1/2° observation angle approximated a driver viewing an overhead sign illuminated by headlamps from a typical vehicle at a distance between 200 and 600 ft. The 600-ft distance is the generally accepted legibility distance for the 12-in. letters (50-ft legibility per in. of letter height) used on the experimental louvered sign (Fig. 13). At distances less than 200 ft from the sign a driver would no longer need to read the sign in most instances.

TABLE 1
SPECIFIC LUMINANCE OF VARIOUS MATERIALS ON CONVENTIONAL AND LOUVERED SIGNS

Sign Material	Specific Luminance (candela per ft-candle per sq ft of sign area)		
	Entrance Angle, degrees[1]		
	0	20	30
Legend, 12-in. letters			
1. Cut-out letters, silver reflective sheeting	70.5	57.5	41.5
2. Embossed letter, silver reflective sheeting, high-intensity	120.0	115.0	110.0
3. Embossed letter, 16 reflector buttons, 1-1/4 in. diam	155.0	110.0	30.0
Background			
4. Green reflective sheeting	15.5	12.0	8.5
5. Green reflective sheeting, high-intensity	25.0	18.5	18.0
6. Curved louvers, painted green, non-reflectorized	0.24	0.24	0.24
7. Curved louvers, green reflective sheeting	0.79	0.58	0.41
8. Curved louvers, green reflective sheeting, high-intensity	2.2	1.6	1.1

[1] at an observation angle of 1/2° (representative of viewing distances from 200 to 600 ft)

The letters applied to the experimental louvered sign are covered with high-intensity reflective sheeting. The sign background was non-reflectorized and painted with a green sign enamel. From Table 1, then, the legend-to-background brightness contrast ratio was 120 (legend) to 0.24 (background); or 500 to 1. This brightness ratio provided more than adequate contrast for optimum legibility under the prescribed conditions. T. M. Allen et al (3) measured legibility distances at two contrast levels, 100 percent and 75 percent. They found that the 75 percent level produced legibility distances approximately 12 percent less than those of the 100 percent contrast level which is known to be associated with optimum legibility. Therefore, near maximum legibility distances can be obtained with contrast levels no less than approximately 75 percent, i.e., with a luminance ratio between legend and background not less than 4 to 1.

By way of explanation, a 4 to 1 brightness contrast ratio occurs where either the legend is four times the brightness of the background or vice versa. A 4 to 1 contrast ratio is equivalent to a 75 percent contrast level, since percent contrast level = $100 \times \frac{B_L - B_B}{B_L}$, where $B_L > B_B$. In this case $B_L = 4$ and $B_B = 1$ and hence $100 \times \frac{4 - 1}{4} = 75$ percent.

Most reflectorized signs with conventional backgrounds yield contrast ratios of approximately 5 to 1 (See Table 1, ratio of Nos. 1 to 4, or 2 to 5) or an 80 percent contrast level. The louvered sign at 500 to 1 contrast ratio has a nearly 100 percent legend-to-background contrast.

The louvered background will appear essentially black in comparison with the legend, under nighttime conditions (See Fig. 13a). In addition, Figure 13b shows the signs as they appeared in daylight, and the increased legend contrast provided by the louvered background is again evident in comparison with the two adjacent conventional signs.

It is obvious from Table 1 that the application of reflectorized sheeting to louvered signs cannot be justified. The louvers are at such an acute angle that the reflective sheeting cannot provide any significant reflex-reflectorization and, therefore, the appearance of the background is not significantly changed when viewed under headlamp illumination from the normal angle. Reflectorization of the louvered sign background could not enhance legibility since it would not increase the legend-to-background contrast ratio.

Since sign size, legend size, and spacing are the same for both louvered and conventional signs, and because of the considerations of night or day contrast noted above, it is concluded that the louvered sign with a non-reflectorized background should provide legibility that is better than the standard highway signs used in Michigan and in many states.

Visibility

The nighttime luminances of the louvered sign in Figure 13 were measured with a Pritchard Brightness Photometer and are listed in Table 2. Standardized headlamp beams on a 1969 model automobile illuminated the sign.

It is apparent from Table 2 that with a 200 ft sight distance at least, it would be difficult if not impossible to perceive the green sign background against the dark nighttime sky even if it were covered with high-intensity reflective sheeting. The luminance of the background material is higher at 500 ft since the major portion of the headlamp beams pass under an overhead sign at 200 ft. From measurements made on the overhead louvered sign it was found that the sign luminance peaked at a 500 ft driver viewing distance and would be approximately five times the luminance at 200 ft.

Figure 13. Mounted full-size louvered sign model showing night (a) and day (b) legend contrast.

TABLE 2
LOUVERED SIGN, NIGHT-TIME LUMINANCE,
ILLUMINATED BY VEHICLE AT 200 FT

Sign Material	Average Luminance, ft-L	
	Upper Beams	Lower Beams
1. Legend, silver reflective sheeting, high intensity	2.65	0.50
2. Louvered background painted green, non-reflectorized	0.01	0.01
3. Louvered background, green reflective sheeting[1]	0.02	0.01
4. Louvered background, green reflective sheeting, high intensity[1]	0.05	0.01
5. Sign surround (sky, no moonlight)	~0.01	~0.01

[1] Since the louvered sign in Figure 13 did not have this material affixed to it, the luminance values for this were obtained by calculation from laboratory measurements of a scaled section of the louvered sign.

Therefore, at any viewing distance it can be expected that the contrast between a louvered sign background, even with green high-intensity reflective sheeting under upper beam illumination, and the surrounding darkness would probably be little greater than 25 to 1 (five times ratio of Nos. 4 to 5, Table 2). According to the "Illuminating Engineering Society Handbook" (3rd Edition, 1959), Figure 2-24, a contrast ratio of 25 to 1 (for 1/5 seconds exposures to 4 minutes of arc targets) at the sign brightness levels given above for the green background of a louvered sign may not be sufficient for an average driver to detect the sign against a nighttime background with 99 percent accuracy. Therefore, no state-of-the-art reflective material would enable a louvered sign background to be seen with a high degree of reliability at night at freeway speeds by the average driver.

Since a louvered sign has better than average contrast for good legibility, and no known background reflectorization will enhance the visibility of a louvered sign background, does the reflectorized legend itself provide adequate recognition of the sign in advance of a need to read the sign?

T. W. Forbes' (4) formula for the recognition distance of a sign is

$$P = \frac{(\%C_L + \%C_B) \times ER}{2}$$

where C_L = legend contrast (contrast between legend luminance and sign background luminance)

C_B = background contrast (contrast between the sign background luminance and the sign surround luminance)

and ER = maximum expected recognition distance, suggested by Forbes as about 1,200 ft per ft of sign height.

The louvered sign with high-intensity reflective sheeting legend on a painted green background has a contrast ratio of approximately 500 to 1 or a nearly 100 percent contrast level. Therefore C_L = 100 percent, and C_B would be some nominal percent due to the very low contrast between the surrounding darkness and the sign background. Based on these values the expected recognition distance of the louvered sign would be approximately 50 percent of the maximum expected recognition distance. The maximum expected recognition distance is still 1,200 ft per foot of sign height even for non-reflectorized sign backgrounds since Forbes assumed that the legend usually comprised about half the sign area. With the use of reflective materials to produce a sign background, the expected recognition distance of the louvered sign would be somewhat greater than 50 percent of the maximum expected recognition distance. Table 2 shows that either type of reflectorized background (Nos. 3 or 4) provides about as little contrast with the night surround (No. 5) as does the painted background (No. 2). The maximum expected recognition distance is always far greater than the legibility distance. In the case of the louvered sign, 8 ft high with 50 percent of maximum expected recognition distance, the actual recognition distance would be more than 4,500 ft, even though the sign cannot be read until the driver approaches to within 600 ft. Therefore, the louvered sign seems to have adequate detection distance. Undoubtedly the detection distance could be increased still further by addition of a button-type reflective border on the sign.

To summarize, in comparison with reflectorized signs with conventional backgrounds the louvered sign has better legibility and adequate visibility.

When the planned experimental program had been completed on the louvered sign, the Department's Traffic Division determined a local site for installation of the sign. It was erected on an overhead support on I 96, about 15 miles east of Lansing, near Williamston (Fig. 13). The sign will be examined periodically for determination of its durability over a longer period of time when subjected to typical field exposure.

DESIGN CONSIDERATIONS

While the bid price to manufacture the background for a single sign of the louvered type was roughly $18 per sq ft, plus tooling costs, we would expect that this value could be lowered by perhaps a factor of two, or more, in quantity production. However, even if that reduction were to be obtained, the louvered sign background would still be priced high in comparison with conventional materials. Additional costs for surface treatment, painting, letters for message, and mounting the message would increase costs still further. The embossed letters for the experimental sign cost over $40, or roughly 40 cents/sq ft. Quantity purchase would reduce this cost to some extent.

The State of Illinois has experimented with a heavier louvered sign (7 lb/sq ft), assembled from aluminum extrusions and die castings. This sign now is available from a supplier at a cost of approximately $15 per sq ft. The Illinois investigators estimated the total cost of an overhead installation with louvered panels, to be about 6 percent less than a comparable standard installation (5).

Due to the relatively fragile nature and high cost of louvered signs, they do not seem suitable for roadside installations where probability of damage from impacting autos is high. The advent of modern wooden and steel breakaway supports have reduced the danger to occupants of vehicles that collide with such supports. In general, overhead truss-type supports are designed for the maximum span and largest square footage of signs that might be placed upon them. Therefore, at many locations they are capable of supporting additional signs, existing signs with greater span, or larger signs than now are mounted. New Michigan projects requiring signs only on one side of the roadway are being furnished with large cantilever supports instead of overhead supports. The cantilever supports with reach up to 45 ft, are reported to give 30 ft set-back with cost savings of 30 percent or more when compared to overhead trusses. If signs are required over several lanes, trusses are required, of course.

Design calculations for supporting a louvered sign on the large cantilever structure in place of a solid sign indicate that although the normal force is decreased by a factor of two for such a sign, the arm or reach of the cantilever structure could be increased by less than 10 ft. This is due to the relatively high side force generated by the sign when the wind approaches at an oblique angle.

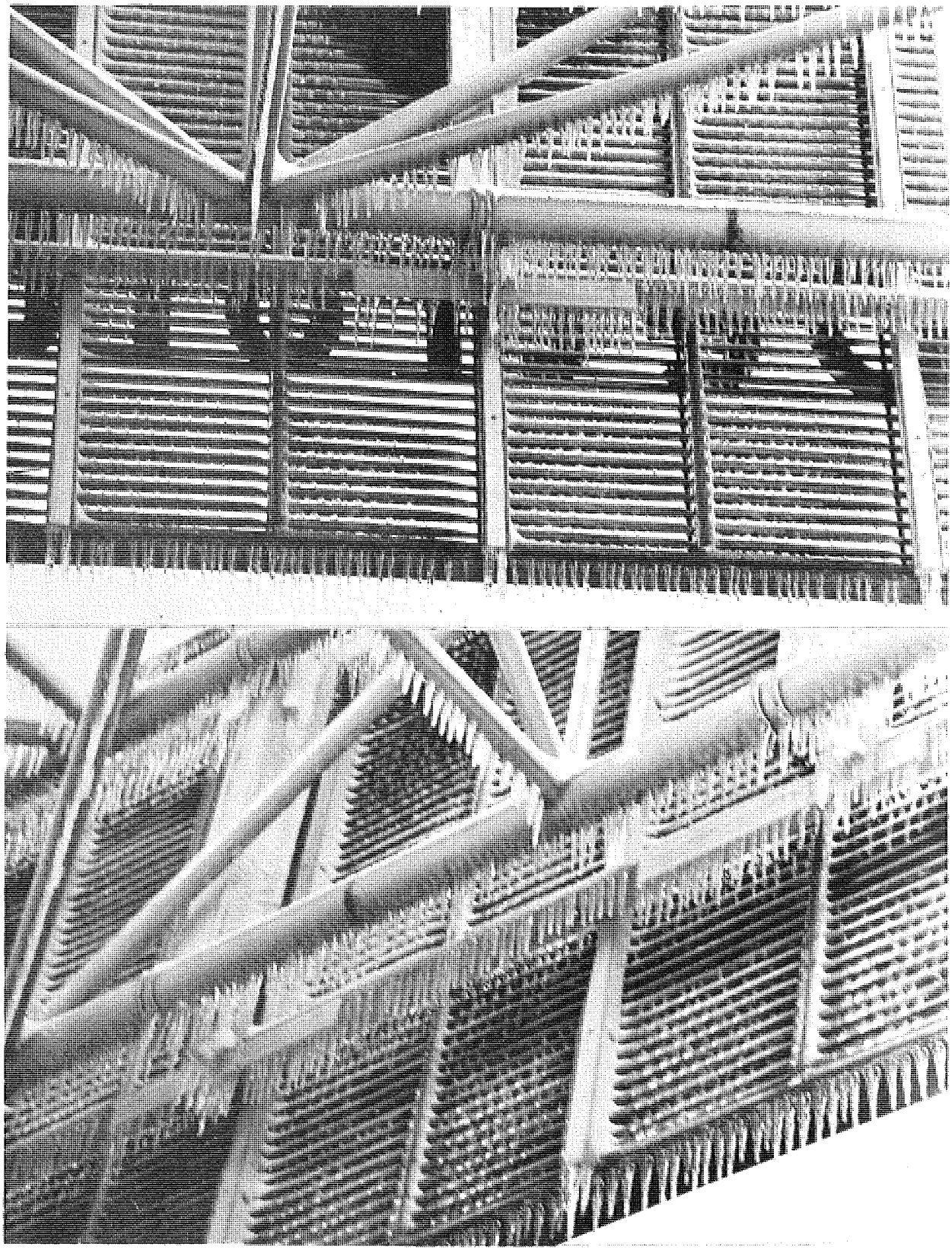


Figure 14. Louvered sign after a recent sleet storm.

It is obvious that similar situations could result in overhead trusses which usually are not designed with a great deal of lateral load carrying capacity. In each individual case, however, calculations would be required to determine whether the desired new sign configuration would be within the load carrying capacity of that particular support. Thus, it seems that modest increases in span, or area of sign, could be made at many locations by the substitution of louvered for conventional signs. There would be a corresponding increase in the cost of the signs, which does not seem to be justifiable in general. However, there may be special situations where safety requirements would warrant unusual expenses or where an existing structure could be used instead of erecting a new one.

Another unknown factor that exists in cases utilizing louvered signs, is the amount of dead-load due to ice that should reasonably be considered for a sign that has so much surface area. Also, there is a question as to what would be a reasonable value for additional wind resistance due to constriction of the louvered passages by snow or ice. The experimental sign was subjected to snow and sleet storms while at the field test site, and seemed to clear itself quite readily within a day or so, as temperatures moderated, but no measurements of wind resistance were possible while such conditions existed. Figure 14 shows recent photographs of the louvered sign at the freeway site. These pictures were taken after a sleet storm and show the possibilities of ice accumulation in the louvers. Slight changes in temperature and wind conditions could result in higher accumulations of ice on the sign.

In short, it appears that high cost of fabrication, increased lateral wind resistance, and other previously stated considerations, make the louvered sign an attractive theoretical concept that is not generally practical.

CONCLUSIONS

1. A louvered sign background has been developed that can be manufactured by standard sheet metal shop techniques.

2. The louvered background causes a reduction of about 50 percent in wind load normal to the sign face when a typical message is attached to the sign.

3. Transverse wind load is approximately equal to normal wind load.

4. Reflective sheeting applied to the louver surfaces does not provide sufficient performance to justify the cost.

5. The louvered sign is compatible with typical overhead sign mounts.

6. Channels for legend attachment seem to be satisfactory.

7. Contrast ratio between legend and background has been increased above the value obtained in reflectorized signs, so legibility should be slightly improved.

8. Further information is required concerning reasonable design values for ice load on louvered signs, and possible increased wind loading due to louver constriction by ice and snow.

9. The use of louvered signs for general application does not appear to be practical because of high cost and uncertainties of design in areas subject to ice and snow, but they may be useful in special instances because of safety considerations where greater set-back is required, or at locations where additional signing is required on existing supports.

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