Wind Tunnel Investigation of Nonsolid Sign Backgrounds

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The needs of modern highway systems dictate large sign backgrounds to convey essential information to the motorist. Large signs mean high wind loadings, which in turn lead to large and relatively massive support structures. A feasibility study was made of six types of nonsolid backgrounds, with a solid background as control. Specimens, 2 by 1.5 ft, were tested at 50, 75, and 100 mph in a 7- by 10-ft subsonic wind tunnel at angles of wind incidence (rotation about vertical axis) of 15, 30, 45, 60, 75, and 90 deg. Results indicate that a louvered background offers promise from the standpoints of reduction of wind loadings and of satisfactory visibility characteristics.

•THE PURPOSE of this research was to investigate the feasibility of using nonsolid sign backgrounds. Large sign backgrounds are often required on modern highway systems to convey essential information to the motorist. Large sign backgrounds result in high wind loadings which, in turn, lead to relatively large sign-support structures. With increased size, sign-support structures generally present greater collision hazards to the motorist.

It is emphasized that only six selected nonsolid backgrounds were considered. It was not intended to make an exhaustive study, but rather to determine if nonsolid backgrounds offer the possibility of producing a substantial reduction in wind loads on the sign structures.

TESTING FACILITIES

The 7- by 10-ft subsonic wind tunnel at Texas A and M University was used in the experimental work. Figure 1 shows an external view of the wind tunnel. Specimens were tested at velocities of 50, 75, and 100 mph. They were oriented at angles of incidence (rotation about vertical axis) of 0, 15, 30, 45, 60, 75, and 90 deg with respect to the direction of wind in the tunnel. Figure 2 is a drawing of a test specimen subjected to the wind force. The side, normal, and lift forces are components of the wind force. The moment refers to the twisting moment about the vertical axis.

Figure 3 shows one of the test specimens mounted in the tunnel. The method of mounting the sign on X-bracing may be seen.

TEST SPECIMENS

All specimens were 2.0 ft wide and 1.5 ft high. Sign backgrounds investigated were the following:

1. Solid plate (100 percent solid)[a]—used as a basis of comparison for other specimens, of 0.081-in. thick aluminum (Fig. 4).

[a]The term percent solid as used here refers to the percentage of solidity as viewed along a normal to the plane of the sign.

Paper sponsored by Committee on Bridge Design.

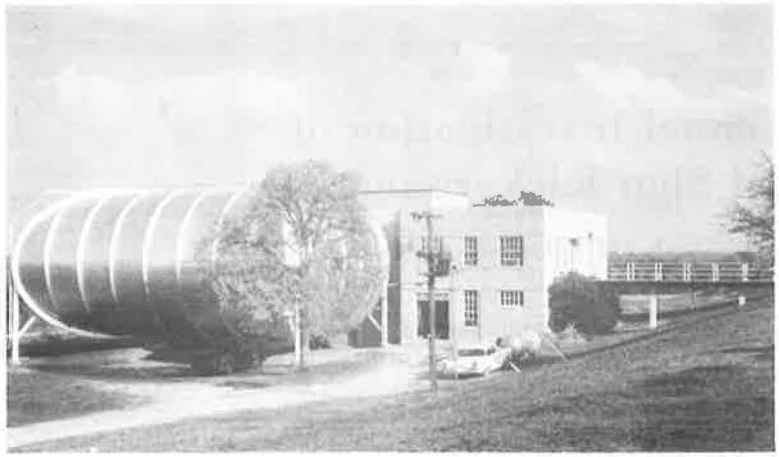

Figure 1. Wind tunnel facility.

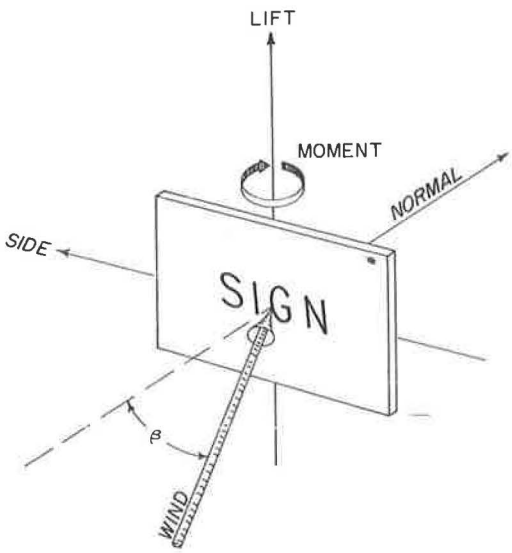

Figure 2. Forces acting on sign.

Figure 3. Test specimen mounted in wind tunnel.

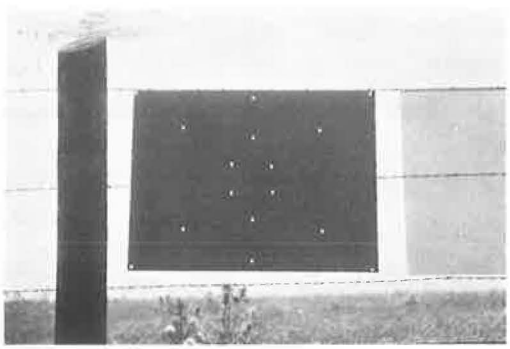

Figure 4. Solid plate, 100 percent solid.

2. Perforated plate (62.5 percent solid)—0.031-in. thick steel with 32.3 holes/sq in., each hole 0.125 in. in diameter (Fig. 5).

3. Perforated plate (93.8 percent solid)—0.250-in. thick fiberboard plate with 1 hole/sq in., each hole 0.281 in. in diameter (Fig. 6).

4. Expanded metal (39.2 percent solid)—original 0.046-in. thick steel sheet flattened, with openings of 1-in. major diagonal and 0.325-in. minor diagonal (Fig. 7).

5. Honeycomb (2.4 percent solid)—1-in. thick aluminum with regular hexagonal cells having 0.188-in. diagonals and 0.0004-in. wall thickness (Fig. 8).

6. Honeycomb (4.0 percent solid)—1.9-in. thick paper-based material with

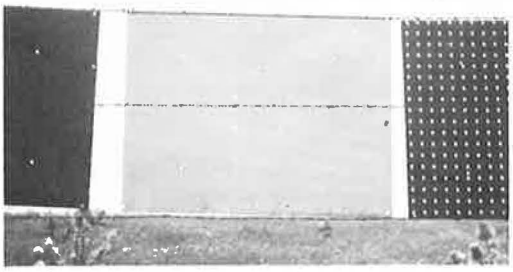

Figure 5. Perforated plate, 62.5 percent solid.

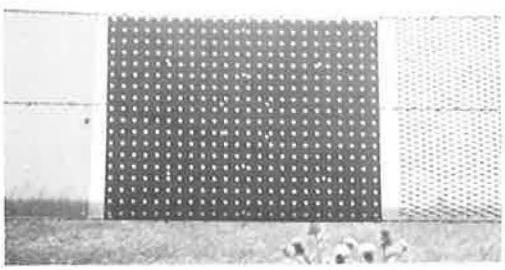

Figure 6. Perforated plate, 93.8 percent solid.

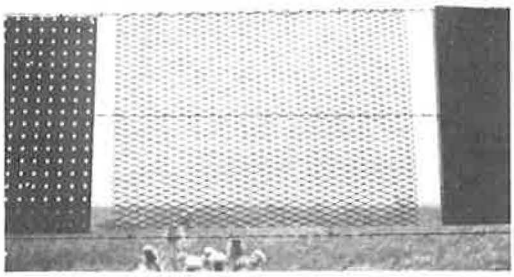

Figure 7. Expanded metal, 39.2 percent solid.

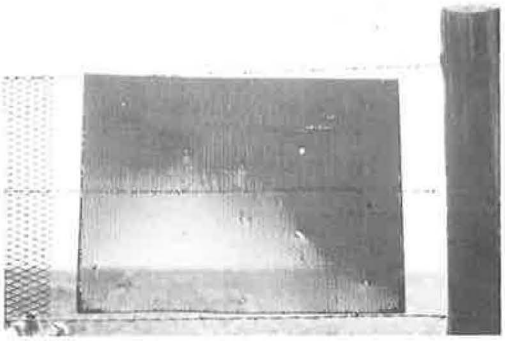

Figure 8. Honeycomb, 2.4 percent solid.

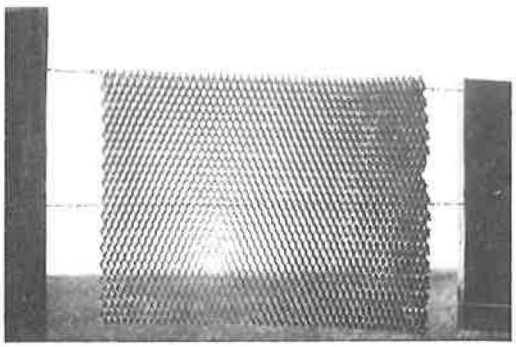

Figure 9. Honeycomb, 4.0 percent solid.

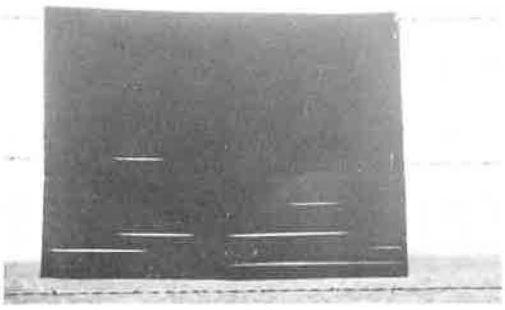

Figure 10. Louvers, 100 percent solid.

elongated hexagonal cells having 0.20-in. short side, 0.45-in. long side, 0.90-in. long diagonal, and 0.009-in. single wall thickness (Fig. 9).

7. Louvers (100 percent solid) — 1.73-in. overall thickness; each louver 2.0 in. deep, 0.052 in. thick, and spaced at 1-in. intervals at an angle of 30 deg with the horizontal (Fig. 10).

TABLE 1

WIND TUNNEL RESULTS—SOLID PLATE
(100 Percent Solid)

Velocity (mph)	Angle (deg)	Side Force (lb)	Normal Force (lb)	Resultant Force (lb)	Moment (ft-lb)
50.0	0.0	0.0	24.8	24.8	0.0
50.0	15.0	0.1	25.3	25.3	-1.4
50.0	30.0	-0.3	24.5	24.5	-2.7
50.0	45.0	-0.2	23.8	23.8	-3.2
50.0	60.0	-0.8	24.5	24.5	-7.5
50.0	75.0	0.0	10.0	10.0	-3.5
50.0	90.0	0.3	0.4	0.5	1.9
75.0	0.0	0.2	57.2	57.2	0.3
75.0	15.0	0.2	55.6	55.6	-3.1
75.0	30.0	-0.3	53.3	53.3	-5.6
75.0	45.0	-0.6	50.4	50.4	-6.6
75.0	60.0	-2.4	55.9	56.0	-16.8
75.0	75.0	-1.3	23.6	23.6	-8.0
75.0	90.0	0.3	1.0	1.0	3.9
100.0	0.0	-0.1	103.1	103.1	0.3
100.0	15.0	-0.1	97.2	97.2	-5.6
100.0	30.0	-1.0	92.0	92.0	-9.8
100.0	45.0	-2.5	87.2	87.2	-12.1
100.0	60.0	-4.2	100.6	100.7	-30.1
100.0	75.0	-1.7	42.6	42.7	-14.3
100.0	90.0	0.7	2.4	2.5	6.5

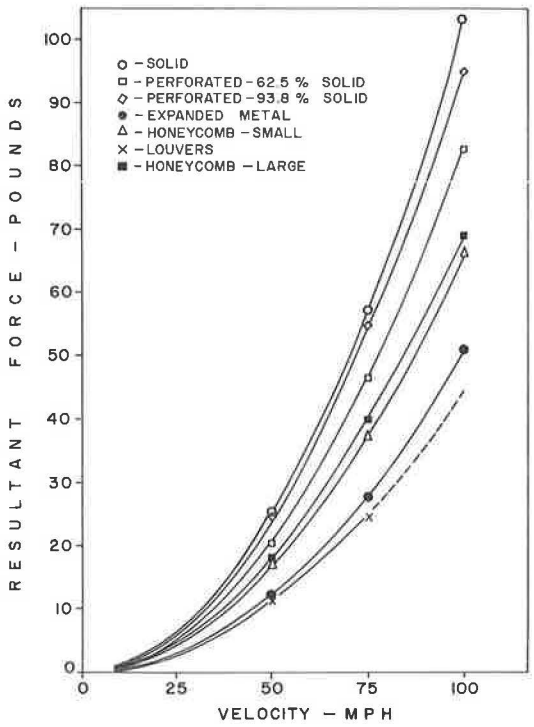

Figure 11. Variation of maximum force with velocity.

The picture of the louvered panel (Fig. 10) was taken after wind tunnel testing. A structural failure at the welds occurred during the 100-mph test, and no data were obtained for this run. Figure 4 reveals the slight imperfections remaining after the panel was reassembled for the purpose of making the photograph.

Some of the pictures of sign backgrounds show the mounting holes for attaching to the X-bracing. Specimens shown in Figures 4 through 10 were suspended from a fence wire.

RESULTS

Tables 1 through 7 provide the data acquired from the wind tunnel tests. For each angle of incidence (β in Fig. 2) of 0, 15, 30, 45, 60, 75, and 90 deg, data were recorded for side force, normal force, resultant force, and moment (twist about vertical axis).

Figure 11 shows a plot of maximum resultant force vs velocity for each sign background. For the louvered panel, the curve is extrapolated to 100 mph as indicated by the dashed line. Figure 12 shows a plot of maxi-

TABLE 2

WIND TUNNEL RESULTS–PERFORATED PLATE
(62.5 Percent Solid)

Velocity (mph)	Angle (deg)	Side Force (lb)	Normal Force (lb)	Resultant Force (lb)	Moment (ft-lb)
50.0	0.0	0.1	20.6	20.6	-0.0
50.0	15.0	0.4	19.6	19.6	-0.7
50.0	30.0	0.8	18.0	18.1	-1.5
50.0	45.0	1.6	15.2	15.3	-1.8
50.0	60.0	1.8	10.3	10.4	-0.8
50.0	75.0	1.4	4.0	4.2	-0.3
50.0	90.0	0.4	0.1	0.4	0.6
75.0	0.0	0.2	46.4	46.4	0.1
75.0	15.0	0.1	42.2	42.2	-1.7
75.0	30.0	1.4	40.6	40.6	-3.6
75.0	45.0	3.1	35.0	35.1	-4.5
75.0	60.0	3.3	23.7	24.0	-3.6
75.0	75.0	1.8	9.9	10.0	-1.0
75.0	90.0	0.8	0.4	0.9	1.0
100.0	0.0	0.4	82.4	82.4	0.2
100.0	15.0	1.3	79.7	79.7	-3.3
100.0	30.0	3.0	71.5	71.6	-6.1
100.0	45.0	4.4	61.7	61.9	-8.2
100.0	60.0	4.7	42.1	42.4	-4.9
100.0	75.0	3.4	18.4	18.7	-2.0
100.0	90.0	0.8	1.0	1.3	1.6

TABLE 3

WIND TUNNEL RESULTS–PERFORATED PLATE
(93.8 Percent Solid)

Velocity (mph)	Angle (deg)	Side Force (lb)	Normal Force (lb)	Resultant Force (lb)	Moment (ft-lb)
50.0	0.0	0.2	19.1	19.1	0.0
50.0	15.0	0.5	24.4	24.4	-1.1
50.0	30.0	-0.3	20.8	20.8	-2.1
50.0	45.0	0.4	19.6	19.6	-4.3
50.0	60.0	0.3	18.3	18.3	-3.4
50.0	75.0	0.3	8.1	8.1	-2.1
50.0	90.0	0.6	-0.0	0.6	1.5
75.0	0.0	0.3	54.5	54.5	0.6
75.0	15.0	0.7	54.2	54.2	-2.7
75.0	30.0	-0.1	47.6	47.6	-4.0
75.0	45.0	-0.7	42.9	42.9	-6.1
75.0	60.0	0.8	41.5	41.5	-7.0
75.0	75.0	0.1	19.1	19.1	-5.2
75.0	90.0	1.0	0.3	1.0	3.3
100.0	0.0	0.4	94.7	94.7	0.6
100.0	15.0	0.7	93.1	93.1	-4.7
100.0	30.0	-0.1	85.9	85.9	-8.6
100.0	45.0	-0.0	78.0	78.0	-12.7
100.0	60.0	1.3	73.0	73.0	-12.5
100.0	75.0	0.6	35.1	35.1	-9.4
100.0	90.0	1.8	0.9	2.0	6.1

TABLE 4

WIND TUNNEL RESULTS—EXPANDED METAL
(39.2 Percent Solid)

Velocity (mph)	Angle (deg)	Side Force (lb)	Normal Force (lb)	Resultant Force (lb)	Moment (ft-lb)
50.0	0.0	0.2	12.2	12.2	-0.3
50.0	15.0	0.1	12.1	12.1	-0.6
50.0	30.0	0.0	10.7	10.7	-0.8
50.0	45.0	0.1	8.2	8.2	-0.8
50.0	60.0	0.7	5.2	5.2	-0.0
50.0	75.0	0.5	2.4	2.4	-0.0
50.0	90.0	0.3	0.0	0.3	0.2
75.0	0.0	0.5	27.7	27.7	-0.4
75.0	15.0	-0.0	27.1	27.1	-1.6
75.0	30.0	-0.0	24.8	24.8	-2.0
75.0	45.0	0.4	19.3	19.3	-1.6
75.0	60.0	0.9	12.0	12.1	-0.9
75.0	75.0	0.4	6.1	6.1	-0.0
75.0	90.0	0.1	0.2	0.2	0.6
100.0	0.0	0.9	50.8	50.8	0.0
100.0	15.0	0.4	50.4	50.4	-2.9
100.0	30.0	0.2	45.9	45.9	-4.0
100.0	45.0	0.4	35.3	35.3	-3.4
100.0	60.0	1.2	21.7	21.7	-1.6
100.0	75.0	0.9	11.1	11.1	-0.4
100.0	90.0	0.1	0.6	0.7	0.8

TABLE 5

WIND TUNNEL RESULTS—HONEYCOMB
(2.4 Percent Solid)

Velocity (mph)	Angle (deg)	Side Force (lb)	Normal Force (lb)	Resultant Force (lb)	Moment (ft-lb)
50.0	0.0	0.4	4.3	4.3	0.0
50.0	15.0	10.7	4.5	11.6	1.9
50.0	30.0	16.5	3.9	16.9	2.9
50.0	45.0	15.2	2.1	15.3	2.6
50.0	60.0	10.7	1.4	10.8	0.7
50.0	75.0	4.5	0.5	4.5	1.1
50.0	90.0	2.1	0.5	2.2	0.6
75.0	0.0	0.5	8.1	8.1	0.4
75.0	15.0	22.8	8.0	24.1	4.3
75.0	30.0	36.1	7.0	36.8	6.4
75.0	45.0	34.9	5.1	35.3	7.7
75.0	60.0	23.3	2.9	23.5	4.5
75.0	75.0	9.4	1.5	9.5	2.4
75.0	90.0	2.5	1.1	2.8	0.6
100.0	0.0	0.2	14.6	14.6	0.4
100.0	15.0	41.6	14.2	44.0	7.4
100.0	30.0	64.8	12.1	65.9	11.3
100.0	45.0	62.9	8.9	63.5	11.1
100.0	60.0	40.6	4.7	40.9	8.0
100.0	75.0	16.2	2.4	16.4	4.1
100.0	90.0	4.9	2.8	5.6	1.2

TABLE 6

WIND TUNNEL RESULTS–HONEYCOMB
(4.0 Percent Solid)

Velocity (mph)	Angle (deg)	Side Force (lb)	Normal Force (lb)	Resultant Force (lb)	Moment (ft-lb)
50.0	0.0	0.4	3.8	3.8	0.4
50.0	15.0	11.9	3.1	12.2	2.6
50.0	30.0	17.7	2.4	17.9	4.0
50.0	45.0	16.6	0.7	16.6	4.7
50.0	60.0	11.8	0.1	11.8	2.9
50.0	75.0	4.8	-0.2	4.8	1.5
50.0	90.0	2.2	0.4	2.2	0.4
75.0	0.0	1.1	8.6	8.6	0.4
75.0	15.0	26.7	8.2	27.9	6.4
75.0	30.0	39.2	6.0	39.6	9.4
75.0	45.0	36.0	2.3	36.1	8.9
75.0	60.0	24.0	0.1	24.0	6.3
75.0	75.0	8.8	-0.2	8.8	2.9
75.0	90.0	1.8	1.1	2.1	1.0
100.0	0.0	1.8	18.2	18.3	1.4
100.0	15.0	46.9	17.1	49.9	12.5
100.0	30.0	67.7	11.9	68.7	16.8
100.0	45.0	62.6	5.7	62.8	15.6
100.0	60.0	43.3	1.1	43.3	11.1
100.0	75.0	16.2	0.1	16.2	4.9
100.0	90.0	15.3	2.6	15.5	2.0

TABLE 7

WIND TUNNEL RESULTS–LOUVERS
(100 Percent Solid)

Velocity (mph)	Angle (deg)	Side Force (lb)	Normal Force (lb)	Resultant Force (lb)	Moment (ft-lb)
50.0	0.0	-0.3	10.9	11.0	-0.3
50.0	15.0	2.4	11.0	11.3	-0.2
50.0	30.0	4.1	9.3	10.1	0.2
50.0	45.0	2.7	4.3	5.1	-0.1
50.0	60.0	3.4	3.2	4.7	0.8
50.0	75.0	2.8	1.4	3.1	1.1
50.0	90.0	1.6	0.5	1.7	0.3
75.0	N.D.	–	–	–	–
75.0	15.0	4.7	24.0	24.4	0.1
75.0	30.0	7.8	19.7	21.2	0.9
75.0	45.0	8.0	12.9	15.2	1.5
75.0	60.0	6.4	7.4	9.8	2.1
75.0	75.0	5.7	3.5	6.7	2.6
75.0	90.0	-0.2	1.0	1.0	1.0
100.0	0.0	–	–	–	–
100.0	15.0	–	–	–	–
100.0	30.0	–	–	–	–
100.0	45.0	–	–	–	–
100.0	60.0	–	–	–	–
100.0	75.0	–	–	–	–
100.0	90.0	–	–	–	–

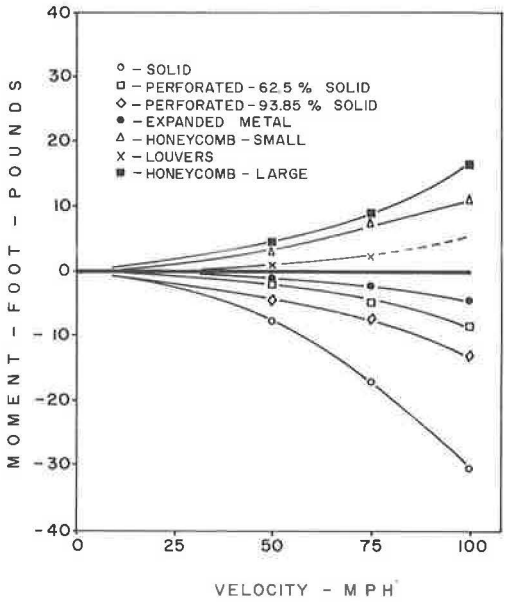

Figure 12. Variation of maximum moment with velocity.

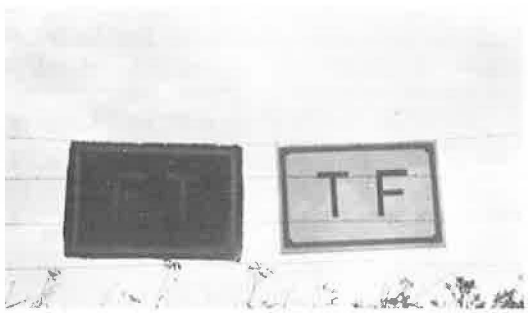

Figure 13. Visibility observations.

TABLE 8

REDUCTION IN MAXIMUM FORCE AND MOMENT AT 100 MPH

Sign Backgrounds	Reduction (%)	
	Force	Moment
Louvers[a]	57	83
Expanded metal	51	87
Honeycomb, 2.4% solid	36	63
Honeycomb, 4.0% solid	33	44
Perforated plate, 62.5% solid	20	73
Perforated plate, 93.8% solid	8	58

[a] Based on extrapolated data.

mum moment vs velocity for each sign background. Data for plotting the curves of Figures 11 and 12 are taken from Tables 1 through 7.

Table 8 provides comparisons of percent reduction in maximum forces and in maximum moment for the sign backgrounds. In each case, the solid background is used as the basis of comparison.

The X-bracing on which the sign backgrounds were mounted resulted in some interference effect on the nonsolid backgrounds. Consequently, some inherent inaccuracies of this nature exist in the data. However, these inaccuracies are small.

CONCLUSIONS

From the results of the investigation, it is concluded that the use of nonsolid sign backgrounds appears feasible. However, other factors not evaluated in this research need to be weighed before a preference of one type of sign background over another can be established. For example, the matter of cost needs consideration. The cost of sign supports would probably be reduced as a result of reduced wind loadings. However, additional complexity of manufacturing and mounting might well lead to a total cost in excess of that for the solid background sign structure.

Visibility also merits consideration. Although no organized research was performed with respect to visibility characteristics, a few observations were made, two of which are shown in Figure 13. On the right, suspended from a fence wire, is a sign background constructed from the perforated plate having 0.125-in. holes. On the left is a background constructed from the aluminum honeycomb. Visibility would be an important factor in considering the use of nonsolid backgrounds.

The louvered background offers the greatest percent reduction in wind force, as well as the possibility of providing a solid appearance through a proper design of louvers.

The writers wish again to call attention to the fact that this research was not intended to be comprehensive. Obviously, only a few of the many possibilities with respect to shape of openings, dimensions, positioning of louvers, etc., have been considered.

ACKNOWLEDGMENT

The authors wish to acknowledge the facilities provided for this research by the Texas Engineering Experiment Station at Texas A and M University.