State of Illinois
DEPARTMENT OF PUBLIC WORKS AND BUILDINGS
Division of Highways
Bureau of Research and Development

SPECIAL REPORT
ON
A COMPARATIVE FIELD INVESTIGATION OF WIND LOADS ON LOUVERED AND SOLID HIGHWAY SIGNS

Conducted by the
Illinois Division of Highways

September 1970

COMPARATIVE FIELD INVESTIGATION OF WIND LOADS ON LOUVERED AND SOLID HIGHWAY SIGNS

ABSTRACT

The large solid highway sign panels in current use by the State of Illinois offer high resistance to wind and must be accompanied by supports with sufficient strength to withstand large wind loads. A method of reducing the wind loads acting on the signs would be beneficial in developing a lighter and more economical design for the support structures.

Louvered panel configurations have been proposed as one method for reducing wind loads on signs. In order to study the comparative field effect of wind loads on louvered and solid signs, a louvered sign was fabricated and a limited field test was conducted near Bloomington, Illinois.

This report includes a description of the test instrumentation and procedures and an analysis of the data recorded. The results of this limited research indicate that a substantial reduction in wind loads can be achieved by the louvered configuration under study.

COMPARATIVE FIELD INVESTIGATION OF WIND LOADS ON LOUVERED AND SOLID HIGHWAY SIGNS

Introduction

The efficient and orderly flow of large volumes of high speed traffic on the modern interstate highway requires an extensive signing system to warn and direct the motorist. For a sign system to be effective in relation to the overall highway plan, the sign message must be clearly legible at all hours of the day and night and must be discernible at distances which allow sufficient driver response time. This requirement often necessitates the use of sizable lettering and, consequently, large sign backgrounds.

The large solid sign panels in current use offer high resistance to wind and must be accompanied by supports with sufficient strength to withstand large wind loads. This results in support structures with relatively stiff and heavy members. A method of reducing the wind loads transmitted from the sign to the supporting structure would be beneficial in developing a lighter and more economical design for the support structures.

Also of interest is a current plan to add lighting fixtures to existing overhead sign structures to improve the night-time visibility characteristics. The attachment of the lighting brackets to the existing support trusses will require that the existing signs be raised approximately 1'-3". The resulting offset of the center of the sign in relation to the centerline of the truss will induce torsional forces in the truss from wind loads acting normal to the sign. At the same time, the visibility of the existing sign system will be improved by increasing the areas of the signs. The resulting increase in wind resistance will cause larger bending moments in the horizontal truss and side frames as well as larger overturning moments at the foundations. In most cases, the additional bending moments and the induced torsional forces will result in stresses in the truss members above those for which the structure was designed. The development of a sign panel with a substantial reduction in wind resistance would help to compensate for the eccentricity of the signs and the increased sign areas, and allow the existing support trusses to be utilized in a more effective manner.

Louvered panel designs have been proposed as one method for reducing wind loads on signs. The louvered configuration permits the flow of air through the panel to reduce wind resistance. The louvers can be spaced and angled to maintain the appearance of a solid background, resulting in good visibility characteristics.

Sign support structures in use by the State of Illinois include overhead trusses, cantilever trusses, and shoulder mounted posts. Although the development of a sign panel with reduced wind resistance would affect all supporting structures to some degree, the greatest effect would be on overhead support structures due to their long span lengths.

The work described herein consisted principally of a series of field measurements of strains (and consequent stresses) induced in supports by wind forces ranging between 10 and 30 mph on one louvered sign configuration and on a standard sign.

Review of Previous Research

Until 1965, no literature was published dealing specifically with wind loads on nonsolid sign backgrounds. In that year, Tidwell and Samson of the Texas Transportation Institute published a paper entitled "Wind Tunnel Investigation of Non-Solid Sign Backgrounds." The nonsolid background models studies in this research included perforated plate, expanded metal, honeycomb, and louvered. A solid background model was tested to serve as a basis for comparing the effectiveness of the various nonsolid models.

The test specimens all measured 2 by 1.5 feet and were all tested in a wind tunnel at wind velocities of 50, 75, and 100 mph at various angles of wind incidence.

Of the models tested, both the louvered and expanded metal specimens showed reduction in wind loads greater than 50 percent when compared with the solid model. The louvered model with a 57 percent reduction in wind force gave the best results.

In 1967 the Texas Transportation Institute published a report entitled "Wind Loads on Roadside Signs," as a part of their research project on highway sign supports. The study consisted of wind tunnel tests on louvered, expanded metal, and solid models as well as the field testing of a full-scale solid sign to compare the wind tunnel results with actual field behavior.

The expanded metal models tested in this research showed little ability to reduce wind loads. Models composed of both straight and curved louvers of different widths and set at various angles of attack produced more encouraging results. The louvered backgrounds subjected to test showed reductions in wind loads in the order of 50 percent and greater when compared with the solid model. The results of the wind tunnel tests and the field tests on the solid sign specimens correlated well and served as an excellent control.

Scope of this Study

The office of Bridge and Traffic Structures of the Illinois Division of Highways planned and designed a louvered sign (Figures 1, 2, and 3) of different configuration than those tested in the wind tunnel by the Texas Transportation Institute. In order to study its effectiveness in reducing wind loads under field conditions, a full-scale sign of the type was fabricated and subjected to limited field testing in the overhead situation simultaneously with a conventional solid sign of the same area. Included in this report are a description of the test installation and procedure and an analysis of the data collected. A small investigation on the effect of truck traffic on both overhead and shoulder mounted signs is also discussed.

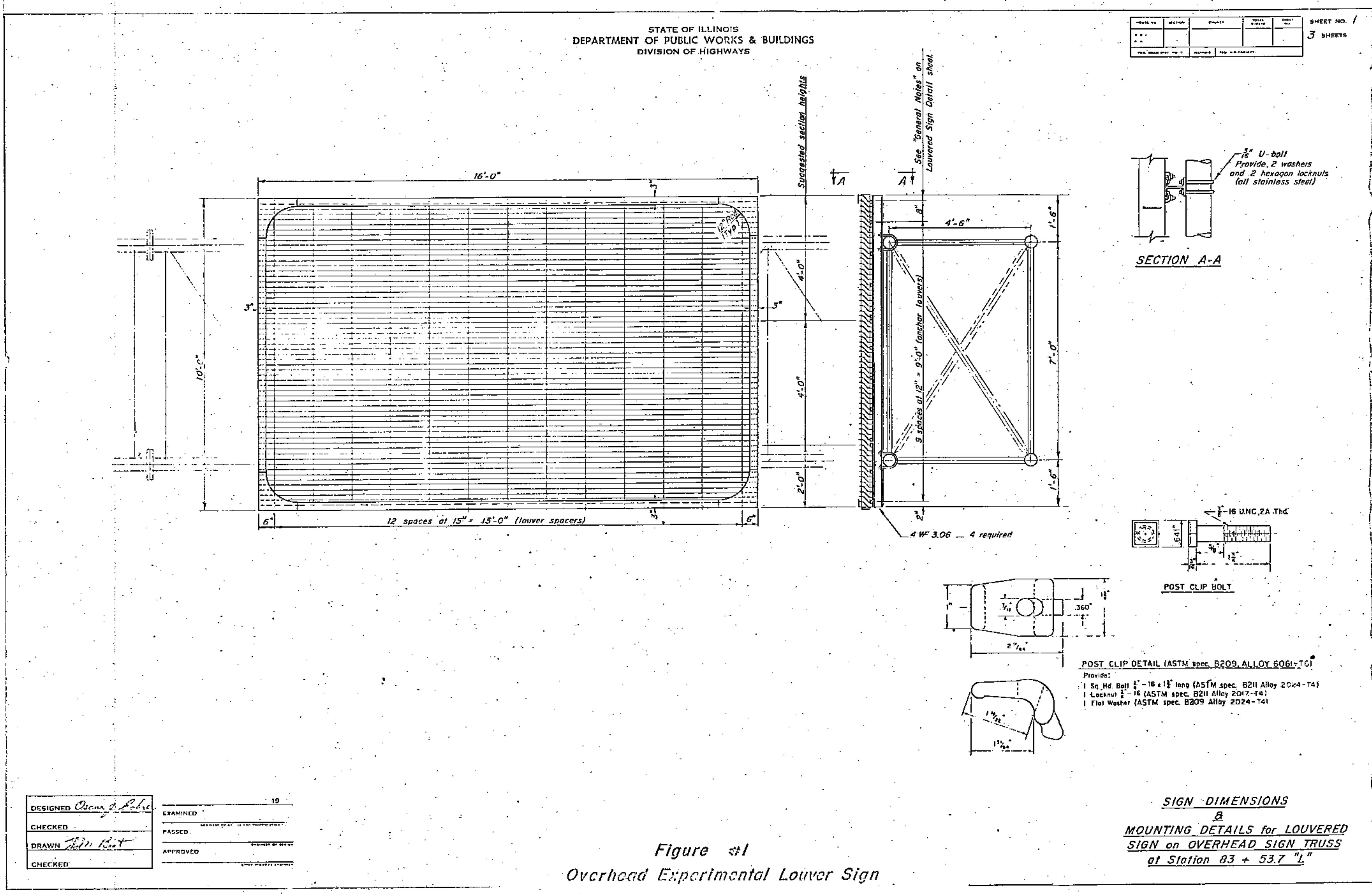

Figure #1
Overhead Experimental Louver Sign

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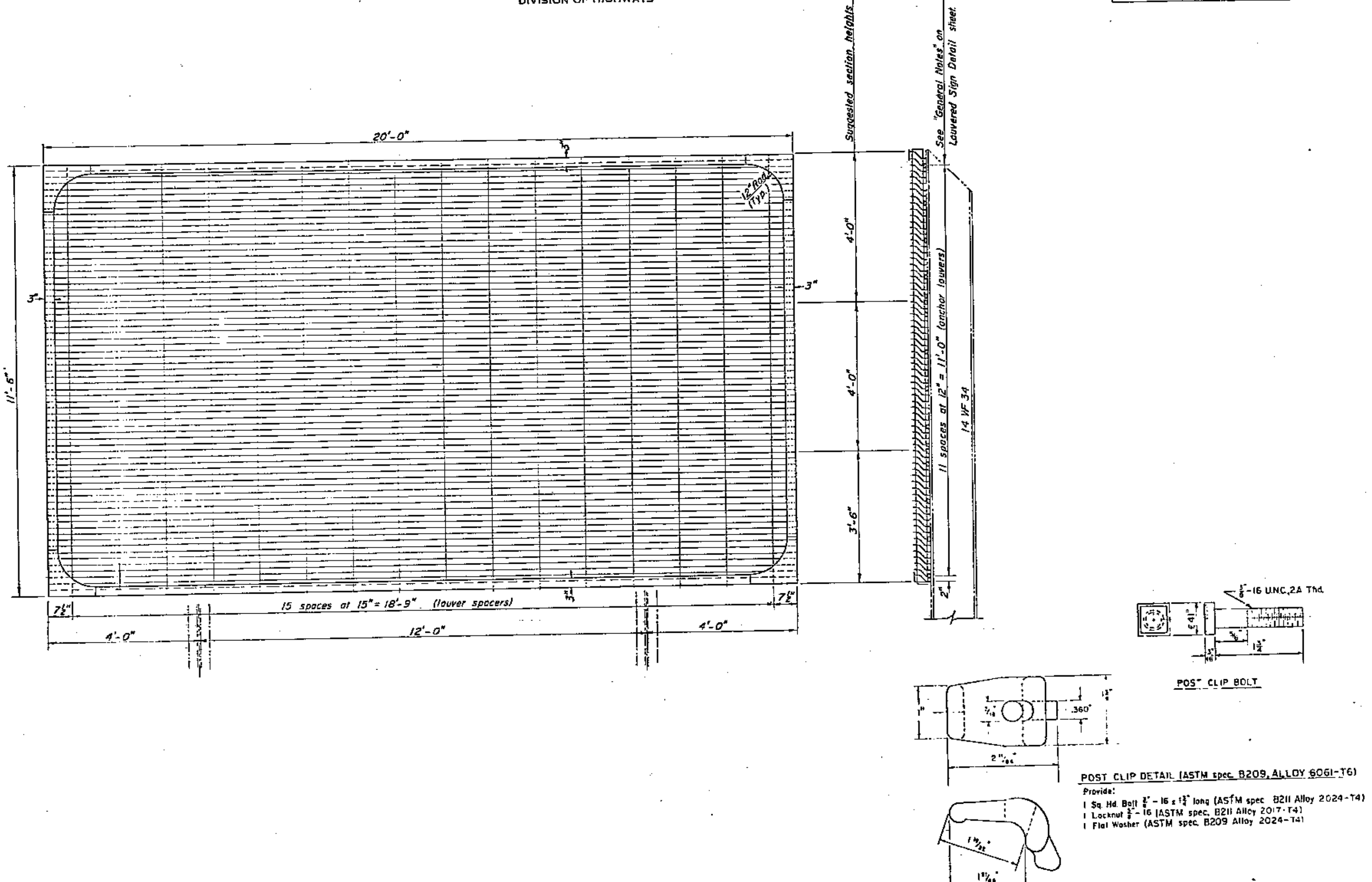
SHEET NO. 2
3 SHEETS



DESIGNED Oscar J. Rohrer
CHECKED
DRAWN
CHECKED

19
EXAMINED
PASSED
APPROVED

Figure #2
Shoulder Mount Experimental Louver Sign

SIGN DIMENSIONS
&
MOUNTING DETAILS for LOUVERED
SHOULDER MOUNT SIGN
at Rt. Station 581 + 87

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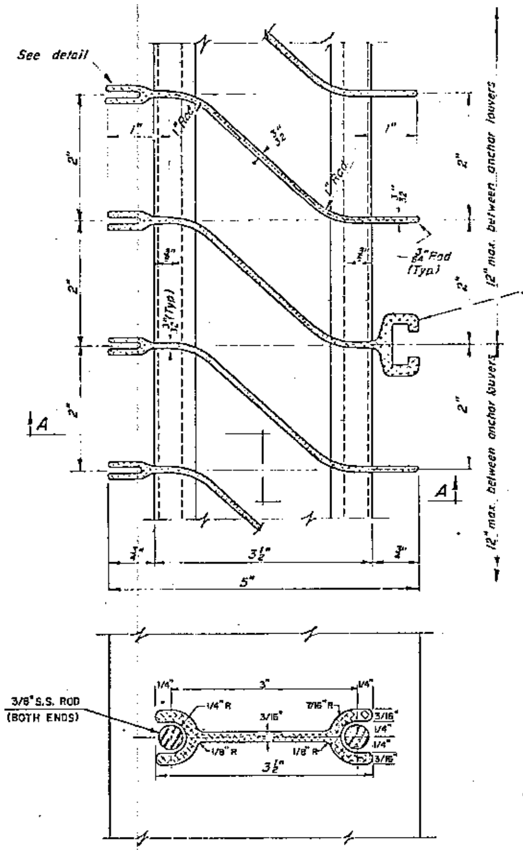
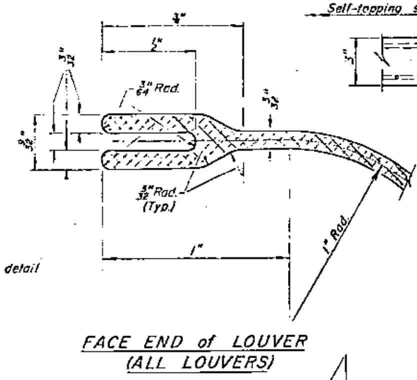
SHEET NO. 3
3 SHEETS

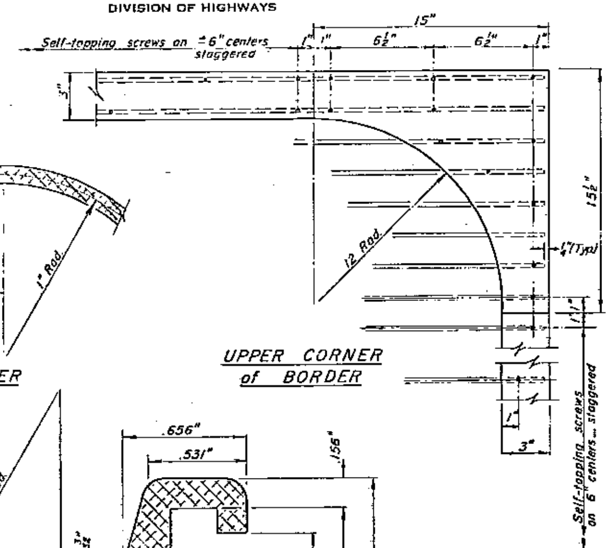


SECTION A-A

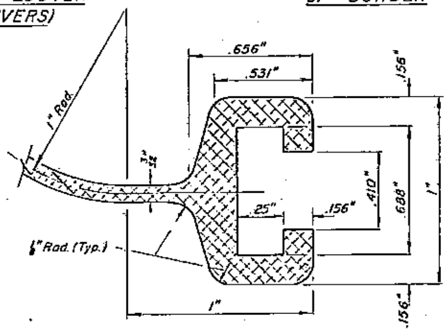
LOUVER DETAILS



FACE END of LOUVER (ALL LOUVERS)



UPPER CORNER of BORDER



LOUVER ANCHOR DETAILS

GENERAL NOTES

MATERIAL SPECIFICATIONS:

The curved louvers shall conform to ASTM designation B-221 Alloy 6061-T6.

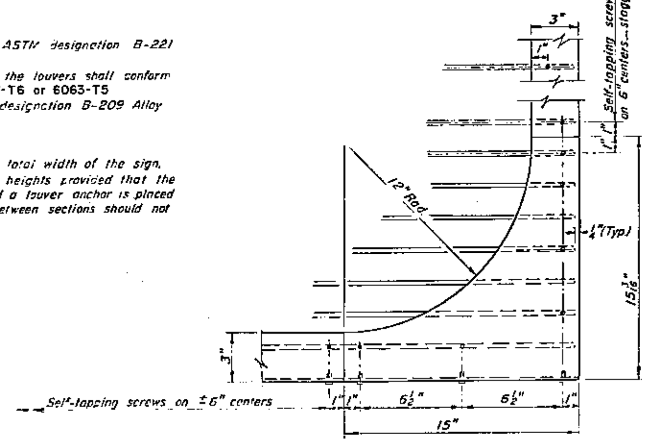
The spacers or channels supporting the louvers shall conform to ASTM designation B-221 Alloy 6061-T6 or 6063-T5.

The border shall conform to ASTM designation B-209 Alloy 3003-H14 or same alloy as letters.

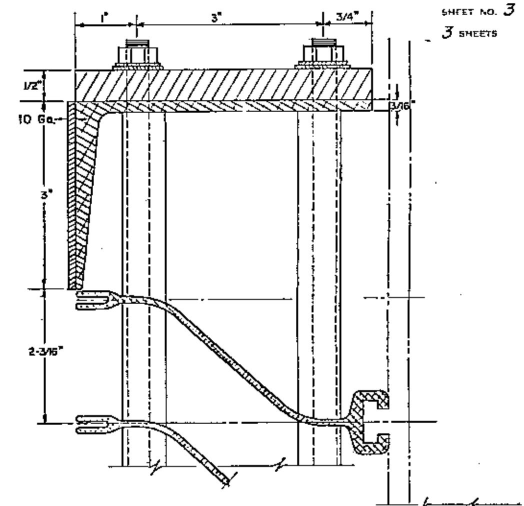
FABRICATION:

All louvers shall be continuous the total width of the sign.

The sign may be built in modular heights provided that the sections are 2'-0" or greater height and a louver anchor is placed on the two outside edges. The joint between sections should not pass thru message.

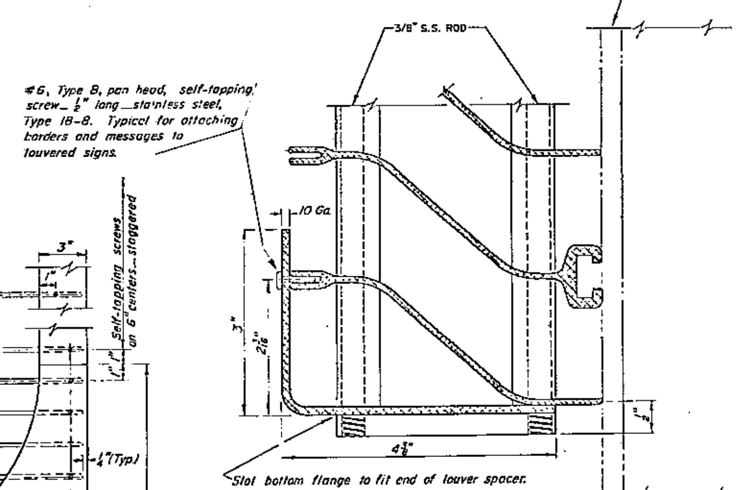


LOWER CORNER of BORDER



TYPICAL SECTION thru UPPER BORDER

#6, Type B, pan head, self-tapping screw 1/2" long stainless steel, Type 18-8. Typical for attaching borders and messages to louvered signs.



TYPICAL SECTION thru LOWER BORDER

LOUVERED SIGN DETAILS

DESIGNED [illegible]	EXAMINED	19
CHECKED	PASSED	
DRAWN [illegible]	APPROVED	
CHECKED		

Figure #3
Louver Sign Details

Tests of a model of this louvered sign and a solid counterpart in a wind tunnel are planned for the near future. The results of these tests will be reported when the information becomes available.

Description of Field Test

Sign structures for the Interstate Highway System in Illinois are currently designed for wind velocities based on a fifty year mean recurrence interval. The variation of these wind velocities at a height of 30 feet above the ground range from 100 mph, corresponding to a wind pressure of 55 lbs. per square foot in the extreme northwest corner of the State to 67 mph, or 25 lbs. per square foot, in the southern portion of the State (Figure 4).

The test site selected for comparing the field behavior of louvered and solid overhead signs was located near the interchange of FAI Routes 55 and 74 and Route US 66 about two miles southwest of Bloomington, Illinois. At this location, the fifty year mean recurrence wind velocity is approximately 75 mph, or 30 lbs. per square foot. During the test, which was conducted in April 1970, wind velocities varied from 15 to 30 mph. This is well below design velocity.

The support structure used for this research consisted of an overhead truss with a span of 90 feet. An existing 10'-0" x 14'-6" overhead solid sign was removed from the supporting truss and replaced with a 10'-0" x 16'-0" louvered sign (Figures 5 and 6). The increased area of the louvered sign corresponded to the area of the adjacent solid sign which was to serve as a control during the test. Both signs faced approximately southwest.

Each sign was attached to the supporting truss by four transducers located near the corners of the signs. The transducers were constructed by welding aluminum connecting plates to the ends of 2024-T3 aluminum tubing 2 inches long (Figure 7).

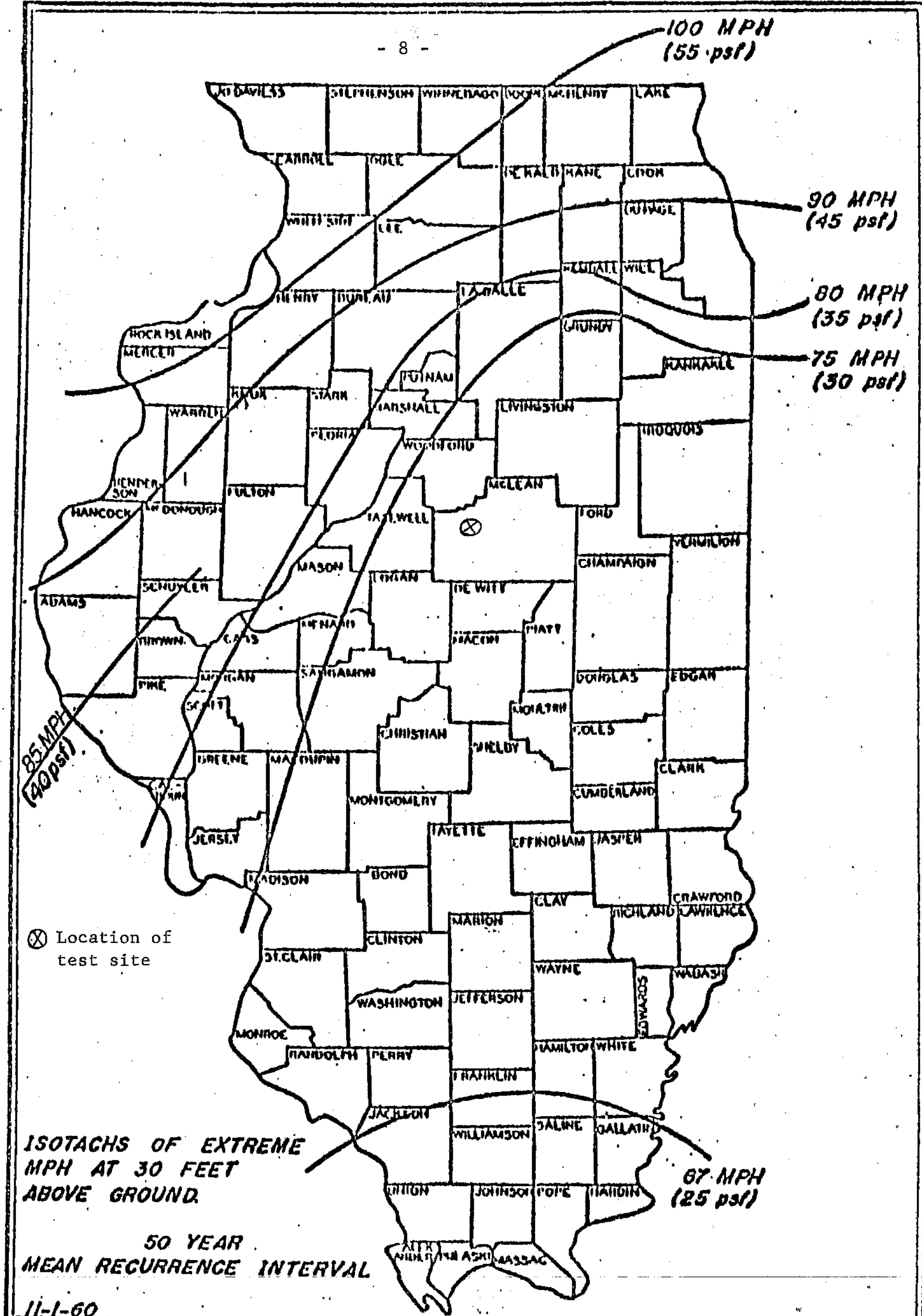

100 MPH
(55 psf)
90 MPH
(45 psf)
80 MPH
(35 psf)
75 MPH
(30 psf)
85 MPH
(40 psf)
67 MPH
(25 psf)
Location of
test site
ISOTACHS OF EXTREME
MPH AT 30 FEET
ABOVE GROUND
50 YEAR
MEAN RECURRENCE INTERVAL
11-1-60
STEPHENSON
McHENRY
LAKE
CARROLL
KANE
COOK
DUPAGE
WILL
HENRY
ROCK ISLAND
MERCER
GRUNDY
KANKAKEE
PUTNAM
STARK
MARSHALL
LIVINGSTON
IROQUOIS
WOODFORD
McLEAN
FULTON
HANCOCK
FORD
VERMILION
MASON
LOGAN
DE WITT
CHAMPAIGN
SCHUYLER
ADAMS
CASS
PIATT
PIKE
MORGAN
SANGAMON
DOUGLAS
EDGAR
SCOTT
CHRISTIAN
COLES
GREENE
CLARK
MONTGOMERY
CUMBERLAND
JERSEY
FAYETTE
EFFINGHAM
JASPER
MADISON
BOND
CLAY
CRAWFORD
MARION
RICHLAND
CLINTON
ST.CLAIR
WAYNE
WABASH
WASHINGTON
JEFFERSON
EDWARDS
MONROE
RANDOLPH
PERRY
WHITE
FRANKLIN
JACKSON
SALINE
GALLATIN
WILLIAMSON
UNION
POPE
HARDIN
MASSAC

Figure 4.

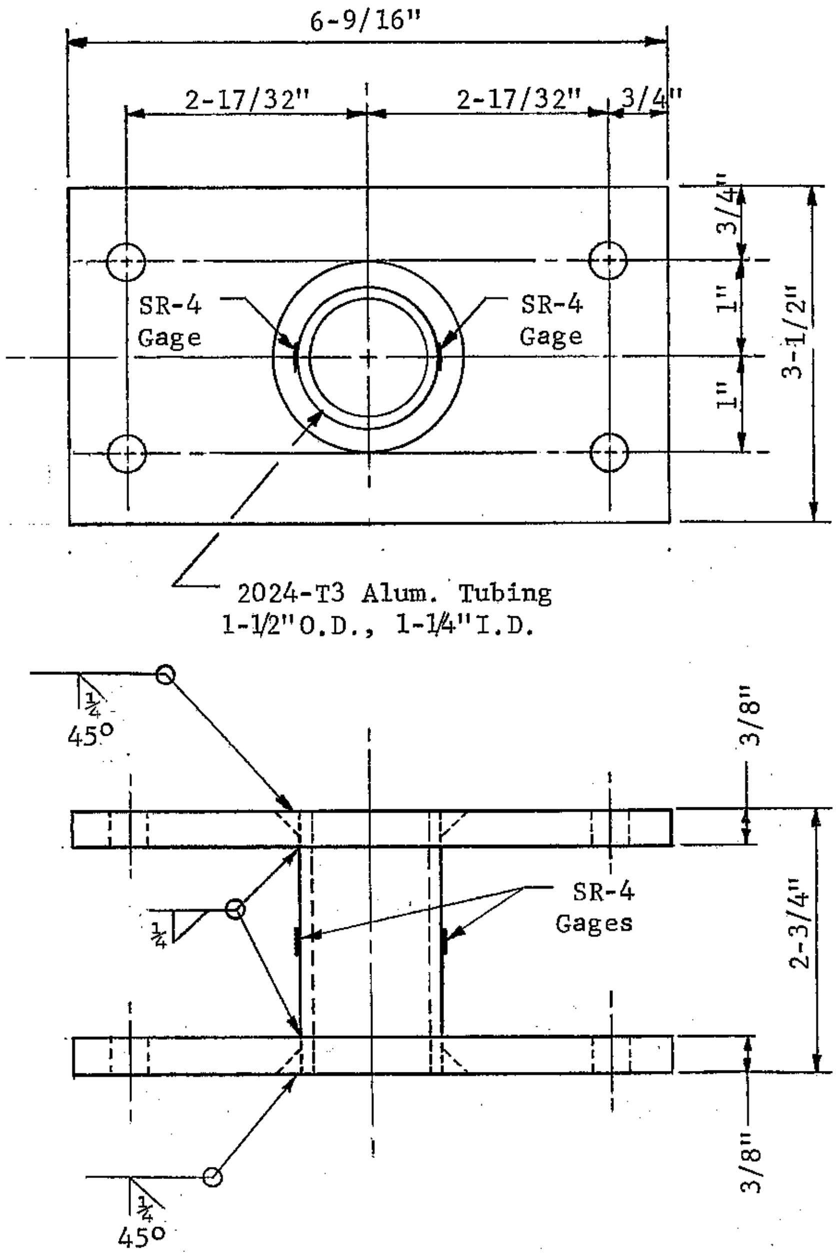


Figure 7. Transducer Details
Scale 1/2" = 1"

Two SR-4 electrical resistance strain gages were bonded to each transducer at locations 180 degrees apart to measure the average strain occurring across the section. The four transducers of each sign were then connected in parallel to a two-channel oscillograph which simultaneously recorded the total instantaneous normal force changes acting on both signs due to changes in wind velocity.

Wind speeds were measured by a three-cup anemometer located near the upper right hand corner of the louvered sign (Figure 6). A permanent pen and ink recording of the wind speeds was made on a separate tape independent of the force measurements. As will be described later, some difficulty was experienced in correlating the force change measurements to changes in wind speeds from the two independent recording systems. Wind directions were estimated from a vane positioned near the anemometer. Both instruments were located near the side of the louvered sign away from the solid sign.

Due to the limitations of the equipment available for this research, only the normal components of the total force acting on the signs were recorded and analyzed. As a result, the effect of twisting moment could not be ascertained as was done in the study by the Texas Transportation Institute. With this limitation, the most realiable data were collected when the wind direction was normal to the face of the sign.

Under field conditions it was not possible to locate a zero reference datum for the force measurements, since a constantly changing wind velocity, however slight, would continually shift the datum plane. Nor was it feasible to establish a reference in the laboratory since the weight of the sign in the field would alter the calibration. Consequently, the data collected represent a differential force change on each sign rather than an absolute force measurement.

In addition to the overhead signs, a solid shoulder mounted sign was attached to two vertical posts with transducers identical to those used in the overhead tests. Limited data were collected on this sign to determine the effect of truck traffic on the solid type shoulder mounted sign.

Analysis of Test Data

The first step taken in analyzing the data was an attempt to correlate the field wind loads on the solid sign with theoretical values for corresponding wind velocities. The theoretical formula used in the analysis is given in the AASHO Specifications for the Design and Construction of Structural Supports for Highway Signs. This formula is as follows:

$$p = 0.00256\ (1.3V)^2\ Cs\ Ch$$

where

p = wind pressure in pounds per square foot

0.00256 = a constant including the mass density of air at sea level, and a factor for converting wind velocity from mph to ft/sec.

V = wind velocity in mph

1.3 = a wind gust factor of 30 percent which is neglected in this study due to the difficulty in correlating sudden wind gusts to force changes with the available instrumentation.

Cs = a sign shape factor which is equal to 1.16 for a 10'-0" x 16'-0" sign.

Ch = a height coefficient which is equal to 1.0 when the centroid of the sign is 15 to 30 feet above ground level.

Inserting these values into the theoretical formula gives:

$$p = 0.00256\ V^2\ (1.16)\ (1.0)$$

$$p = 0.003\ V^2$$

Or denoting by F the total force acting on a sign with an area of 160 square feet gives:

$$F = 0.003\ V^2\ (160)$$

$$F = 0.48\ V^2$$

A plot of this theoretical formula is shown in Figure 8.

The data for wind loads acting normal to the sign were in the form of changes in force for a given change in velocity. The above equation, therefore, was written in the form:

$$\Delta F = K\ \Delta(V^2)$$

or

$$K = \frac{\Delta F}{\Delta(V^2)} = \frac{F_2^{\ 2} - F_1^{\ 2}}{V_2^{\ 2} - V_1^{\ 2}}$$

This formula was solved for K from 100 different data readings at wind velocities ranging from 15 to 30 mph. The results are shown in Figure 8 where curves representing the average K as well as the extreme maximum and minimum K's are plotted.

The values for K showed considerable variation with an average value about 20 percent higher than the value derived from the theoretical formula. The scatter in the data is attributed at least in part to the difference in response time between the force transducer-oscillograph system and the anemometer ink pen recording system. A gust of wind which produces an immediate reaction in the force transducer system must overcome the inertia of the anemometer system before it is recorded. Since the wind speed is continually changing, this lag in response creates difficulty in interpreting the data. The data were analyzed by correlating the peaks and valleys of the two charts representing high and low values of force changes and wind speeds, rather than by relating the charts through an excact time comparison. A typical sample of the data is shown in Figures 9 and 10.

Although the correlation of the field test results with theoretical values for the solid sign showed considerable scatter, it is believed that a good comparison

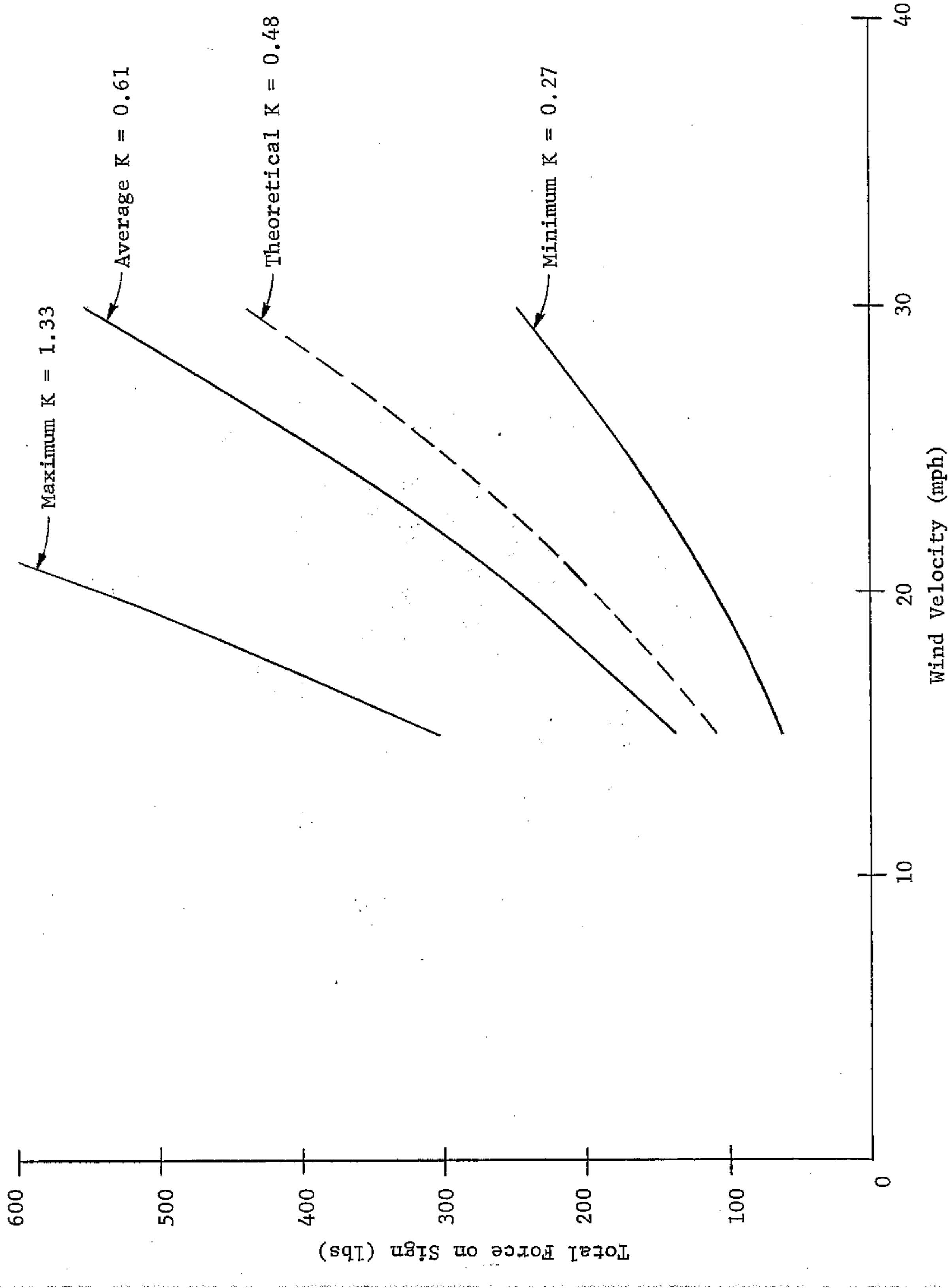


Figure 8. Force vs. Wind Velocity on Solid Sign
(Wind Velocities from 15 to 30 mph)

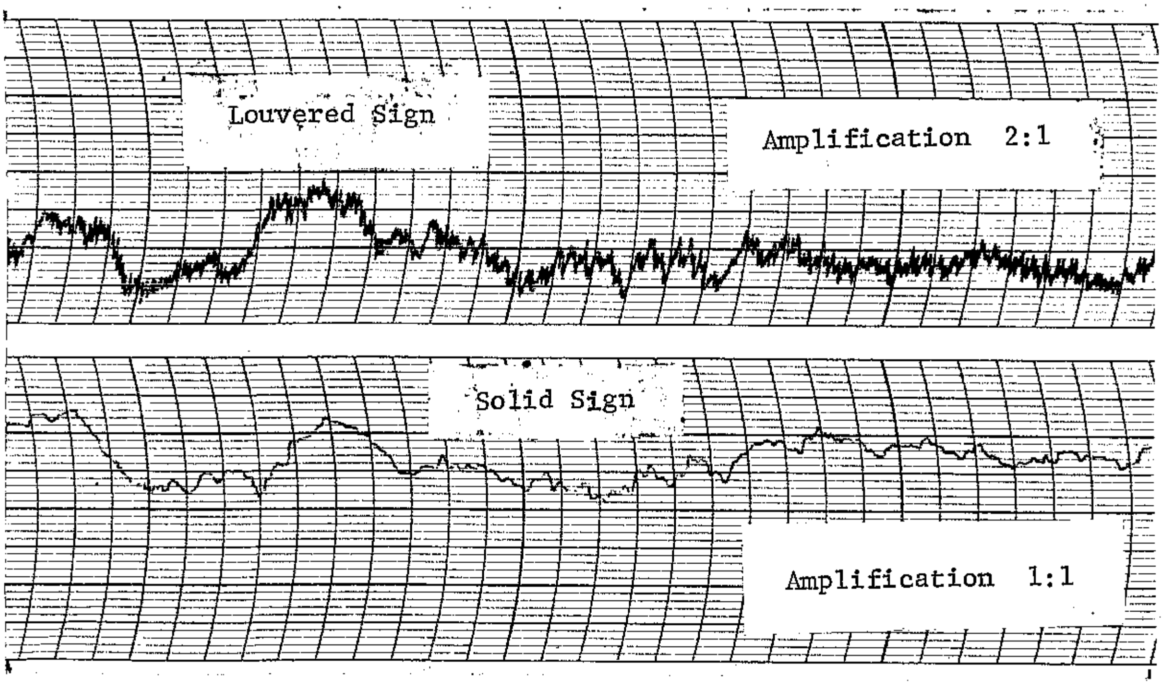


Figure 9.
Force Variations

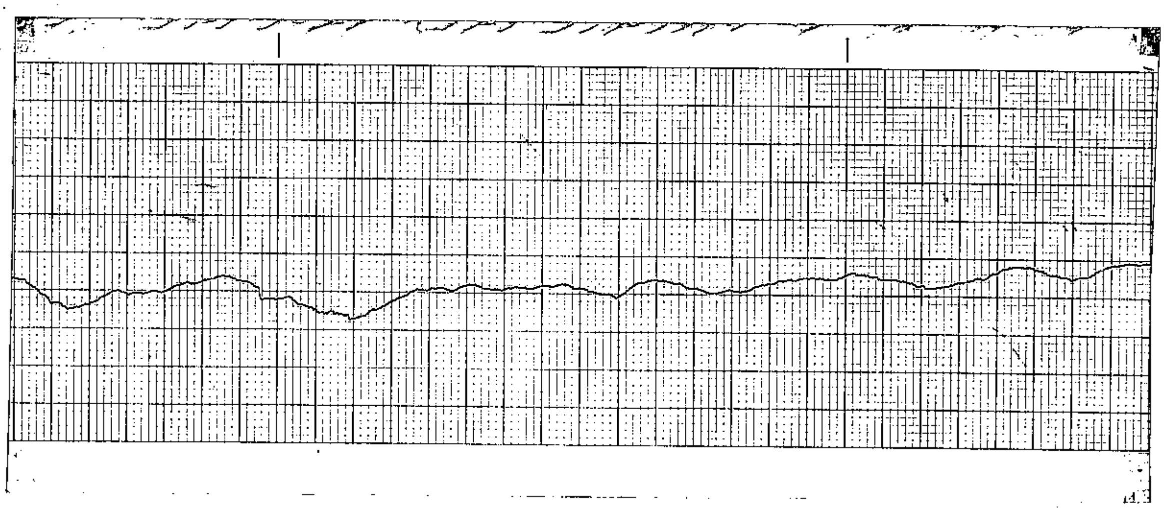


Figure 10.
Wind Speed Variations

of the relative force changes occurring on the louvered and solid signs was possible since the instantaneous force changes were recorded simultaneously on the same tape. The results of 100 data readings comparing the force changes on the two signs are shown in Figure 11. The analysis of the 100 events recorded at wind velocities of 15 to 30 mph indicates that the reduction in wind loads on the louvered sign compared with the solid sign range from 33 percent to 62 percent, with an average value of 50.5 percent. A similar reduction in wind forces is predicted for wind velocities above and below this range. The average reduction of approximately 50 percent is in close agreement with the findings of the wind tunnel tests conducted on other louver-type models by the Texas Transportation Institute.

The major cause for the variation in these values is believed to be a difference in wind velocities acting simultaneously on the two signs. Since the centers of the signs are approximately 20 feet apart, significant differences in wind velocity are possible. Although differences such as these are inherent in a wind load field test, it is believed that the average value of a large number of readings would closely represent the true difference in wind loads on the two signs since the effect of velocity variations above and below the mean would tend to cancel.

The data for the louvered sign consistently indicated more "noise" or oscillations than did the simultaneous force data for the solid sign. This could indicate small vibrations of the louvered sign itself, or it could be indicative of vibrations in the overhead structure. If the support structure is the source of oscillation, the vibrations would be transmitted through the transducers, resulting in oscillation of the experimental signs. The more massive louvered sign with a lower natural frequency would be affected to a greater extent by vibrations of the support structure than would the lighter solid sign.

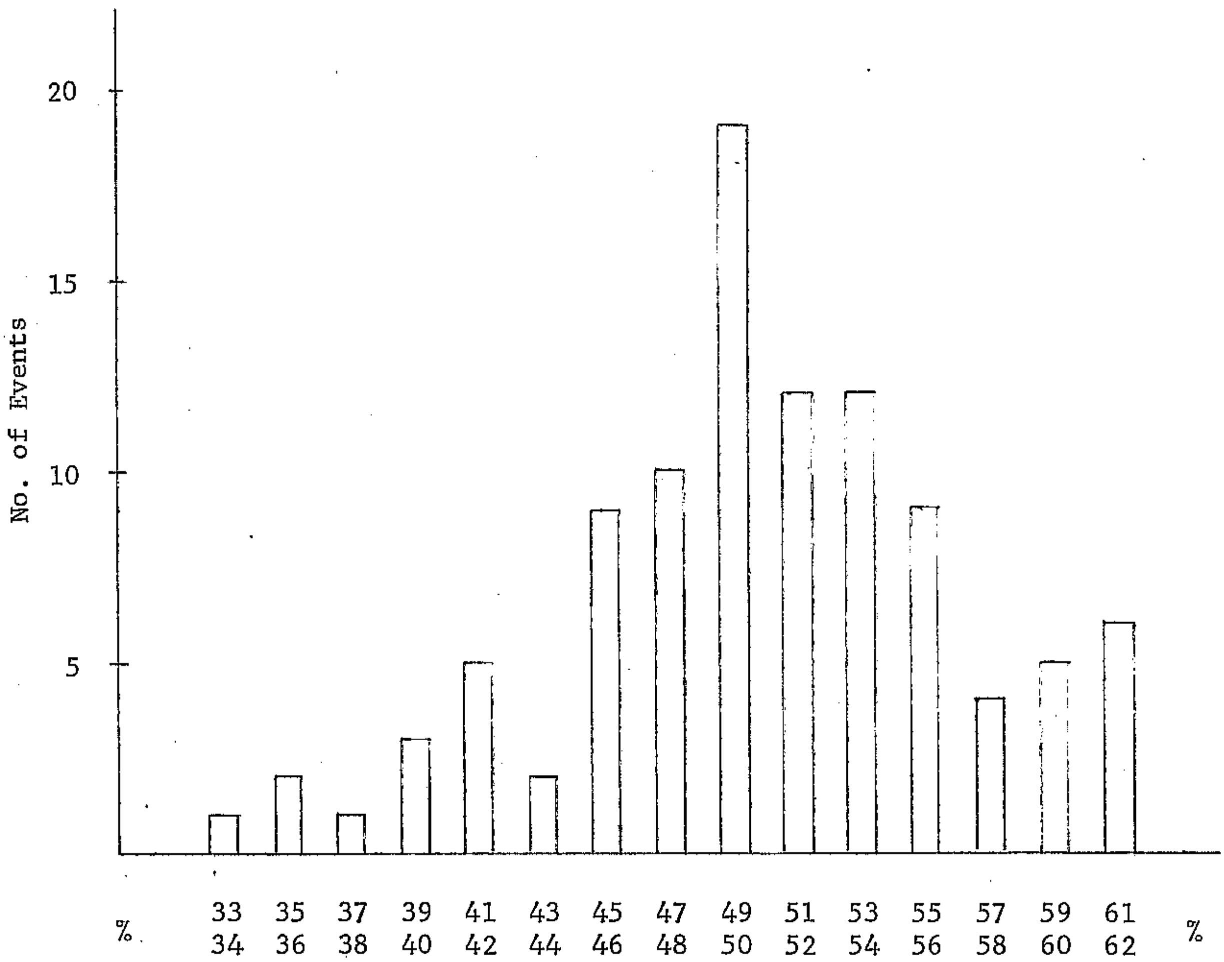


Figure 11. Percent Reduction in Wind Force on Louvered Sign Compared to Solid Sign

(Percent distribution of 100 events at wind velocities of 15 to 30 mph)

In order to study the effect of the structure vibrations on the louvered sign the overhead truss was manually vibrated and the subsequent effect on the force change data was observed. Much larger oscillations were recorded when the structure was manually vibrated than were present during operation of the system under normal wind loads (Figure 12). The oscillations continually present in the data for the louvered sign appear to have an insignificant effect on the structural adequacy of the sign structure under normal operating conditions.

Effect of Truck Traffic on Highway Sign Structure

The effect of wind turbulence from large trucks was considered in the study as a matter of interest. A limited investigation was made of the forces acting on both overhead and shoulder mounted signs due to truck traffic.

A shoulder mounted solid sign with a horizontal clearance of 35 feet from the edge of the roadway was instrumented and data was collected intermittently as large trucks passed the site. No significant change in the force data was recorded as the trucks approached and passed by. Apparently the effect of the turbulence produced by normal truck traffic diminishes to a negligible factor at a distance of 35 feet from the roadway.

The disadvantage of testing the in-service shoulder mounted signs was that only one sign could be tested at any given time. With the available facilities, a direct comparison of the louvered and solid signs under the same field conditions could not be made. Since a zero reference datum could not be established, the only true comparison of the behavior of the two sign types was the correlation of force changes acting simultaneously on the two signs under identical field conditions. A decision was made, therefore, to suspend testing of the shoulder mounted signs and to concentrate the efforts of this research on the overhead installation where force data on the solid and louvered signs could be recorded concurrently.

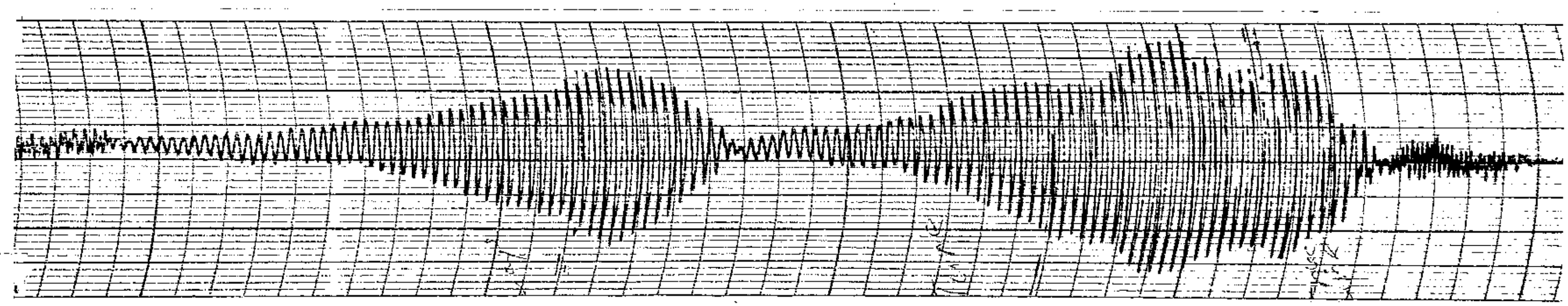


Figure 12. Vibrations Recorded at Louvered Sign Due to Manual Vibration of the Overhead Sign Structure.

At the overhead location, the louvered and solid signs were tested simultaneously for the effect of the wind turbulence produced by truck traffic (Figure 13). Although no substantial force changes were recorded, in certain cases a passing truck produced oscillations in the force data. The recorded vibrations were of similar frequency at both signs, but were of larger amplitude at the louvered sign. The same frequency of the vibrations at each sign indicates that the source of vibrations is the supporting overhead structure common to both signs. The variation in the amplitude of the oscillations can be attributed to the difference in the mass of the two signs. The more massive louvered sign, when set in motion by forces transmitted through the transducers would vibrate at a higher amplitude than would the lighter solid sign. In both the louvered and solid signs, the vibrations caused by truck traffic were minor in nature and dampened quickly.

It should be emphasized that at this site the density of truck traffic is light and characterized in most cases by the random and intermittent passing of single trucks. At locations where the density of truck traffic is greater, it is possible that a number of trucks passing in succession could increase the amplitude of the harmonic vibrations induced in the sign structure to a more critical level.

Summary Comments

The results of this field research indicate that a substantial reduction in wind forces can be achieved by the louvered configuration considered in this study. The recorded reduction in wind forces on the louvered sign compared to the solid sign varied from 33 to 62 percent, with an average reduction of approximately 50 percent.

The variation in the percent reduction is attributed to the lack of environmental control in a field test of this nature. It is possible for the instantaneous

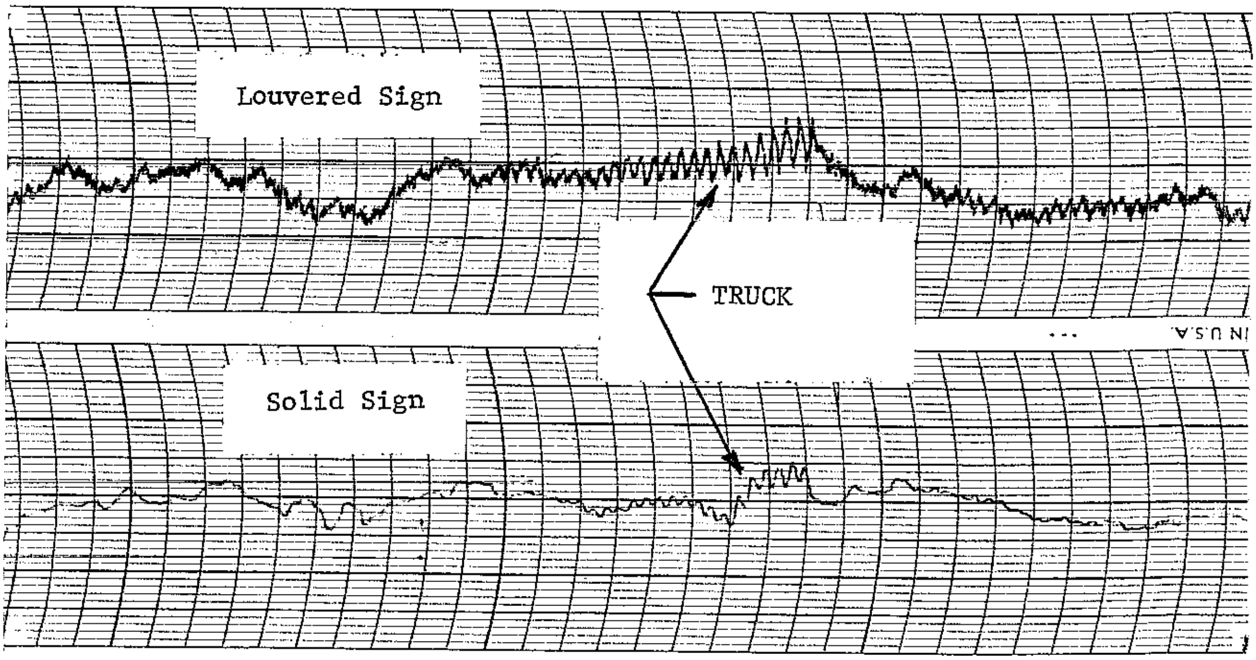


Figure 13. Vibrations of Louvered and Solid Overhead Signs Induced by Passage of Semi-Trailer Truck.

wind velocity gradient to vary greatly over the 20-foot distance between the centers of the two experimental signs. During some recorded events, the wind velocity could be greater at the louvered sign than at the solid sign, while at other instances the opposite could be true. Some discrepancy could be present, therefore, in the individual recordings of the simultaneous normal force changes acting on the two signs.

The average of the 100 force readings should give a good comparison of the force changes acting on the two signs since the readings above and below the mean would tend to equilibrate. It is significant that the average reduction after 50 events was essentially the same as the average after 100 readings.

Considerable variation was also found when attempting to correlate theoretical values with actual wind forces acting on the solid sign. These deviations may be attributed to the difference in response time between the two independent systems for recording wind speeds and changes in normal forces. The wind speeds were measured by an anemometer and recorded on a continuous tape by a pen and ink system. A relatively large time increment is required to overcome the inertia of the wind measuring system, while the response of the strain gage-oscillograph system used to record force changes is nearly instantaneous.

One characteristic of the data for the louvered sign which was not present in comparable data for the solid sign was the consistent indication of vibrations in the system. During this study the exact source of these oscillations was not pinpointed due to the lack of essential equipment. The vibration may stem from the louvered sign itself or possibly from the support structure which could be transmitting forces through the transducers, resulting in a superimposed oscillation of the more massive louvered sign. The lighter solid sign has a higher natural frequency and would not be affected to the same extent by vibrations of the support structure. The recorded oscillations were minor compared to vibrations induced manually into the sign structure, and did not appear to have a detrimental effect on the structural adequacy of the sign or the supporting truss.

The effect of truck traffic on both the solid and louvered overhead signs and a solid shoulder mount sign was observed and recorded. No significant force changes were produced in either the overhead or shoulder mounted installations from normal truck traffic. Although some oscillations due to truck traffic were recorded at the overhead installation, they were minor in nature and dampened quickly.

Truck traffic at this location was characterized by the random and intermittent passage of single trucks. At locations where the density of truck traffic is greater, it is possible that a number of trucks passing in succession could increase the amplitude of the harmonic vibrations induced in the sign structure to a more critical level.