

Effect of a Noise Wall on Snow Accumulation and Air Quality

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ABSTRACT

A noise wall was investigated to assess its effect on snow accumulation and air quality. Wind tunnel studies were undertaken to evaluate (a) possible snow accumulations and (b) the dispersion of particulate concentrations (dust, smoke, and lead particles) and carbon monoxide. Full-scale monitoring of particulate concentrations and carbon monoxide was performed both before and after the noise wall was constructed. The wind tunnel experiments for snow accumulation were conducted on a model wall located in a flat, unobstructed area. A separated flow zone existed upwind of the wall and snow immediately began to accumulate over most of the separated zone. Having the noise wall in an aerodynamically rough area, such as in an urban area as this one was, substantially decreased the amount of snow collected, compared with in the wind tunnel studies, because of turbulence reducing the separation zone. The snow accumulation has not been significantly greater with the noise wall in place than it was before construction and has proven to be of no concern to date. Monitoring for particulate concentrations has shown that the noise wall has had a beneficial effect because the amount of material collected was reduced. With the noise wall in place, monitoring for carbon monoxide has indicated that (a) for equivalent emissions under conditions of high atmospheric stability and low wind speeds, the carbon monoxide levels would be lower; and (b) under conditions of low atmospheric stability and high wind speeds, the carbon monoxide levels would be higher than expected without the wall in place.

Iowa's first Type II (retrofit) noise wall has been effective as a traffic noise screen. However, at an initial public information meeting before construction had taken place, some concern was expressed about the effect that the proposed noise wall would have on snow accumulation and air quality (1). An assessment of the effect of the noise wall on snow accumulation and air quality in the vicinity of the wall is given in this paper.

Figure 1 is a map showing the location of the project in relation to the Des Moines metropolitan area. A steel wall was constructed on the east side of the I-235 Freeway on a general north-south alignment between Easton Boulevard and Guthrie Avenue in Des Moines. The wall consists of steel H beams placed at 16-ft intervals with 16-in. by 16-ft corrugated interlocking steel panels attached to the steel beams by self-tapping screws. These steel panels are coated with a polyvinylfluoride film to make the wall corrosion resistant. The wall is 1,055 m long and varies in height 4 to 5 m along the major portion of its length. At its nearest locations, the wall is 1 to 2 m from the shoulder of the highway; therefore, a guardrail is required on the highway side of the wall. The backyards of numerous residences are adjacent to the wall.

Aerodynamics of a Wall

According to aerodynamic theory, air flow near an exposed wall on the downwind side is said to separate and form aerodynamic eddies and cavities that may concentrate airborne material such as snow or pollutants in localized regions, as shown in Figure 2. On the upwind side, a separated zone also exists,

and material will tend to settle in this region. The extent to which separation occurs depends principally on wind speed, wind direction, and turbulence. On the highway side of a wall, moving vehicles create air turbulence, thoroughly mixing pollutants or snow, or both, with flowing air and greatly reducing the separation zones. On the residential side of the wall, buildings, vegetation, and other obstructions to smoothly flowing air create turbulence, again mixing any pollutants or snow, or both, with air flow and reducing the separation zones.

METHODOLOGY: WIND TUNNEL

A wind tunnel is a useful and convenient experimental facility for providing any wind speed and wind direction by rotating a model of the object under investigation within the tunnel. The Iowa Department of Transportation constructed a model wall approximately 6.35 cm high, placed it on a turntable 76 cm in diameter, and installed it in an Iowa State University wind tunnel. Material representing snow or smoke as pollutants was introduced near the model wall to permit visualization of the air flow and the patterns of drifting snow. A schematic of the wind tunnel and model for the experiments is shown in Figure 3.

WIND TUNNEL STUDIES OF THE EFFECT OF A SOLID WALL ON ACCUMULATING SNOW

The model of the wall, as previously described, spanned the entire wind tunnel floor and thus the experiments represented a two-dimensional flow, that

Location of Project

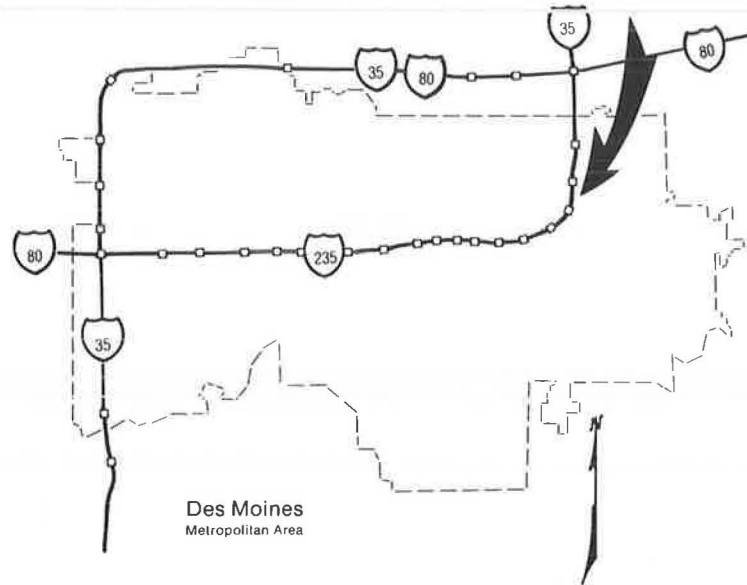


FIGURE 1 Location of the noise wall project.

Horizontal Velocity Profiles

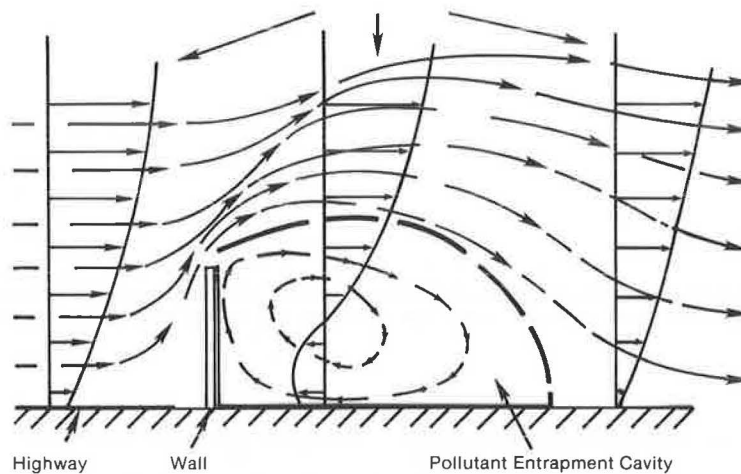


FIGURE 2 Velocity profiles. Note: Upwind of wall, a favorable pressure gradient exists and flow accelerates. Downwind, an adverse pressure gradient exists during deceleration, flow separates at top of wall, flow reverses, and aerodynamic eddies are formed. Size of cavity is dependent on wind speed and wind direction.

is, the results were similar to the snow accumulations resulting from the central portion of a very long wall. The model city was not used for these experiments. The wind direction was normal to the wall and wind speeds for Experiment 1 was 4.9 m/sec and for Experiment 2 was 3.9 m/sec. Full-scale wind speeds would be three times those values and correspond to 33 mph and 24 mph, respectively.

Nearly all of the snow accumulations were deposited on the windward (upwind) side of the wall, which is typical of a tall solid wall without a bottom gap. Eventually, the space to windward will drift full to a windward drift length (normal to wall) of approximately 10 times the wall height and then the leeward (downwind) side will start to col-

lect drifted material, again eventually to a drift length of 10 times the wall height (James D. Iverson, unpublished data, 10/2/79). However, the experiments were not continued long enough to accumulate much leeward drift. Figures 4 and 5 show the timewise accumulation of drift area in plan. A separated flow exists upwind of the wall and immediately material starts to accumulate over most of the separated zone, demonstrated by the sharp increase in plan area for early time in Figure 4. As shown in Figure 4, material accumulates more rapidly for the higher wind speeds.

Figure 5 shows the accumulated upwind drift area as a function of dimensionless time. Note that the data from the two different wind speeds effectively

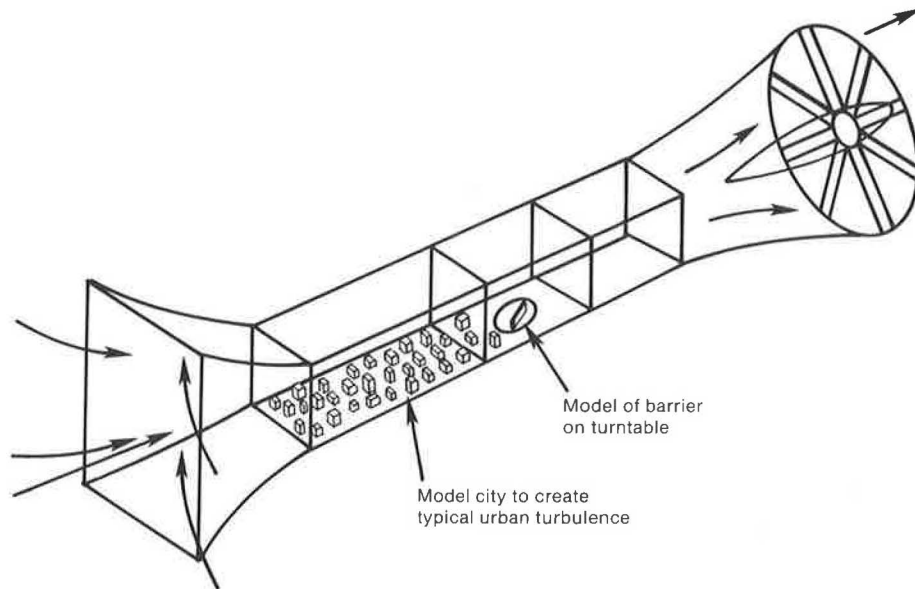


FIGURE 3 Schematic of wind tunnel and model for experiments.

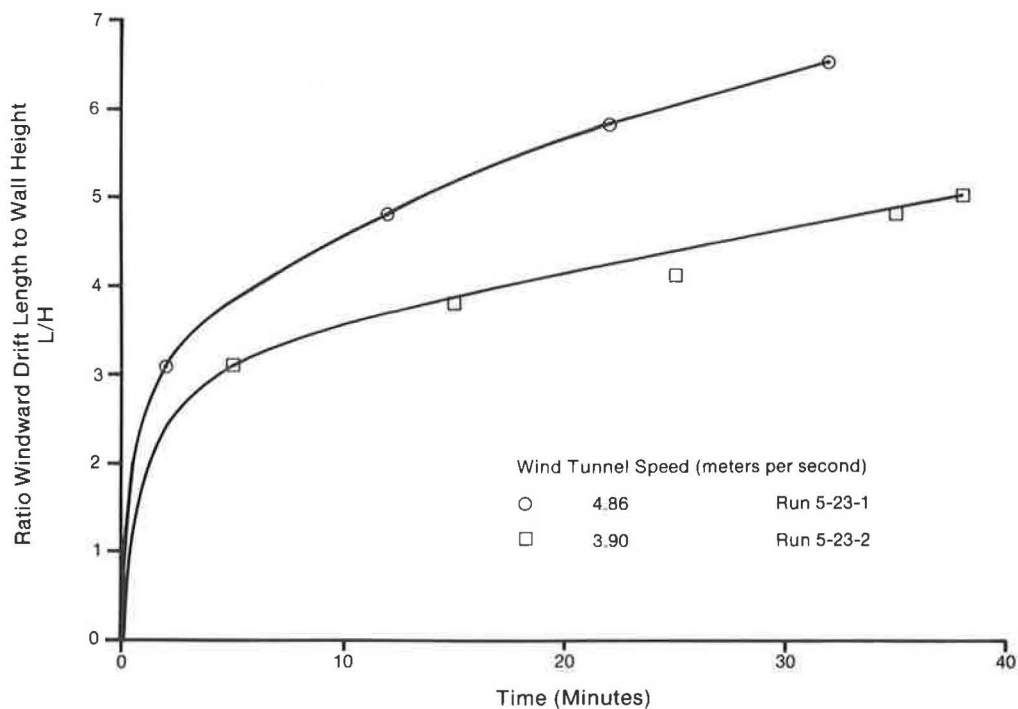


FIGURE 4 Timewise accumulation of drift area in plan.

collapse into one curve. The ratios of full-scale to model time for the two experiments are predicted to be 9.93 for Run 5-23-1 and 10.04 for Run 5-23-2. Thus, Run 5-23-1 corresponds to a full-scale storm with wind speeds of 32 mph lasting 5 hr, 18 min and Run 5-23-2 corresponds to a storm with wind speeds of 24 mph lasting 6 hr, 22 min.

Although the experiments were not continued until equilibrium drift capacity, a significant amount of drifted material was accumulated upwind of the wall, as shown in Figure 6. The experiments correspond to a wall located in a flat unobstructed area. Placing the wall in the middle of an aerodynamically rough area would decrease the amount of material accumulated.

CONCLUSIONS OF THE EFFECT OF A SOLID WALL ON ACCUMULATING SNOW

The wall is located in a relatively flat urban area consisting of many buildings and a significant amount of vegetation, including many trees of substantial size. Snow accumulations have not been a concern in the 4 years since construction of the wall. Apparently, the turbulence created by the aerodynamic roughness of the area and the moving vehicles on the freeway have prevented any substantial drifting, as might be expected from the results obtained from the wind tunnel experiments. A number of snow storms have occurred in the Des Moines area since construction of the wall, although probably not of the in-

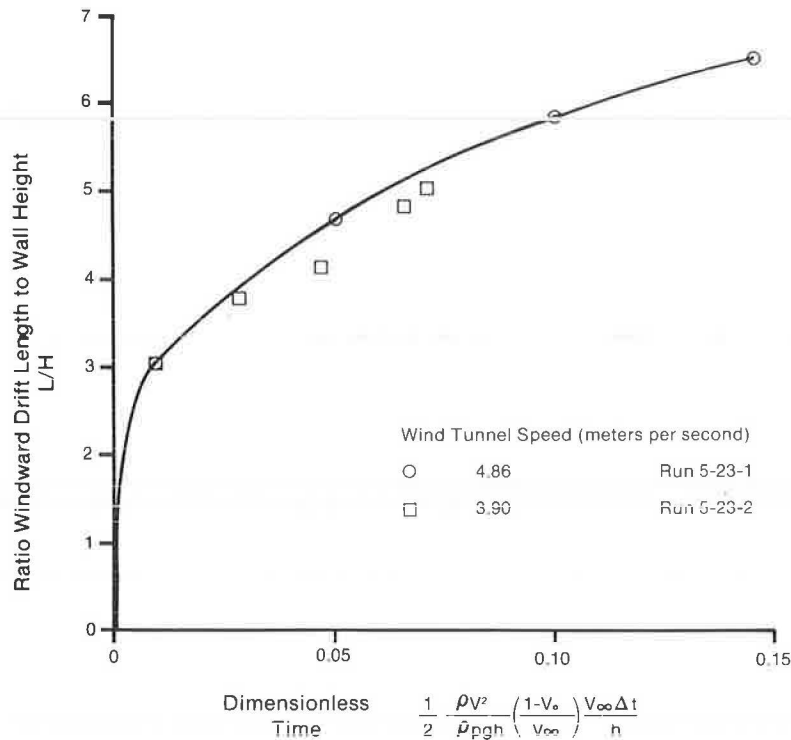


FIGURE 5 Accumulated upwind drift area as a function of dimensionless time.

tensity modeled in the wind tunnel. The wind tunnel results should probably be considered a conservative baseline estimate of what could be possible under extreme conditions.

WIND TUNNEL STUDIES OF THE EFFECT OF A SOLID WALL ON AIR QUALITY

The model of the wall was placed in the wind tunnel, as shown in Figure 3. Smoke was introduced into the tunnel near the model to permit visualization of the flow; qualitative testing was then performed at various speeds and wind directions. (Models of buildings were located within the tunnel upwind of the wall to create turbulence that is found in a typical urban situation.) A number of photographs were taken; examples are shown in Figures 7-10. In general, the flow patterns as depicted in Figure 2 were confirmed, that is, aerodynamic eddies or vortices and cavities are present downwind of a wall under certain conditions; therefore, entrapment and concentration of pollutants near walls are a distinct possibility, especially for certain wind speeds and wind directions.

AIR-QUALITY MONITORING

Because the wind tunnel studies indicated a possibility of increased air pollutant concentrations when the wall was in place and because of the concern brought out at the initial public information meeting that the wall would have an adverse effect on general air movements and dispersion of exhaust emissions from the I-235 Freeway, a small-scale research project was proposed to monitor the air quality before and after construction and to evaluate the results.

The primary air pollutants from the internal combustion engine are carbon monoxide, hydrocarbons,

oxide of nitrogen, lead, and other particulates--primarily dust and smoke. A steady stream of moving vehicles on a highway constitute a line source of these pollutants. The air turbulence created by the moving vehicles thoroughly mixes the pollutants with air. The region where this occurs is called the mixing cell, the limits of which are defined and confirmed by studies to be approximately twice the height of the average vehicle in the vehicle mix (approximately 4 m), the width of the highway, including medians up to 9 m wide, and 3 m on each side of the highway to account for horizontal turbulence; the ambient pollutant level is excluded. The uniform well-mixed pollutant source contained in the mixing cell is then dispersed downwind. This definition of the mixing cell is shown in Figure 11 for a typical carbon monoxide concentration level pattern.

Monitoring for carbon monoxide entailed the use of four portable carbon monoxide monitors calibrated using the Des Moines nondispersive infrared monitoring unit. A meteorological bivan was used for wind speed and wind direction. Strip-chart recording instruments were interfaced with the monitors and a climate-controlled trailer was used to house the instrumentation.

Preconstruction monitoring for carbon monoxide began on July 1, 1979. The climate-controlled trailer was positioned near the midpoint of the proposed noise wall location. The intakes, connected to the monitoring units with polyvinyl tubing, were located at the right-of-way fence--the proposed location of the wall--and at distances of 5, 15, and 23 m from the fence at a height of 2 m.

In addition to carbon monoxide dispersion, particulate (dust, smoke, and lead particles) concentrations arising from the freeway were also of concern in relation to the effects of the noise wall. This type of pollutant was measured by two high-volume samplers, an instrument that draws a 24-hr sample of known volume through a filter of predetermined weight. The amount of particulates retained on this

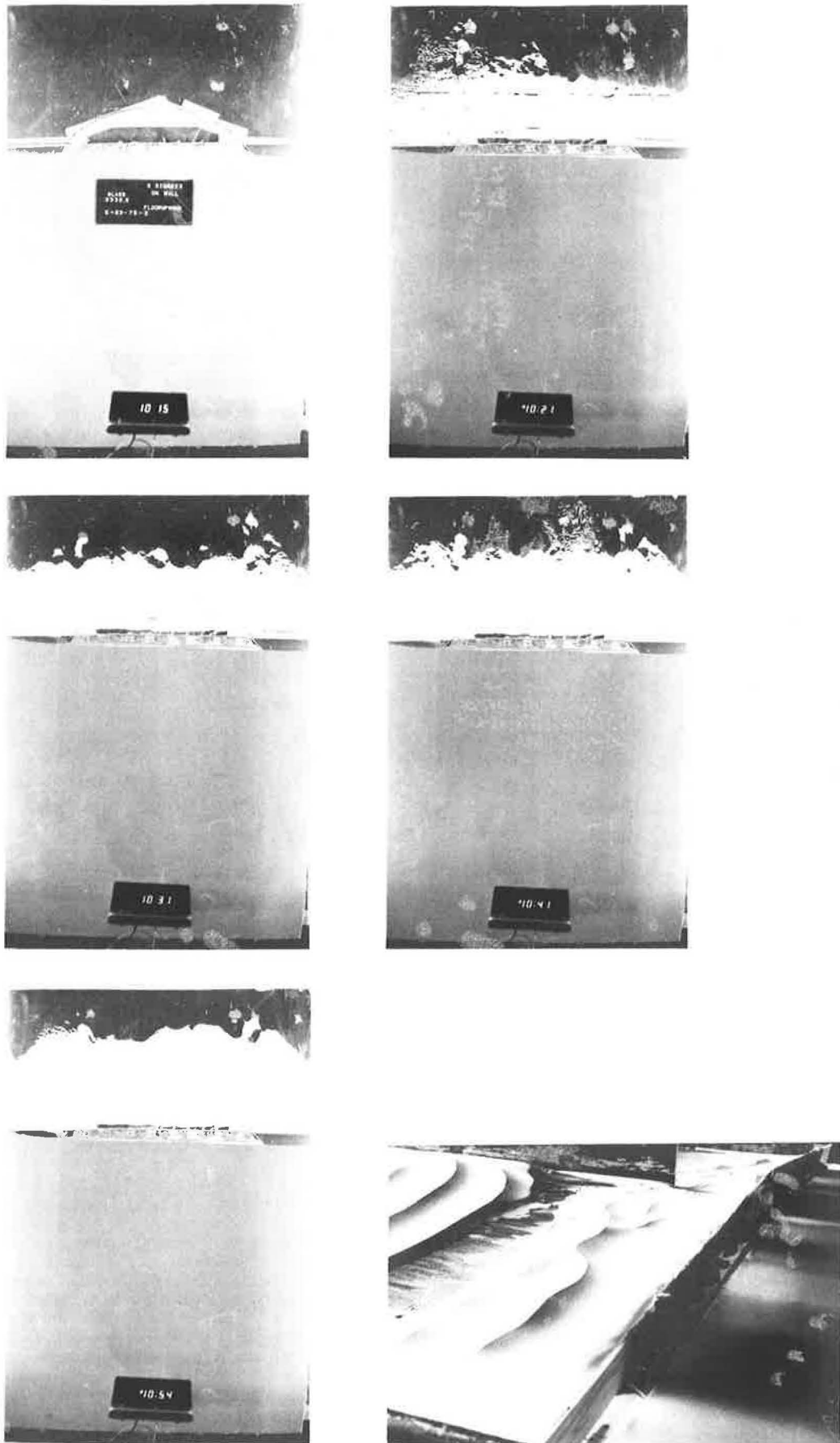


FIGURE 6 Significant amount of drifted material accumulated upwind of wall.

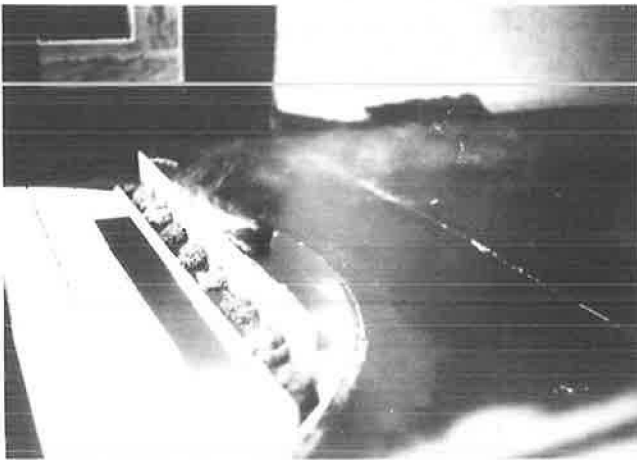


FIGURE 7 Plate No. 1: General view of model wall on turntable. Note: Shrubbery can be seen in front (upwind) of wall and flow is 90 degrees with respect to wall. Black strips in front of and behind wall were placed on turntable to enhance flow visualization after it was found that it was difficult to see smoke over the white turntable.

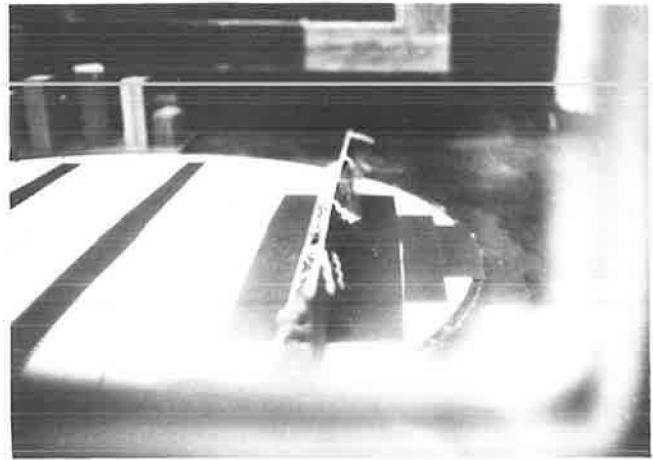


FIGURE 9 Plate No. 3: General view of model wall, showing tufts of yarn attached to top of wall with tape to further enhance flow visualization. Note: Part of model city can be seen in the upper left corner.



FIGURE 8 Plate No. 2: View of model wall and turntable from top viewing window. Note: Flow is from lower right corner to upper left corner and is approximately 45 degrees with respect to wall. Blocks in lower right corner are part of model city. A side viewing window can be seen in the upper right.



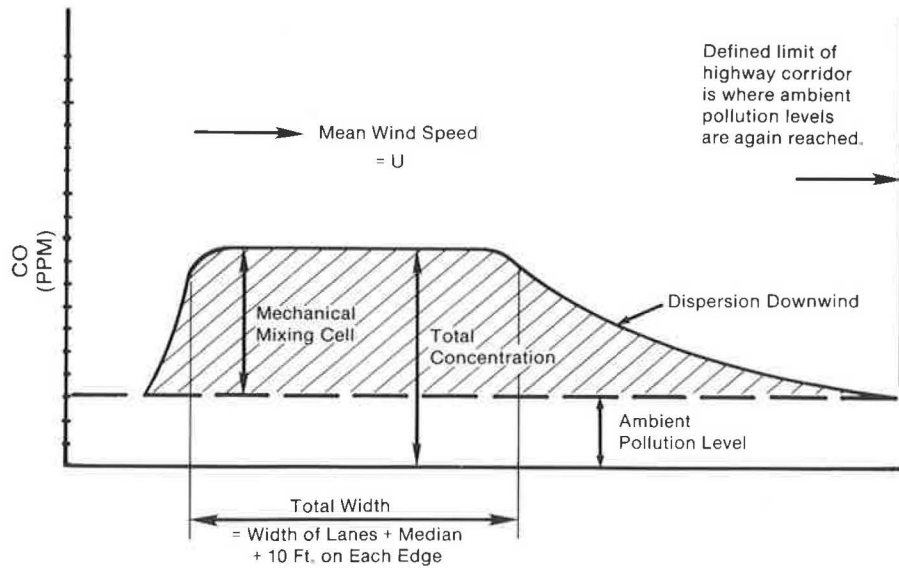
FIGURE 10 Plate No. 4: General view of model wall showing pollutant entrapment cavity. Note: Flow is left to right at approximately 45 degrees with respect to wall. Pollutant entrapment cavity can be seen as a white cloud near center of photograph and just downwind of wall. Random motion, vortices, aerodynamic eddies, and flow reversal are indicated by the wisps of smoke in cavity. Above and downwind of cavity, smoke (seen as less dense than in cavity) is moving uniformly.

filter was converted to the concentration per cubic meter of air. One sampler was located 5 m from the right-of-way fence and a second one 15 m from the right-of-way fence.

The meteorological bivane to measure wind speed and wind direction was calibrated and interfaced with a strip chart recorder for continuous monitoring. Hourly meteorological data for the monitoring period were also obtained from the National Weather Service located at the Des Moines Municipal Airport. This latter information was to be used as a check on the study-site wind data and a backup source for these data if the study-site data instrumentation failed. These data were used to determine the degree of correlation between the measured traffic-related pollutant levels and the wind parameters at the study site. Traffic data were obtained for I-235 during the monitoring period.

The monitoring units were in continuous operation from July 1 to October 1, 1979. Construction of the noise wall began in May 1980 and was completed in July 1980. Air quality monitoring was resumed in July 1980 and continued through September with the noise wall in place. Intakes for the carbon monoxide monitoring system were located on the highway side of the noise wall and at distances of 5, 15, and 23 m from the residential side of the wall at a height of 2 m, similar to the preconstruction layout. Meteorological instrumentation was again put in service, and a new series of particulate samples was integrated with the national total suspended particulate (TSP) monitoring schedules.

It soon became apparent that both the 15-m carbon monoxide monitor and the 23-m monitor were measuring identical and very low concentrations. Consequently, the 15-m intake was eliminated and the 23-m unit



Note: Total concentration = ambient level plus pollutants from the highway line sources.

FIGURE 11 Typical pattern of carbon monoxide concentration level.

continued to measure what were considered background carbon monoxide levels for the study area. Traffic data for I-235 and hourly meteorological data for the monitoring period were obtained from the National Weather Service as they were for the preconstruction period.

STATISTICAL ANALYSIS OF AIR-QUALITY DATA

Table 1 gives the TSP monitoring data for the preconstruction and postconstruction study periods. As shown, the mean TSP at 5 m from the wall was found to be 82 micrograms/m³ before construction and 79 micrograms/m³ after construction, which is not a significant difference. However, at 15 m from the wall the mean TSP was 78 micrograms/m³ before construction and 65 micrograms/m³ after construction. A statistical analysis of the data indicates a significant difference for the ratios of the 5-m values over the 15-m values for TSP before construction and after construction. The average ratio of the 5-m values over the 15-m values for the 1979 preconstruction monitoring period was found to be 1.07, and the average ratio of the 5-m values over the 15-m values for 1980 (or the postconstruction period) was found to be 1.22. Thus, the difference in the average ratios for the two years is 0.15. At the 95 percent confidence level, the range is 0.13, and the upper-level difference is 0.28 and the lower-level difference is 0.02. This implies a beneficial effect of the wall in retarding the dispersion of particulates from the highway to the east-side residential area. The monitor farthest from the wall, the high-volume sampler 15 m from the wall and nearest the residences, shows a somewhat lower seasonal average concentration with the wall in place. The indications are that a portion of the transportation-related particulate matter from the I-235 Freeway quickly settles near the residential side of the wall, its further transport being limited to a degree by the effect of the wall on air movements.

A summary of the observations for carbon monoxide by wind direction is given in Tables 2-5. A statistical matrix is given for 1979 and Monitor 2, the monitor 5 m from the right-of-way fence or the wall (Table 2); for 1979 and Monitor 4, the monitor 23 m

from the right-of-way fence or the wall (Table 3); for 1980 and Monitor 2 (Table 4); and for 1980 and Monitor 4 (Table 5). The frequency and the overall percent of the specific occurrence for wind direction and a given carbon monoxide range of values are given. The intake for Monitor 1, located at the right-of-way fence in 1979 and at the top of the wall on the highway side in 1980, does not provide useful information for comparison because of the

TABLE 1 TSP Monitoring Data for Preconstruction and Postconstruction Study Periods

Date Collected	TSP Concentration (micrograms/m ³)	
	5 m from Right-of-Way/Wall	15 m from Right-of-Way/Wall
07-08-79	76	77
07-14-79	59	49
07-20-79	118	121
07-26-79	87	85
08-01-79	69	67
08-07-79	113	102
08-13-79	102	67
08-19-79	42	51
08-23-79	92	70
08-25-79	65	63
08-31-79	68	68
09-06-79	79	66
09-12-79	83	94
09-18-79	128	124
09-24-79	68	72
09-30-79	87	91
10-04-79	67	57
(Wall constructed June 1980)	Mean = 82	Mean = 78
07-26-80	44	35
08-01-80	76	67
08-07-80	80	67
08-13-80	59	51
08-19-80	76	62
08-25-80	96	83
08-31-80	29	26
09-06-80	68	57
09-12-80	96	71
09-18-80	99	57
09-24-80	89	71
09-30-80	76	85
10-06-80	135	112
10-12-80	85	72
	Mean = 79	Mean = 65

TABLE 2 Average Carbon Monoxide at Monitor 2 (ppm) and Average Wind Direction per Hour

Avg at Monitor 2	Wind Direction			Total ^a
	East	West	Calm	
0 to 1 ppm				
Frequency	892	360	146	1,398
Percent	32.98	13.31	5.40	51.68
Row percent	63.81	25.75	10.44	
Column percent	57.03	43.01	48.03	
2 ppm				
Frequency	568	381	106	1,055
Percent	21.00	14.09	3.92	39.00
Row percent	53.84	36.11	10.05	
Column percent	36.32	45.52	34.87	
3 ppm				
Frequency	89	87	40	216
Percent	3.29	3.22	1.48	7.99
Row percent	41.20	40.28	18.52	
Column percent	5.69	10.39	13.16	
4 to 5 ppm				
Frequency	15	9	12	36
Percent	0.55	0.33	0.44	1.33
Row percent	41.67	25.00	33.33	
Column percent	0.96	1.08	3.95	
Total ^a				
Frequency	1,564	837	304	2,705
Percent	57.82	30.94	11.24	100.00

Note: 1979 data.

^aSome totals off by 0.01 due to rounding.**TABLE 3 Average Carbon Monoxide at Monitor 4 (ppm) and Average Wind Direction per Hour**

Avg at Monitor 4	Wind Direction			Total ^a
	East	West	Calm	
0 to 1 ppm				
Frequency	1,308	620	201	2,129
Percent	48.70	23.08	7.48	79.26
Row percent	61.44	29.12	9.44	
Column percent	84.50	74.34	66.12	
2 ppm				
Frequency	214	195	73	482
Percent	7.97	7.26	2.72	17.94
Row percent	44.40	40.46	15.15	
Column percent	13.82	23.38	24.01	
3 ppm				
Frequency	20	16	28	64
Percent	0.74	0.60	1.04	2.38
Row percent	31.25	25.00	43.75	
Column percent	1.29	1.92	9.21	
4 to 5 ppm				
Frequency	6	3	2	11
Percent	0.22	0.11	0.07	0.41
Row percent	54.55	27.27	18.18	
Column percent	0.39	0.36	0.66	
Total ^a				
Frequency	1,548	834	304	2,686
Percent	57.63	31.05	11.32	100.00

Note: 1979 data.

^aSome totals off by 0.01 due to rounding.

change in position of the intake. Therefore, Monitor 2 information, where the intake is located 5 m from the wall or 5 m from the right-of-way fence in the preconstruction phase, is the one chosen for the comparison study. Also, the intakes of the monitors are downwind from the I-235 Freeway only for west winds. Therefore, only west winds are considered in the following analyses.

In comparing 1979 and 1980 data for Monitor 2 (Tables 2 and 4) for west winds, it can be seen that the percentages tend to be lower for the lower carbon monoxide ranges in 1979 compared with those in 1980,

TABLE 4 Average Carbon Monoxide at Monitor 2 (ppm) and Average Wind Direction per Hour

Avg at Monitor 2	Wind Direction			Total ^a
	East	West	Calm	
0 to 1 ppm				
Frequency	822	198	36	1,056
Percent	50.96	12.28	2.23	65.47
Row percent	77.84	18.75	3.41	
Column percent	71.92	52.38	39.13	
2 ppm				
Frequency	237	133	24	394
Percent	14.69	8.25	1.49	24.43
Row percent	60.15	33.76	6.09	
Column percent	20.73	35.19	26.09	
3 ppm				
Frequency	70	35	12	117
Percent	4.34	2.17	0.74	7.25
Row percent	59.83	29.91	10.26	
Column percent	6.12	9.26	13.04	
4 to 5 ppm				
Frequency	13	7	15	35
Percent	0.81	0.43	0.93	2.17
Row percent	37.14	20.00	42.86	
Column percent	1.14	1.85	16.30	
>6 ppm				
Frequency	1	5	5	11
Percent	0.06	0.31	0.31	0.68
Row percent	9.09	45.45	45.45	
Column percent	0.09	1.32	5.43	
Total ^a				
Frequency	1,143	378	92	1,613
Percent	70.86	23.43	5.70	100.00

Note: 1980 data.

^aSome totals off by 0.01 due to rounding.**TABLE 5 Average Carbon Monoxide at Monitor 4 (ppm) and Average Wind Direction per Hour**

Avg at Monitor 4	Wind Direction			Total ^a
	East	West	Calm	
0 to 1 ppm				
Frequency	995	329	54	1,378
Percent	61.69	20.40	3.35	85.43
Row percent	72.21	23.88	3.92	
Column percent	87.05	87.04	58.70	
2 ppm				
Frequency	123	23	22	168
Percent	7.63	1.43	1.36	10.42
Row percent	73.21	13.69	13.10	
Column percent	10.76	6.08	23.91	
3 ppm				
Frequency	18	8	12	38
Percent	1.12	0.50	0.74	2.36
Row percent	47.37	21.05	31.58	
Column percent	1.57	2.12	13.04	
4 to 5 ppm				
Frequency	7	13	4	24
Percent	0.43	0.81	0.25	1.49
Row percent	29.17	54.17	16.67	
Column percent	0.61	3.44	4.35	
>6 ppm				
Frequency	0	5	0	5
Percent	0.00	0.31	0.00	0.31
Row percent	0.00	100.00	0.00	
Column percent	0.00	1.32	0.00	
Total ^a				
Frequency	1,143	378	92	1,613
Percent	70.86	23.43	5.70	100.00

Note: 1980 data.

^aSome totals off by 0.01 due to rounding.

and higher for the higher carbon monoxide ranges. For example, in 1979 43.01 percent of the west winds are in the 0 to 1 parts per million (ppm) range, and in 1980 52.38 percent of the west winds are in the 0 to 1 ppm range. However, in 1979 45.52 percent of the west winds are in the 2 ppm range, whereas in

1980 only 35.19 percent of the west winds are in the 2 ppm range. This tends to indicate that the wall may have a beneficial effect and may lower the carbon monoxide levels. Monitor 4 levels (Tables 3 and 5) are all somewhat lower than Monitor 2 levels, which is to be expected. Also, east winds for both monitors in both years tend to result in higher percentages for the lower carbon monoxide levels, which again is to be expected.

Data collected from the National Weather Service and data from the meteorological bivane were used to calculate the stability class for each hour of carbon monoxide levels obtained from Monitor 2, and the data on wind speed and wind direction obtained from the meteorological bivane were combined with the determined stability class in a statistical analysis. It was assumed that the following is true:

$$CO = \text{function } (T, E.F., U\sin\phi, S.C.)$$

where

- CO = carbon monoxide (ppm),
- T = traffic (vehicles/hr),
- E.F. = emission factor (g/vehicle-mile),
- ϕ = angle (degrees between wind direction and highway alignment),
- $U\sin\phi$ = crosswind speed (mph), and
- S.C. = stability class.

The emission factors for 1979 and 1980 were computed; by using the data obtained from this study, the following were obtained for west winds only. For the preconstruction year of 1979,

$$CO = 1.03 + .000015(E.F.)(T)(U\sin\phi)^{.033} S.C.^{.174} \quad (1)$$

and for the postconstruction year of 1980,

$$CO = 1.14 + .0000297(E.F.)(T)(U\sin\phi)^{.67}/S.C.^{.99} \quad (2)$$

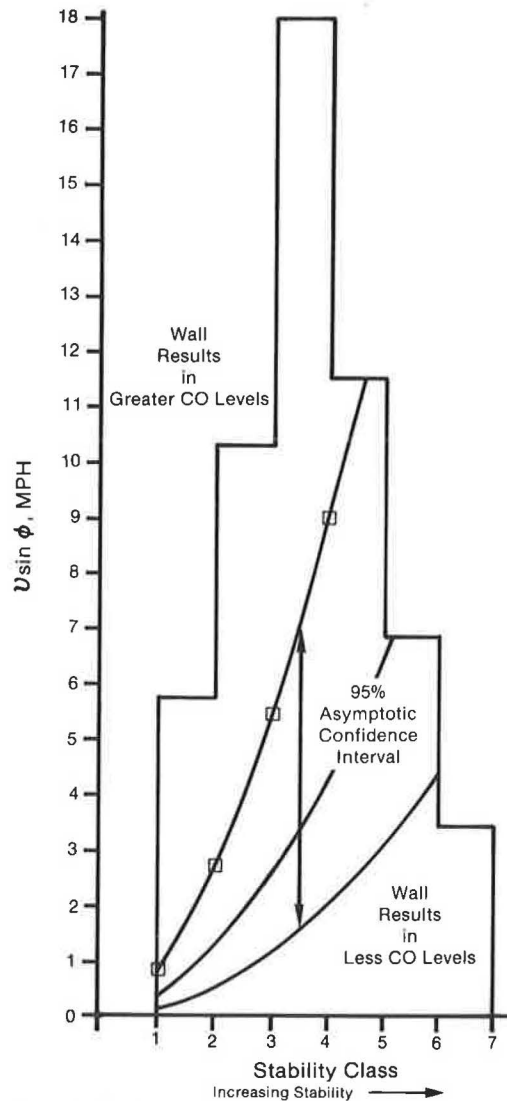
It is observed that in 1979 carbon monoxide levels were largely dependent on emission factors and traffic. In 1980, with the wall in place, carbon monoxide levels were significantly affected by stability class and the crosswind speed as well. It is interesting to note that the lower the wind speed and the higher the stability class (more stable conditions), the lower are the carbon monoxide levels. This is contrary to the usual carbon monoxide line source models, which suggests that for low wind speeds and stable meteorological conditions, the wall contains the mixing cell on the highway side. With higher wind speeds and unstable conditions, the wall is not as effective in containing the pollutants on the highway side.

Assuming the first term in each of the equations is a background of ambient carbon monoxide level and equating the second terms, the intersections of the 1979 and 1980 carbon monoxide level plots can be found for a given stability class or a given $U\sin\phi$. For comparison, equivalent emissions are assumed for 1979 and 1980, making the product of E.F. and T for 1979 equal to the product of E.F. and T for 1980, and the effect of only the wall is thus obtained. The result of the intersections can then be plotted as shown in Figure 12.

CONCLUSIONS OF THE EFFECT OF A SOLID WALL ON AIR QUALITY

The total suspended particulate monitoring data has suggested that the wall has had a beneficial effect in retarding the transportation-related particulate matter from the I-235 Freeway. The extent to which this may occur cannot be quantified for a solid wall in general. The statistical sample was small, and it was not possible to correlate pertinent meteorological data on a continuous basis. Nevertheless, sufficient data is available for a qualitative assessment, and it appears that a benefit is realized from presence of a wall.

Figure 12, developed from the carbon monoxide monitoring data, clearly indicates that as the atmospheric stability is increased or the crosswind speed is reduced beyond a certain level for west winds and equivalent emissions, or both, the carbon monoxide levels are lower when the noise wall is in place. This would indicate that the wall is contain-



Note: Critical crosswind components versus stability class of CO levels obtained at Monitor 2; west winds; equivalent emissions.

FIGURE 12 Effect of noise wall on air quality.

ing the mixing cell on the highway side under the conditions of low wind speed and high atmospheric stability. Conversely, as the atmospheric stability is decreased or the crosswind speed is increased beyond a certain level for west winds and equivalent emissions, or both, the carbon monoxide levels are higher when the noise wall is in place. This suggests that a higher-than-expected concentration of carbon monoxide is occurring near the wall because of aerodynamic entrapment.

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Publication of this paper sponsored by Committee on Transportation and Air Quality.

Caltrans Experiences with Earthborne Vibration

MAS HATANO and RUDOLF W. HENDRIKS

ABSTRACT

An overview of vibration investigations performed by the California Department of Transportation since 1958 is presented. These investigations involved measurement of earthborne vibrations induced by highway vehicles, construction equipment, and train passbys. All of the investigations indicated vibration levels below the criterion established for architectural damage (plaster cracking). However, pile driving and pavement breaking were potential problems and monitoring was suggested for these situations. Two case studies are also presented, one on a train passing near a machine shop and a second on a new free-way alignment near a manufacturing plant.

Since 1958, the California Department of Transportation (Caltrans) has conducted more than 40 investigations of earthborne vibrations induced by construction equipment, highway vehicles, and train passbys. All of these investigations were performed because of complaints or concerns about adverse impacts on activities inside buildings or damage to buildings. Earthborne vibrations are caused by construction activities from pile driving, pavement breaking, and moving construction equipment. Vibrations generated by highway truck traffic become a problem when the pavement is rough (potholes) or because of stepped joints. Train passbys also create earthborne vibrations.

Presented in this paper are some of the fundamentals of earthborne vibrations, guidelines for assessing their impact, Caltrans experiences over 26 years, and some case histories.

FUNDAMENTALS OF EARTHBORNE VIBRATIONS

Earthborne vibrations are mainly from P-waves (compression), S-waves (shear), and Raleigh waves (surface). The Raleigh waves are generally the problem and are used by Caltrans in its studies.

Peak particle velocity within the range of normal earthborne vibrations correlates best with architectural damage and intrusion, whereas acceleration and displacement do not. Therefore, the peak particle

velocity (in in./sec) is used as the descriptor for Caltrans studies. Particle velocity is further defined to mean the vertical velocity at which the soil particles or other materials vibrate locally as opposed to the propagation velocity of vibrations. The latter is the speed at which vibrations travel through the ground away from the source.

GUIDELINES FOR ASSESSING IMPACT OF EARTHBORNE VIBRATIONS

No single standard exists for assessing the level at which earthborne vibrations will cause annoyance to people, cause architectural damage (plaster cracking), or be disruptive to precision operations. However, Table 1 shows guideline velocities (in in./sec) from various sources. Caltrans uses the guidelines established by Whiffin and Leonard of the Road Research Laboratory in England (1).

Instrumentation

The following instruments were used to collect vibration data:

- 4 seismometers (Kinometrics Ranger SS-1)
- 1 signal conditioner (Kinometrics SC-1)
- 1 graphic level recorder (Clevite Brush 16-2300-00), oscillograph