The Use of a Screen to Subdue Gale-Force Winds on a Mountain Bridge

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This is a study to determine the feasibility of employing wind screens as a means for preventing vehicle accidents caused by high-velocity crosswinds. An experimental wind screen was installed on a mountain bridge where truck trailers had been overturned by sporadic gale-force crosswinds. The 10-ft-high screen was made of 9-gage galvanized steel chain-link mesh fencing with all of the apertures filled with crimped aluminum slats vertically placed. The spaces between the slats resulted in a porosity of 20 percent. The screen has been completely successful in preventing either the overturning of vehicles or loss of driver control during a 2-year test period. This paper suggests other types of locations that may benefit from wind protection and offers basic design considerations.

•THIS PAPER discusses a method for preventing vehicular highway accidents caused by high-velocity crosswinds that are known to occur in California and various parts of the world. Dangerous conditions are often developed in mountainous or undulating terrain where motor vehicles are suddenly exposed after emerging from the protection of earth cuts or embankments.

The protecting device is an experimental wind screen made of chain-link mesh fencing, fabricated from 9-gage galvanized steel wire. All of the apertures are filled with crimped aluminum slats vertically placed. The spaces between the slats yield a porosity of about 20 percent.

The experimental wind screen was installed on a relatively new, 2-lane, high-elevation freeway bridge across a mountain ravine. The screen extends 8 ft above the 2-ft-high concrete parapet of the bridge barrier rail, giving a total height of 10 ft above the pavement.

Before the wind screen was installed, the winds sometimes reached velocities that could overturn large truck trailers and often produced forces that impaired driver control of other vehicles. This condition made it necessary to restrict truck traffic during periods of high winds.

After the wind screen was installed, the hazard of the crosswind was eliminated. Some low-velocity headwinds now find a protected path along the bridge behind the wind screen but have not been a problem. These are the only winds that can now be measured anywhere on the bridge because the filtered crosswinds are below the velocity level of the head winds.

Instrumentation for and analysis of wind data are described, and recommendations are made as to procedures for adaptation of design ideas to other locations.

THE PROBLEM

A new 4-lane divided freeway, I-8, is replacing the older 2-lane highway, US-80, between San Diego and El Centro, California. Most of the westbound lanes of the new freeway were completed first in the Laguna Mountain area to give the motorist a safer

Paper sponsored by Committee on Guardrail, Median Barriers and Sign, Signal and Lighting Supports and Committee on Bridge Design.

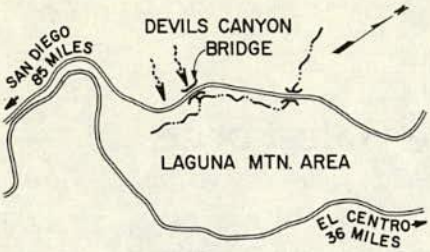


Figure 1. Location of Devils Canyon Bridge.

high-level route with fewer turns and hazards from falling rock. Some of the newly completed westbound lanes, therefore, were required to handle both east and westbound traffic while work continued on the unfinished eastbound lanes (Fig. 1).

The 2-way use of the westbound lanes began in December 1963, and during the following weeks a few reports were received from various sources that there were strong but sporadic west winds along the route. These reports were dramatically verified on April 2, 1964, when 2 truck and trailer combinations traveling in the westbound lane had their trailers overturned on Devils Canyon Bridge at 1:45 and 2:15 in the morning (Fig. 2). This bridge runs from north to south, and west winds are at normal incidence. The bridge was completely blocked by the overturned vehicle in 2 separate places, and all traffic was halted for over 10 hours. Fortunately, there were no human injuries, and the California Highway Patrol was able to prevent any collisions with the trucks and trailers. The portent of accidents of greater severity was, however, very clear. Either a collision or crushing accident could have occurred had any other vehicles been in the eastbound lane. Had the trucks been traveling in the eastbound lane, the trailers would likely have toppled over the barrier rail. After this accident, the California Division of Highways and the California Highway Patrol jointly assumed the responsibility to restrict truck and camper traffic during periods of high winds.

RESEARCH METHOD

Plans were initiated to measure separately and simultaneously the winds on the bridge and in a free-wind area. These measurements were to be made over long time intervals to yield reference values before and after the placement of a wind screen. The plan seemed entirely feasible but nature managed to inject one unforeseen variable—the head winds mentioned earlier.

Another aspect of the plan was to identify other hazardous locations in the general area that might need similar wind protection. This part of the program is continuing.

Instrumentation

The remote bridge location had no electrical power, and most long-interval recording anemometers are ac-operated devices. A search was made for a wind recording instrument that could operate for a period of about 2 months unattended. The answer was found in Model 1071, Mechanical Weather Station, available from Meteorology Research, Inc. These instruments will record wind velocity, direction, and temperature for a period of 8 weeks and require only two D-cells to power the clock for the calibrated chart-drive system.

The velocity information records continuously but is most accurately presented as average wind speeds for hourly intervals. Maximum peak velocities can be approxi-

Figure 2. Two large truck trailers blown over at 1:45 and 2:15 in the morning on April 2, 1964.

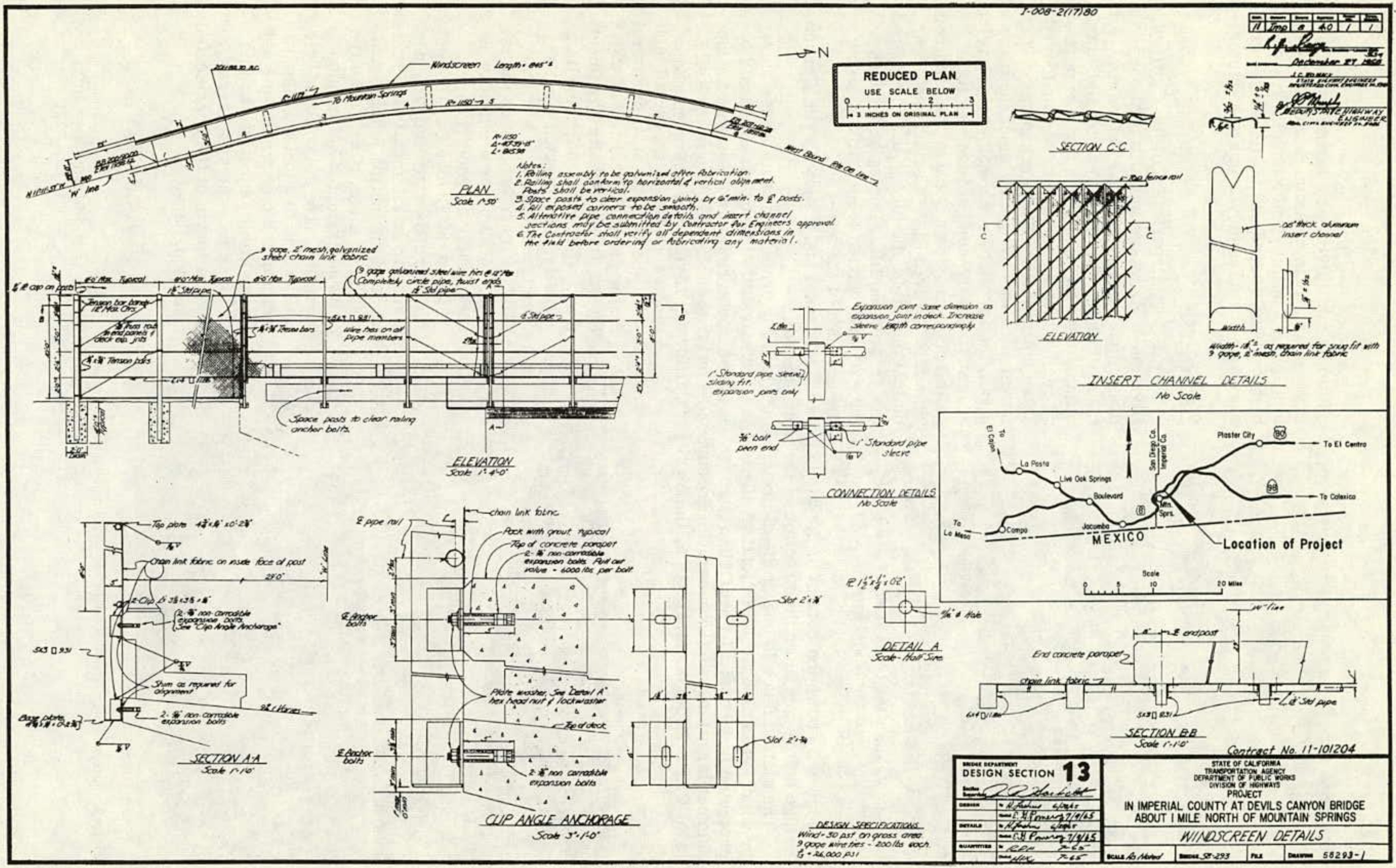


Figure 3. Details of wind screen.

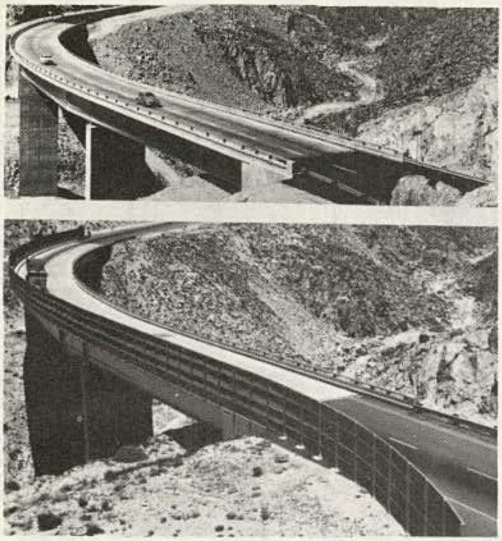


Figure 4. View of bridge toward north before and after installation of wind screen.

mated by multiplying any 1-hour average mph by 1.6. It is common practice (2) to multiply a 5-min average mph by 1.5 on higher speed recorders, so 1.6 seems conservative for an hourly average K-factor.

Wind Screen

The Bridge Department of the California Division of Highways initially furnished preliminary designs for a wind screen made of chain-link mesh fencing and aluminum slats for all but the topmost portion where horizontal louvers were considered as an upward deflecting mechanism. The louver idea was eventually discarded; instead, the air turbulence that would develop at the face of the wind screen was to be relied on to provide any extra lift required. This later proved to be a sound and economical decision: the higher the wind speed, the greater the lift. During high winds the extra lift varies from 2 to 3 ft above the top edge of the screen.

Figure 3 shows the details of the wind screen. Figures 4 and 5 show Devils Canyon Bridge before and after the erection of the wind screen.

The slatted fence is one of the old reliable devices for protection from either snow or wind. It is also very efficient. A 10-ft-high all-metal slatted fence has successfully protected hydroponically nourished citrus trees whose roots dangle in a saturated atmosphere in large tanks and whose trunks are supported by large cushioned clamps. The site is the Citrus Experimental Station, University of California, Riverside, where sporadic winds sometimes exceed 40 mph.

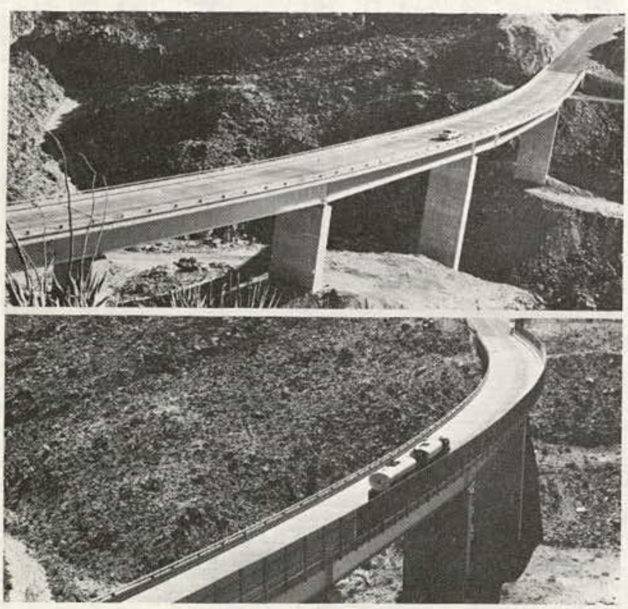


Figure 5. View of bridge toward south before and after installation of wind screen.

At the College of Agricultural Engineering, University of California, Davis, Schultz has found that a wood-slatted fence with a porosity of 25 percent can reduce free winds to 0.4 or less within 4 fence heights on the lee side. A 50 percent porosity is very nearly as good (1).

When the Bridge Department staff furnished preliminary designs for an all-metal wind screen made of chain-link fencing and aluminum slats, it was unaware of these examples but in good company. The reduction of bridge crosswinds to about half the velocity of the free winds seemed a reasonable objective, as this would reduce the side forces to about a fourth of the unprotected condition, based on

$$G \cong (V/20)^2$$

where G = psf and V = mph.

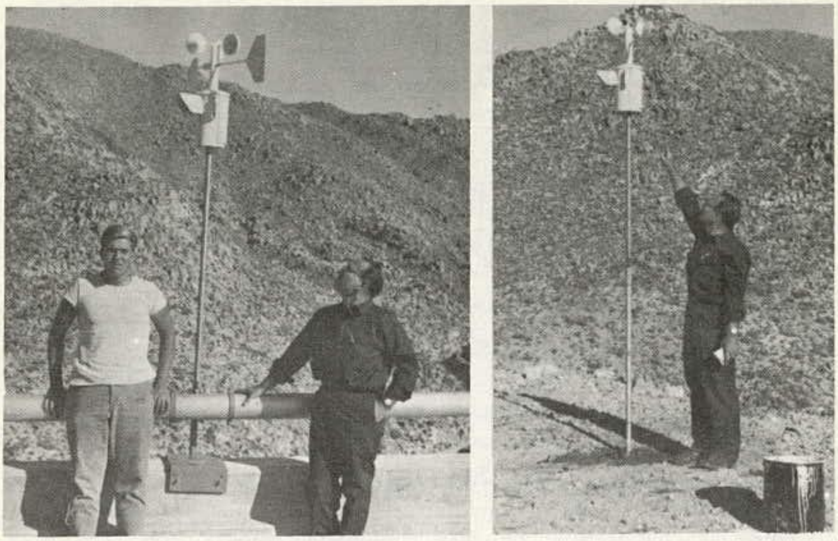


Figure 6. Wind-measuring instruments placed 9 ft above deck and 40 ft below bridge.

MEASUREMENT

Wind measurements were begun on October 19, 1965, in two places: 9 ft above the paved deck of the bridge and 40 ft below the bridge on a windswept ledge (Fig. 6). Measurements were taken for over 6 months through mid-April 1966. The free wind site below the bridge gave no signs of interfering turbulence from the structure during any of the long-term tests. West winds showing hourly averages of 18 mph or more at the free wind site were considered significant for reducing the data. None of the east winds ever exceeded 16 mph. The wind screen was completed in September 1966, and a second set of measurements was taken during the period from October 19, 1966, through April 1967. This is almost exactly the same seasonal time period as that of the first measurements, but one year later.

Table 1 gives the predominant west crosswind data recorded at the two instrumentation locations before the wind screen was erected along the west side of the bridge, and Figure 7 shows chart samples from the wind-measuring instruments.

After the wind screen was installed, the crosswinds were no longer measurable on the bridge because of some low-velocity south head winds that now find a protected path

TABLE 1

WEST CROSSWINDS BEFORE INSTALLATION OF WIND SCREEN

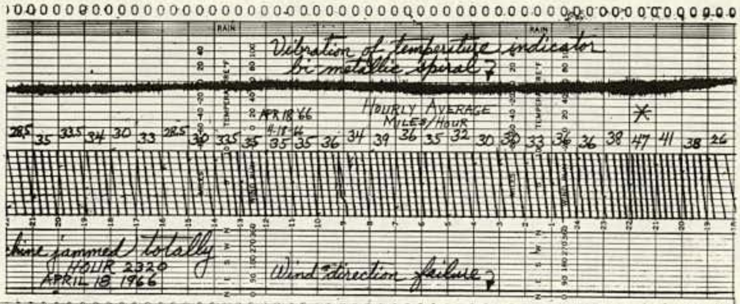
Item	Free Winds 40 Ft Below Bridge	Bridge Winds 9 Ft Above Deck	
		Leeward	Windward
Total range recorded, 6-month hourly average, mph	0 to 52	0 to 47	0 to 49[a]
Ratio of bridge winds to free winds	—[b]	±0.85	±0.95
Maximum hourly average, mph	52	47	49[a]
Highest peak velocity[c], mph	83	75	78
Critical region[d] for vehicles, hourly average, mph		30 to 35	30 to 35

[a]Estimated.

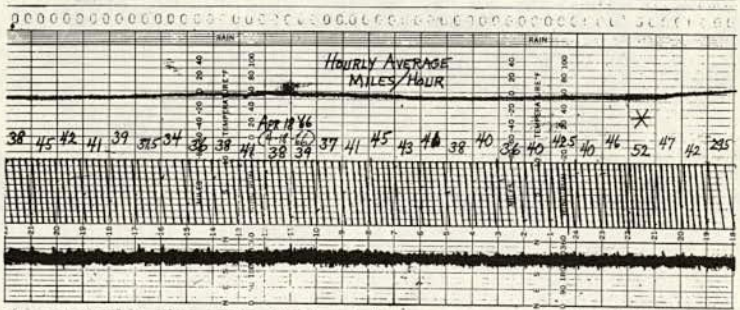
[b]Reference = all winds over 18 mph average.

[c]Estimated by multiplying 1.6 by maximum hourly average.

[d]Hourly average of critical crosswind speed is based on the probability that crosswind gusts in excess of 50 mph will be developed on the bridge.



Bridge winds 9 ft above deck: 21 to 47 mph west winds.



Free winds 40 ft below bridge: 28.5 to 52 mph west winds.

Figure 7. Charts from two measuring locations before installation of wind screen.

behind the wind screen for the full length of the bridge. The south head winds have replaced the damaging west crosswinds as the predominant wind on the bridge. The highest head wind velocity measured over a 6-month period was an hourly average of 23 mph. The crosswind that filters through the screen is completely turned within 1 in. of the screen surface and merges with the head wind. It is estimated that the screen is reducing the crosswind to about 0.35 of the free west wind velocity. A comparison of the south head winds on the bridge after erection of the wind screen and the west free winds is given in Table 2. Figure 8 shows chart samples from the wind-measuring instruments at the two locations after the wind screen installation. Since the wind screen was installed, the head winds have not proved hazardous during a trial period of 24 months. Large vehicles are no longer restricted from traveling the westbound lanes of I-8 because of winds.

PROBE TESTS

Some special probe tests were conducted across the bridge, first with a small wind flag mounted on a long pole and later with a 15-ft pole having alternate short and long

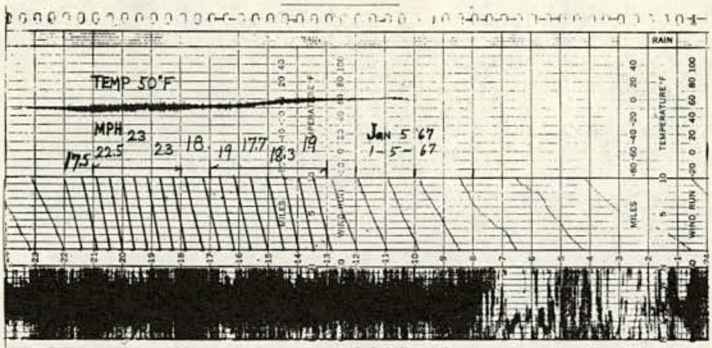
TABLE 2

WEST CROSSWINDS AND SOUTH HEAD WINDS AFTER INSTALLATION OF WIND SCREEN

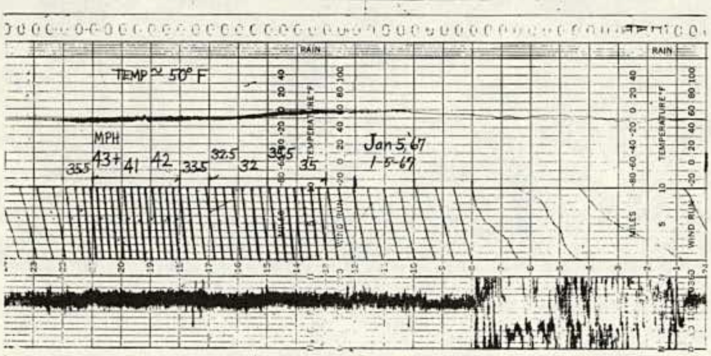
Item	West Crosswinds 40 Ft Below Bridge	South Head Winds 9 Ft Above Deck
Total range recorded, 6-month hourly average, mph	0 to 43.5	0 to 23
Ratio of head winds to free west winds	—[a]	±0.53
Maximum hourly average, mph	43.5	23
Highest peak velocity[b], mph	70	37

[a]Reference = all winds over 18 mph average.

[b]Estimated by multiplying 1.6 by maximum hourly average.



Bridge winds 9 ft above deck: 18 to 23 mph south headwinds.



Free winds 40 ft below bridge: 32 to 43 mph west crosswinds.

Figure 8. Charts from two measuring locations after installation of wind screen.

ribbons spaced 1 ft apart. These tests were helpful in explaining the baffling change in wind direction on the bridge after the screen was installed.

Source of Head Winds

Some of the strong west winds over the entire area find a spillway beyond the south gap of the bridge. The contours of the terrain at this location reduce and deflect the west wind to a half velocity head wind that filters through the south gap and travels north on the bridge (Fig. 9). This head wind was readily turned by the predominant west crosswind on the bridge before the screen was installed, and no evidence of a head wind appeared on the wind instruments mounted near the center of the bridge (Fig. 10). After

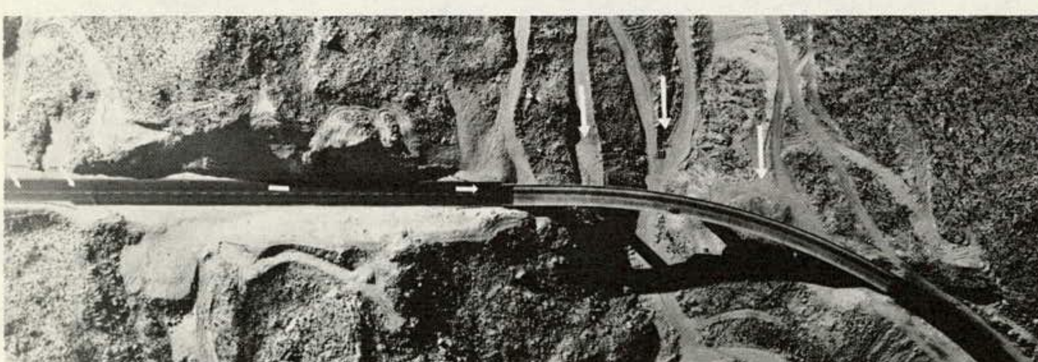


Figure 9. Effect of terrain in reducing and deflecting crosswinds on bridge.

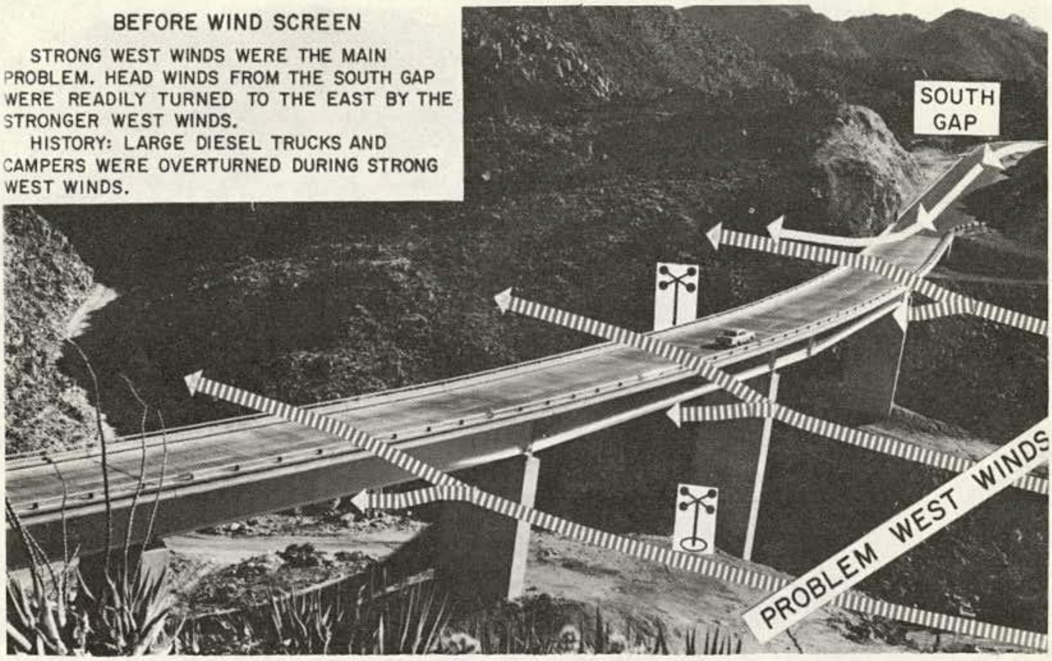


Figure 10. South head winds and west crosswinds on bridge before installation of wind screen.

the screen was installed, the west crosswind was so drastically reduced that the south head wind became the predominant wind measured on the bridge (Fig. 11).

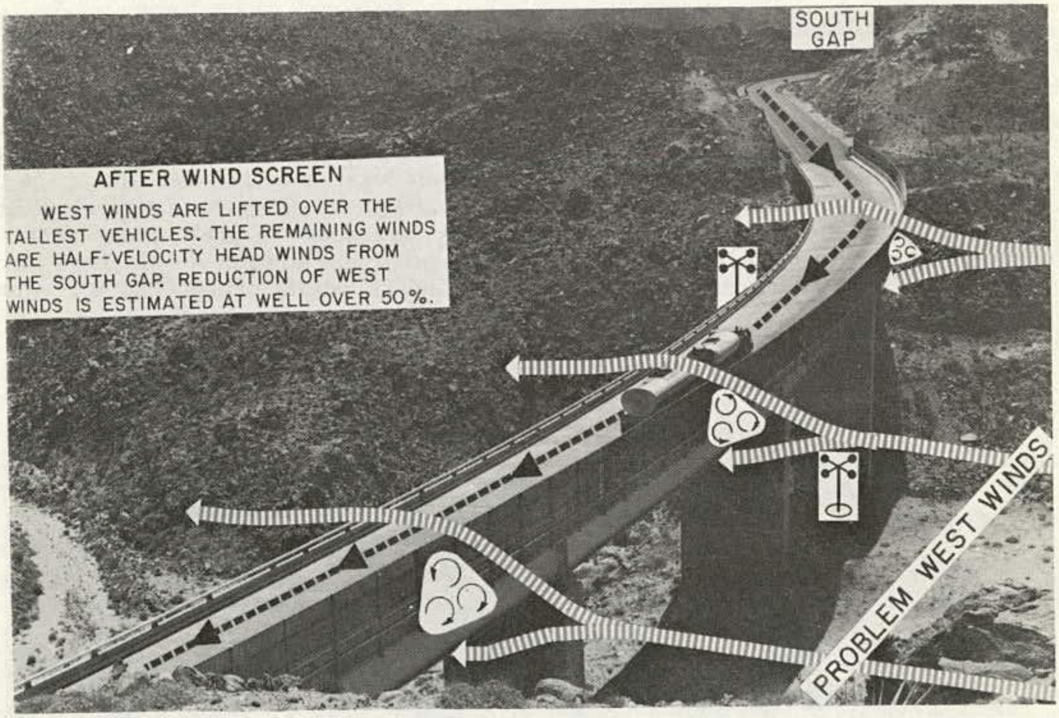


Figure 11. South head winds and west crosswinds on bridge after installation of wind screen.

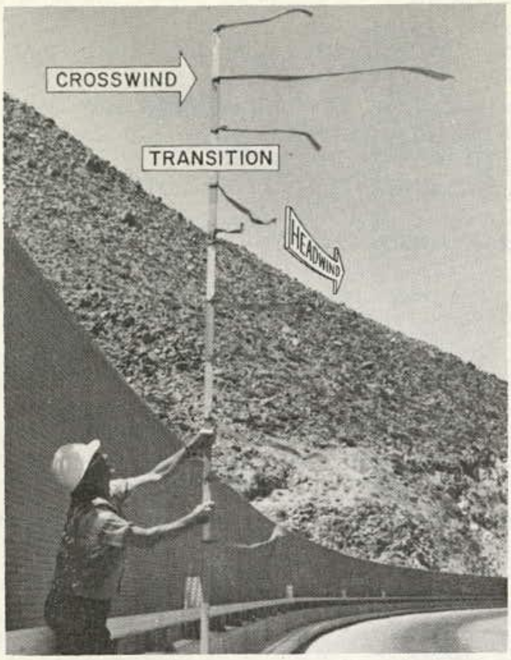


Figure 12. Wind flag used in probe tests to show that west crosswinds are deflected overhead and south head winds remain on bridge.

Lifting of Crosswinds

Wind flag probes were also valuable in disclosing that the crosswinds were lifted because of the turbulence produced on the windward face of the screen. The amount of wind lift varies with the wind speed thus producing a higher zone of protection when it is most needed for tall trucks during strong wind gusts. Typical values of extra wind lift varied from 20 to over 30 percent higher than the wind screen itself during the tests. This extra lift was sustained across the entire 37-ft width of the bridge (Fig. 12). Experience with the low-velocity head winds on the bridge during the 2 years since the wind screen was installed is that they are completely free from side vector and seem to act more as a stabilizing force to prevent the waggle of trailers.

It seems important to observe that some of the most valuable information was disclosed with very simple wind-flag devices used as a supplement to the more sophisticated wind recording instruments.

RECOMMENDATIONS

The accident-reducing possibilities offered by wind screens appear to have more merit than may have been recognized thus far in highway planning. The greatest need usually exists wherever recurrent or persistent crosswinds lead to inadequate driver control or the overturning of vehicles. Some hazardous situations may be difficult to anticipate but others are fairly obvious. These include bridges across mountain ravines, elevated highways that cut straight through undulating topography where protection alternates with exposure, and on long downgrade curves where vehicles first receive tail winds and then turn broadside to the wind forces.

The requirements for a wind screen are fairly broad: a height of about 10 ft with respect to the pavement at its highest point; a dependence on no more than 5 fence heights laterally in the protected zone, at this stage of experience; and a porosity between 20 and 50 percent, at the option of the engineer. The lower percentage values probably give more wind lift but experience more wind loading on the screen.

The slatted chain-link mesh fence seems to be one of the most economical ways of producing the properties desired.

ACKNOWLEDGMENTS

The authors wish to thank H. B. Schutz, Agricultural Engineering Department, University of California, Davis, and Ralph L. Maki, National Aeronautics and Space Administration, Ames Research Center, Moffett Field, California, for valuable suggestions and encouragement during the planning stages of this experiment; and encouragement during the planning stages of this experiment; and Ed Kubichek, John Reeder, William Hartnett, and others at the District 11 Materials Department, California Division of Highways, San Diego, San Diego, for their valuable assistance on field trips and instrument maintenance.

This paper reports on work performed in cooperation with the U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads. The opinions, findings, and conclusions are those of the authors and not necessarily those of the Bureau of Public Roads.

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