WIND LOADS ON LOUVERED SIGNS

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Results of a series of wind tunnel tests of both straight and curved louver sign models are presented in this paper. A total of 16 different models were tested to determine the effect of louver angle, louver width, sign height to width ratio, and sign message on the wind loads. Dimensionless force and moment coefficients are presented in graphical form, providing a concise and convenient source of information for determining wind loads on full-scale louvered signs. Comparisons are made between the wind loads on a conventional sign and wind loads on louvered signs of various configurations. For a given frontal area, tests show that wind loads on a louvered sign are approximately 50 percent less than those on a conventional solid background sign. Gross estimates of louvered sign costs are given and compared with conventional sign costs. The visibility aspect of a louvered sign is briefly discussed. Actual field installations of louvered signs are shown and discussed.

• MANY signs on the Interstate freeway system are of necessity very large. Massive supports are required to resist the wind loads of these signs and as a consequence the supports present a hazard to motorists since the sign is usually in close proximity to the roadway. Economically, costs increase as the size of the sign's support structure increases.

Development of "breakaway" supports for roadside signs has greatly reduced the hazard. Research is now in progress on breakaway supports for overhead sign bridges.

Another concept which can reduce the hazard of the sign's supports and quite possibly the costs of the entire structure is the use of a louvered sign in lieu of the conventional solid-background sign. Tests have shown that the louvered sign can reduce wind loads on a conventional sign by 50 percent. Considerable reduction in the mass of the supports could be expected as a result of the reduced wind loads. Analysis of breakaway supports for sign bridges at the Texas Transportation Institute have shown that as the mass of the support is reduced impact forces on a colliding vehicle are reduced.

Recent studies of wind loads on solid-background conventional signs were conducted at TTI and have been documented (1). However, research in the area of nonsolid signs has been very limited. The only published data available on nonsolid sign backgrounds specifically is that of Tidwell and Samson (2). In their study, several types of nonsolid configurations were model tested, viz., expanded metals, honeycomb materials, and a louvered sign. Of the types tested, the louvered configuration appeared to offer the greatest promise from the standpoint of wind-load-reducing capabilities and visibility. When compared to a flat plate, the louvered model showed a 57 percent reduction in maximum force and an 83 percent reduction in twisting moment. It also provided a solid appearance.

A literature survey of topics within the aerodynamics field revealed that a very limited amount of information existed which could be applied to the investigation of wind loads on louvered signs. Previous work in the area of louvers (or cascaded airfoils)

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has, for the most part, been directed toward turbine or axial compressor applications (3). In most of these cases, the cascades were smooth airfoil shapes and were oriented at small angles of attack (less than 10 deg), in which case the air flow over and under the cascade does not separate. For the flat plate cascades (as in the louvered sign) the air flow will separate for all but the smaller angles of attack (about 15 deg or less).

TEST PROCEDURE

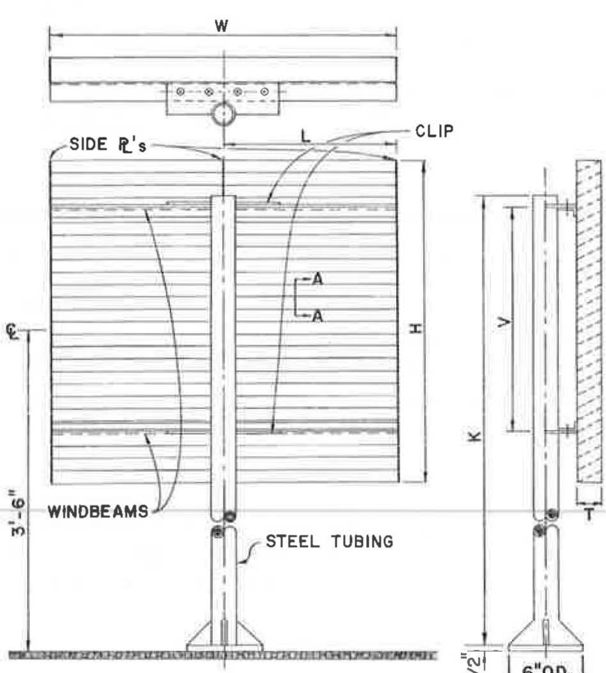
Since the studies of Tidwell and Samson were limited to one particular louver configuration more information was needed on the relationship between wind loads and louver angle, louver width, and the sign height to width ratio. To determine these relationships 13 straight-louver sign models and 3 curved-louver models were constructed. Details of these models are shown in Figures 1 and 2.

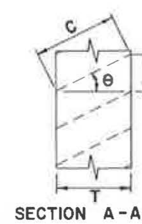
To assemble the models the louvers were fillet welded to the side plates. The windbeams were then welded to the side plates, and the mounting gussets were bolted to the windbeams and welded to the support pole.

Models 1 through 3 were used to determine the effects of the wind-tunnel wall interference on the measured wind loads. For any given wind tunnel there is a limit to the model size that can be tested before appreciable errors occur in the measured wind loads. Models 3 through 11 were used to determine the amount by which the wind loads were affected by variations in the louver angle, louver width, and Reynolds number. Models 7, 12, and 13 were used to determine the wind load variations as a function of the model's height to width ratio, sometimes called the aspect ratio.

To compare the results, the tests were all conducted at a constant Reynolds number ($R_E = 1.56 \times 10^5$), with the exception of the Reynolds number tests. The louver width was chosen as the characteristic length in the Reynolds number.

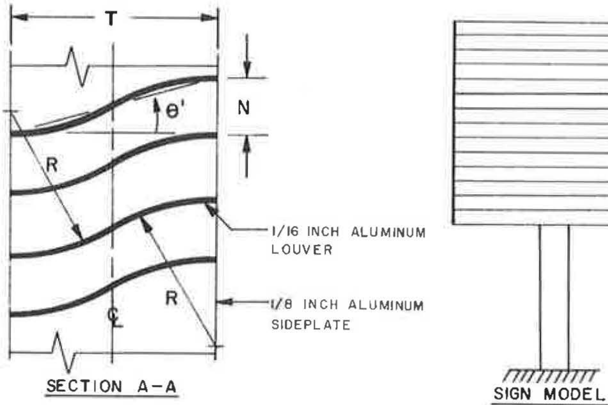
In designing the curved louver models, advantage was taken of the flat-plate louver tests. Results from these tests showed that the wind loads were practically independent of lower width. For this reason only three models were needed in the curved





	MODEL SCHEDULE									
	LOUVER					SIDE ℞		MISC.		
MOD NO	L	C	NO REQ'D	θ	N	H	T	W	K	V
1	21	2.8	42	45°	2	42.0	2	42.4	60.5	28
2	15	2.8	30	45°	2	30.0	2	30.4	54.5	20
3	12	2.8	24	45°	2	24.0	2	24.4	51.5	18
4	12	2	34	45°	1.4	23.8	1.4	24.4	51.5	18
5	12.1	2.3	30	45°	1.6	24.0	1.6	24.6	51.5	18
6	12	2	48	30°	1.0	24.0	1.7	24.4	51.5	18
7	11.9	2.3	44	30°	1.1	24.2	2.0	24.2	51.5	18
8	12	2.8	34	30°	1.4	23.8	2.4	24.4	51.5	18
9	11.9	2	92	15°	.52	23.9	2.0	24.2	51.5	18
10	12.1	2.3	82	15°	.59	24.2	2.2	24.6	51.5	18
11	12	2.8	66	15°	.73	24.1	2.7	24.4	51.5	18
12	15.5	2.3	28	30°	1.1	15.3	2.0	31.4	47.0	8.9
13	8.9	2.3	48	30°	1.1	27.0	2.0	18.2	53.0	21

Figure 1. Details of straight-louver sign models.



MODEL SCHEDULE											
	LOUVER						SIDE PLATE		MISC.		
MOD. NO.	L*	C**	R	θ'	N	NO. REQD	H*	T	W*	K*	V
14	24.0	4.60	2.50	26.6°	2.0	12	24.0	4.0	24.4	51.5	18.0
15	24.0	4.37	3.05	20.6°	1.5	16	24.0	4.0	24.4	51.5	18.0
16	24.0	4.17	4.26	14.1°	1.0	24	24.0	4.0	24.4	51.5	18.0

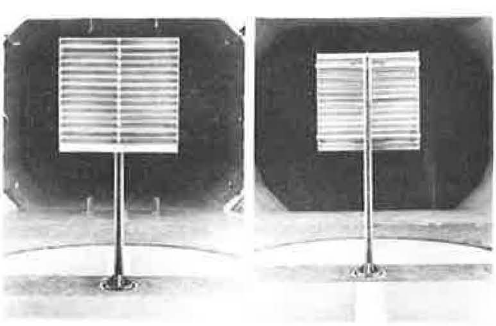
*REFER TO FIGURE 1 FOR GEOMETRIC DESCRIPTION
**ARC LENGTH

Figure 2. Details of curved-louver sign models.

louver tests. From these three models the relation between wind load and louver angle could be ascertained.

The models were tested in the 7- by 10-ft Low Speed Wind Tunnel at Texas A&M University. Figure 3 shows a front and rear view of model number 5 in the wind tunnel. Sign model number 8 was tested with and without a typical message. Model 8 with the message attached is shown in Figure 4. Curved louver model number 14 is shown in Figure 5.

All the models were subjected to wind velocities in the 0 to 100-mph range.



(a) FRONT VIEW (b) REAR VIEW

Figure 3. Louvered model no. 5 mounted in wind tunnel.

(a) NORMAL VIEW (b) SIDE VIEW

Figure 4. Louvered model no. 8 with message.

TEST RESULTS

For convenience, results of the wind tunnel tests were reduced to dimensionless coefficient form. These coefficients are defined as follows:

$$C_N = \frac{F_N}{qA_s} = \text{normal-force coefficient;}$$

$$C_T = \frac{F_T}{qA_s} = \text{side-force coefficient;}$$

$$C_L = \frac{F_L}{qA_s} = \text{lift-force coefficient; and}$$

$$C_{MT} = \frac{M_T}{qA_sW} = \text{twisting-moment coefficient,}$$

where

F_N = total normal force;
F_T = total side force;
F_L = total lift force; and
M_T = total twisting moment.

These actions are shown in Figure 6 in their positive directions.

Also,

A_s = frontal area of sign;
q = impact pressure = $\frac{1}{2} PV^2$;
P = mass density of air;
V = velocity of air; and
W = width of sign.

Reynolds R_N number is defined by

$$R_N = \frac{Vl}{\nu}$$

where

l = width of louver, and
ν = kinematic viscosity of air.

Necessary limitations on the size of this paper prohibit a full presentation of all test results. Nevertheless, the major findings of the study are presented in the following sections. Full details of the study have been reported elsewhere (4).

Figure 5. Curved-louver model no. 14.

Straight Louver Tests

Curves of the normal-force coefficient, side-force coefficient, lift-force coefficient, and twisting-moment coefficient are shown in Figures 7 through 10, plotted against the angle of attack α (Fig. 6). Each figure shows the results of the three louver-angle configurations for the 2.8-in. louver width. The other curve in Figures 7 and 10 is the result of a flat-plate model test and is included for comparative purposes. Similar results were obtained for the 2.0-in. and 2.3-in. louver widths.

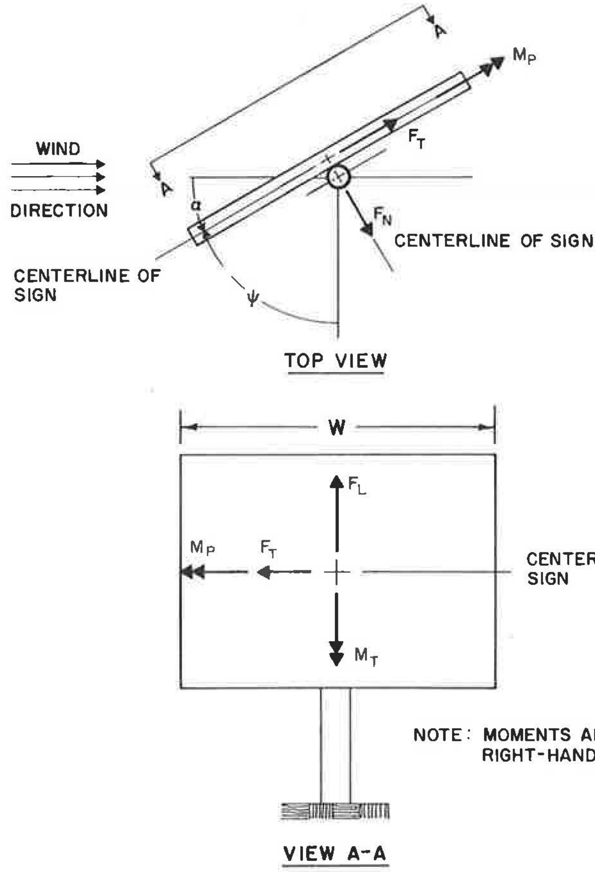


Figure 6. Positive sign convention for sign axis system.

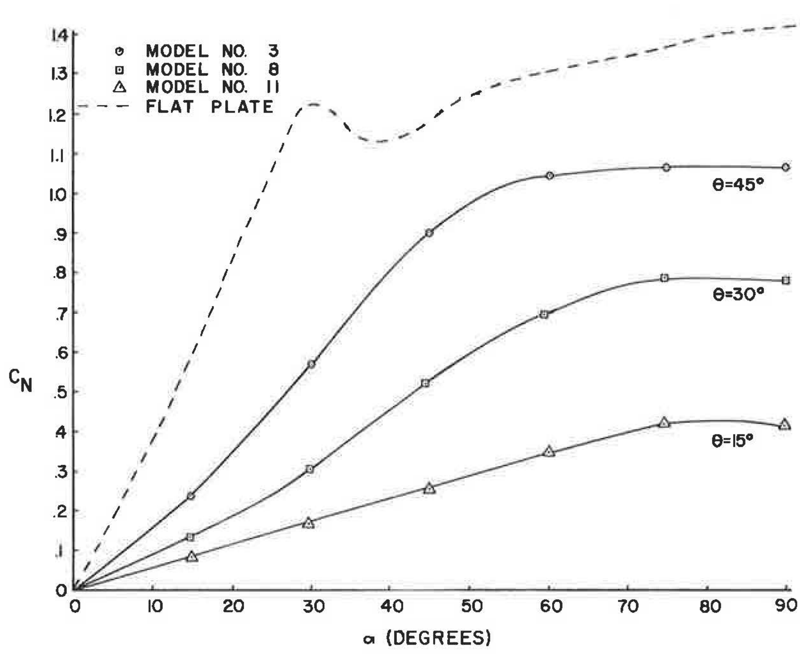


Figure 7. Normal-force coefficient versus angle of attack for straight-louver models, louver width = 2.8 in.

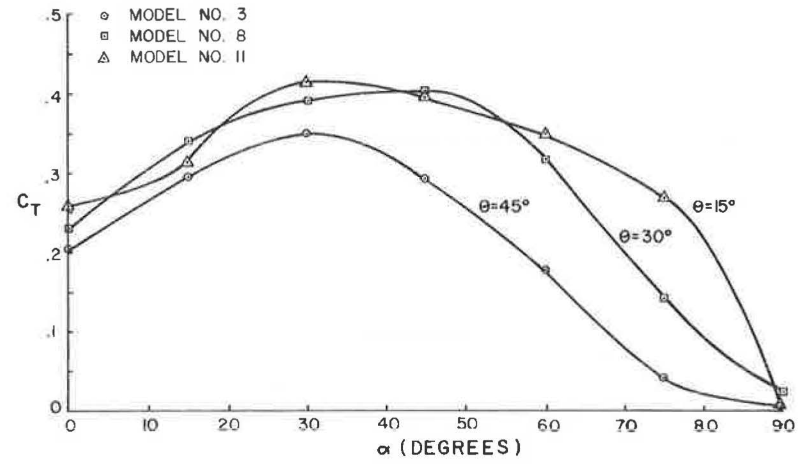


Figure 8. Side-force coefficient versus angle of attack for straight-louver models, louver width = 2.8 in.

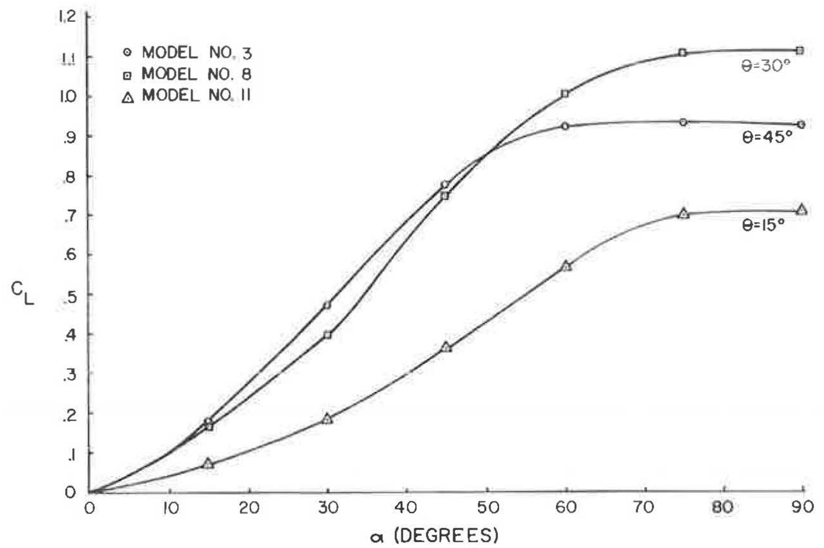


Figure 9. Lift-force coefficient versus angle of attack for straight-louver models, louver width = 2.8 in.

Variations in the normal-force coefficient with louver angle are shown in Figure 11 for the three louver widths. The comparison is shown at an angle of attack of 90 deg. In most cases this is the angle at which the coefficient obtained its maximum value.

It is noted that the variations in the normal-force coefficient are not necessarily attributable to the difference in louver angles alone. The distance between the louvers is dependent on the louver angle and the spacing is therefore different for any two louver angles. Hence, the variations in the coefficients may include the effect of the different louver spacings also.

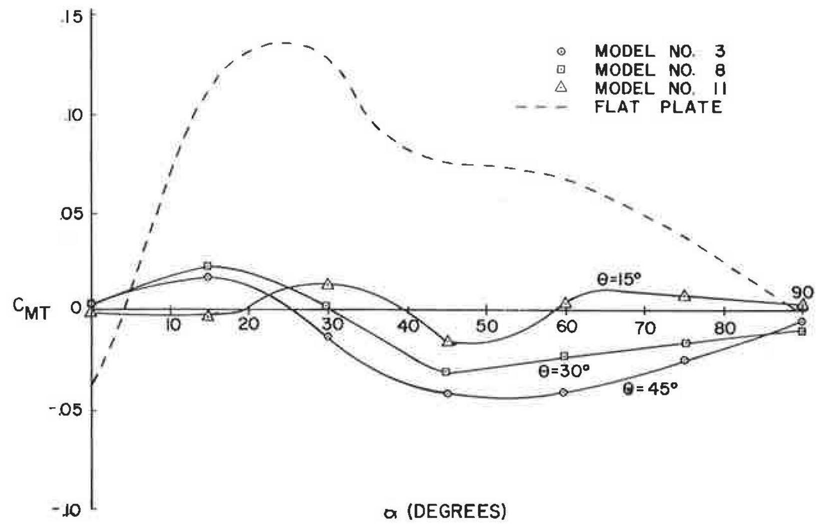


Figure 10. Twisting-moment coefficient versus angle of attack for straight-louver models, louver width = 2.8 in.

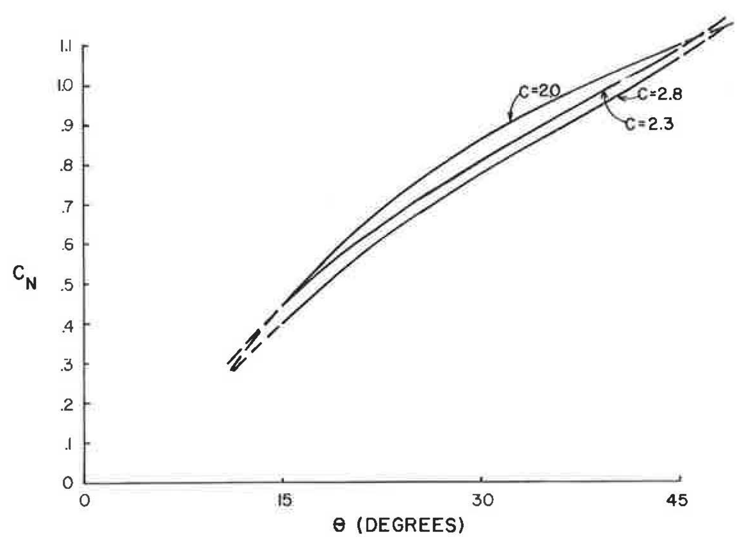


Figure 11. Normal-force coefficient versus louver angle for straight-louver models at α = 90 deg.

The louver spacing on each model was such that a solid appearance was maintained without any louver overlap. As a result, the louver spacing was different on models 3 through 11. An overlap is not necessarily detrimental from either an aerodynamic standpoint or a visibility standpoint. The decision not to overlap was based on economic considerations. It seemed apparent that the cost would increase as the louver overlap increased.

The four coefficient values were found to be practically independent of the aspect ratio and Reynolds number. The normal-force coefficient, twisting-moment coefficient, and the lift-force coefficient were found to be independent of louver width. As expected the side-force coefficient increased as the louver width increased (the width of the side plate increases as the louver width increases).

Model number 8 was equipped with a typical message in order to determine message effects on the wind loads. Although the message caused an increase in the normal force by about 12 percent, it reduced the side- and lift-forces by approximately 10 and 30 percent respectively. Although only one model was tested for message effects, the information obtained is considered to be applicable to the other configurations.

No extreme flutter problems were encountered during the straight louver test. The longest unsupported louver length was 15.5 in. on model number 12. The top and bottom louvers of all models experienced varying degrees of flutter, depending upon the louver configuration, sign angles of attack, and wind velocity. In general, the flutter was more pronounced in the models with the larger louver angles, at a sign angle of attack of 90 deg, and for wind velocities from 80 to 100 mph. The flutter did not become catastrophic in any case and is not believed to be a serious problem. A plate over the top and bottom louvers, making in effect a box-frame for the sign, would likely eliminate the flutter, at the expense of a slight increase in the normal wind force.

Curved Louver Tests

Figure 12 shows the normal-force coefficient versus the angle of attack for the three curved louver models. The maximum values of the coefficient, 0.53 at $\theta' = 26.6$ deg, 0.4 at $\theta' = 20.6$ deg, and 0.31 at $\theta' = 14.1$ deg, are considerably less than the corresponding flat-plate value of 1.4 (Fig. 7).

The side-force coefficients were slightly higher than the straight louvered values. The larger values are attributed in part to the wider side plates used in the curved louver models. Also, the nature of the air flow through the curved louver models likely contributed to the side-force differences.

The geometry of the curved louvers causes a momentum change in the air flow which acts to produce a pitching moment (M_p in Fig. 6) on the background. The pitching moment must be added to that caused by the normal force.

The curved-louver coefficients were found to be independent of Reynolds number. The characteristic length chosen for the Reynolds number was the distance between the

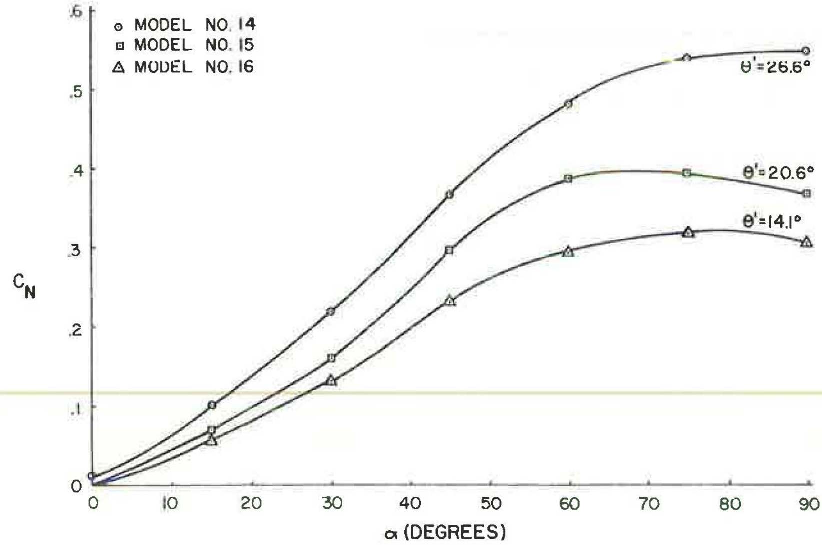


Figure 12. Normal-force coefficient versus angle of attack for curved louvers, side-plate width = 4.0 in.

forward and rear edge of the curved louver. It is the hypotenuse of the triangle whose sides are the side-plate width and the louver spacing.

No data are available on the variations in the coefficients as the aspect ratio is varied for curved louvers, since the three models tested all had the same aspect ratio (1.0). However, it is unlikely that appreciable variations would exist, at least within the range of aspect ratios of most highway signs, since the variations were negligible in the straight-louvered models.

The curved louvers experienced a greater degree of flutter than the straight louvers. The flutter was evident at a wind speed of approximately 75 mph and increased in intensity as the wind speed increased. As in the straight louvers, the flutter was much more pronounced in the upper and lower louvers. The corrective action recommended in the straight-louver flutter problem should also reduce the curved-louver flutter problem.

All of the louver model coefficients include the effects of the windbeams and that part of the supporting pole directly behind the model. The frontal area of the windbeams blocking the air flow totaled about 0.25 sq ft. This comprised about 6.3 percent of the sign's frontal area. The total blockage by windbeams on full-scale signs would likely be about the same amount. Hence, the coefficients can be used in most cases without alterations due to windbeam effects.

It is not recommended that the coefficients be used to include the effects of the sign supports, although the coefficients included the effects of a portion of the model support. The single tubular support is not believed to have affected the wind loads on the models to any extent. In actual design, the wind loads on the sign supports should be computed separately and then added to the background wind loads.

All of the coefficients are shown for positive angles of attack, i. e., wind impinging on the front of the sign. However, the models were tested at negative angles of attack also. The results with negative angles were similar to those at positive angles, with one exception. Winds on the back side of the model caused a negative lift. In designing the sign supports the negative lift would likely be more critical, since it would be a compressive load.

CONVENTIONAL SIGNS VERSUS LOUVERED SIGNS

Wind Loads

A comparison was made between the wind loads that would exist on a straight-louver and a curved-louver sign and a geometrically similar conventional sign. The straight-louver values are based on a lower width of 2.8 in. In the straight-louver case, the wind loads include the effects of a typical message on the sign. A sign having 100 sq ft in frontal area with an aspect ratio equal to 1.0 was chosen as a typical example. The comparative summary is given in Tables 1 and 2.

TABLE 1

STRAIGHT-LOUVER MODEL RESULTS, LOUVER WIDTH = 2.8 IN.

Wind-Load Force Component	Louver Angle (θ)			Flat Plate
	15 deg	30 deg	45 deg	
Maximum normal force F_N (lb)	1,288	2,109	2,867	3,841
Reduction in flat-plate normal force (percent)	66	45	25.4	—
Maximum side force F_T (lb)	1,039	845	707	256
Increase in flat-plate side force (percent)	306	230	176	—
Maximum lift force F_L (lb)	818	1,993	1,507	0
Weight of sign (lb)	450	290	210	300
Decrease (increase) in flat-plate weight (percent)	(50)	3.3	30	—

TABLE 2

CURVED-LOUVER MODEL RESULTS

Wind-Load Force Component	Louver Angle (θ')			Flat Plate
	14.1 deg	20.6 deg	26.6 deg	
Maximum normal force F_N (lb)	1,067	1,259	1,654	3,841
Reduction in flat-plate normal force (percent)	72	67	57	—
Maximum side force F_T (lb)	960	975	991	256
Increase in flat-plate side force (percent)	275	281	287	—
Maximum lift force F_L (lb)	358	851	1,609	0
Weight of sign (lb)	500	370	320	300
Increase in flat-plate weight (percent)	67	23	7	—

An additional force component must be considered in the louvered sign when compared to the conventional sign. That component is the lift force, which acts in either the upward or downward direction, depending upon the wind direction. However, its effect on the structural designs of the sign would probably be small.

The sign weights are based on an aluminum-louvered sign and a plywood conventional sign. The weights include the windbeams but exclude the sign supports.

Costs

Evaluating the economic aspects of the louvered sign proved to be a difficult task. Cost estimates obtained from different industrial firms varied. After considering the estimates it appears that the cost of a straight-louvered aluminum background would be roughly as follows:

Louver Angle	Cost per Sq Ft
15 deg	\$5.00 to \$6.00
30 deg	\$4.50 to \$5.50
45 deg	\$4.00 to \$5.00

These values include the material and fabrication cost of the background but exclude the material and attachment cost of the windbeams, supports, and message. The geometry of the background, for which these prices are based, was similar to that of the models, i. e., a series of 0.0625-in.-thick louvers, 12 in. in length, interlocked by vertical plates (sideplates).

No prices are available on the cost of material other than aluminum. Curved-louver background costs are also unavailable. However, it is likely that their cost would be comparable to the straight louver, using the louver angle (θ) in the straight louvers and the effective louver angle (θ') in the curved louvers as a basis for comparison. The curved louver could probably be extruded for a cost not greatly exceeding the straight louver. The wider unsupported lengths allowable in the stiffer curved louvers would tend to offset the cost differences between the two configurations.

The cost of a plywood background for the conventional signs is estimated to be 75 cents per sq ft. This price would include the cost of the plywood, splice plates, fasteners, and labor to assemble. All other costs are excluded. This price can then be compared with the previously quoted prices for louvered sign backgrounds.

Visibility

The ability of both the curved and straight louvered models to display a message appeared adequate. With the background of the model painted green, the white painted message was clearly visible from the usual viewing angles. Refer to Figure 4 for two views of a straight-louvered model (louver angle = 30 deg) with a message attached.

IMPLEMENTATION

Shown in Figures 13 and 14 are two full-scale louvered signs that have been installed on an experimental basis in the state of Illinois. In Figure 13 the sign on the right is

Figure 13. Conventional and louvered sign on overhead sign bridge.

Figure 14. Shoulder-mounted louvered sign.

louvered and the one on the left is a conventional solid-background sign. The appearance of the message on the louvered signs seems as legible as that on the conventional sign.

The signs shown in Figures 13 and 14 contain curved louvers very similar in geometry to those described in this paper. The louver angle (θ') is approximately 30 deg and the louver width is approximately 3.6 in. Preliminary analysis indicates that wind-load reductions of about 50 percent are being experienced through the use of these louvered signs. Further studies are planned at Illinois with these experimental signs to determine if snow accumulates in the louvers and to determine the cost effectiveness of the sign and its support structure.

CONCLUSIONS

Tests have shown that reductions of approximately 50 percent in wind loads can be realized by the use of louvered signs in lieu of conventional flat-plate signs. Such a reduction would allow a considerable reduction in the weight of the sign's support members, thereby reducing the hazard the sign presents to motorists and the cost of the support structure.

Preliminary observations indicate that the louvered sign can display a message adequately.

It is apparent that the louvered sign itself will be more expensive than a conventional flat-plate sign. Cost-effective studies are needed, however, to determine if reductions in support costs and accident costs would compensate for the increased sign cost. In the author's opinion the study would show that an overall reduction in cost could be realized if louvered signs were employed in lieu of conventional signs, especially in the large overhead sign bridges.

Although models were used to obtain wind loads, tests showed that the dimensionless force and moment coefficients were independent of sign size and shape. The data presented thus provide a concise and convenient source of information for determining wind loads on full-scale louvered signs.

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The opinions, findings, and conclusions expressed in this publication are those of the author and not necessarily those of the Federal Highway Administration and/or those of the state highway departments.

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