

Tunnel Portal Noise

JIM O'CONNOR

ABSTRACT

In this paper the method, analysis, and results are presented of a study to determine the traffic noise field near and surrounding a highway tunnel portal. The purpose of the study was to determine how the increase in noise due to reverberations in a tunnel affects noise levels immediately outside a tunnel. An array of sound-level meters measured the traffic noise simultaneously at various locations near a tunnel portal. The results are given in terms of the statistical noise descriptors L_{10} , L_{50} , and L_{90} . Graphic plots of distance from the tunnel portal versus decibel level are presented. Measurements were taken on top and in front of the tunnel portal. The results indicate that for measurement sites on top of the tunnel, the drop-off in sound level is very abrupt and at 30 to 40 ft (9 to 12 m) behind the portal the traffic noise has diminished to the ambient noise levels of the surrounding area. For sites in front of the tunnel portal, the drop-off rate is less abrupt than that for the sites on top but still rapid and reaches normal free-field traffic noise levels at 60 to 70 ft (18 to 21 m) from the portal.

The Minnesota Department of Transportation (Mn/DOT) is constructing several short tunnels on I-35 in the city of Duluth. On top of the longest tunnel near the west portal, a scenic overlook to Lake Superior is planned. The Mn/DOT landscape architects wanted to know the width of landscaping required to prevent visitors from getting too close to the tunnel portal where they would be exposed to excessive traffic noise. The proposed overlook is shown in Figure 1.

The Mn/DOT Noise Unit studied the traffic noise near and surrounding an existing tunnel portal in the metropolitan area of St. Paul and Minneapolis. Two essential points were of interest. The first is concerned with the noise immediately above the tunnel. What is the sound level from a given volume of vehicles, and how does it vary with distance from the entrance? The second is concerned with the noise directly in front of the tunnel. How far down the highway does the tunnel noise affect the noise levels outside the tunnel and how do these noise levels vary with distance?

The tunnel selected for this experiment is shown in Figures 2 and 3 and is located on Trunk Highway 5 in St. Paul near Fort Snelling, a restored historical site. It is approximately 300 ft (91 m) long, 68 ft (21 m) wide, and 16 ft (5 m) high. It is of the single-barrel design and lined with tile.

MEASUREMENT METHODOLOGY

The basic approach to this study was to collect and evaluate traffic noise at a site where a well-traveled highway enters a tunnel. The highway passing through the tunnel used in this study has an average annual daily traffic of 45,000 vehicles. Twelve noise-measuring sites were chosen around the tunnel entrance, six on top of the tunnel and six in front of the tunnel at traffic elevation. The locations are shown in Figure 4. The field instrumentation for this study consisted of Bruel and Kjaer (B & K) 2209 and 2004 sound-level meters with 1/2-in.

condenser pressure-type microphones and windscreens. The data were gathered with the method described in an FHWA report, Sound Procedures for Measuring Highway Noise (SPMHN) (1). The height of each microphone was 5 ft (1.5 m) above ground for both the top and front tunnel locations (see Figure 5). The microphones in front of the tunnel were located 23 ft (7 m) away and perpendicular to the median of the traffic at 7, 20, 32, 57, 107, and 160 ft (2, 6, 10, 17, 33, and 49 m) north of the north tunnel portal. The microphones on top were 7 ft (2 m) north and 2, 10, 15, 20, and 70 ft (0.6, 3, 4.5, 6, and 21 m) south of the north tunnel portal. Sites 1A, 6, and 7 were measured on a different day than the other sites. Experience has shown that when the distance between source and receiver is less than 50 ft (15 m), changes in meteorological conditions will not affect the overall trend in the measurement results. The 2 days used for the measurement period were both similar in meteorological and traffic conditions. The highway approaching and leaving the tunnel has no significant grade or curve.

DATA ANALYSIS

The measured noise values were determined in the form of statistical descriptors. Of particular interest were L_{10} , L_{50} , and L_{90} . The 95 percent confidence limits were determined as described in SPMHN (1). The values are presented in Table 1. The column labeled Corrected L_{10} in Table 1 represents the middle value within the interval of the confidence limits. Graphic plots were made of decibel level versus distance from the tunnel portal.

RESULTS

The graphic plots shown in Figure 6 indicated that the sites on top of the tunnel (i.e., Sites 1, 2, 3, and 4) have a very abrupt drop-off rate in noise level. Increased noise at the tunnel portal due to reverberation within the tunnel for these sites is insignificant beyond 30 to 40 ft (9 to 12 m). Figure 6 also shows that the sites in front of the tunnel

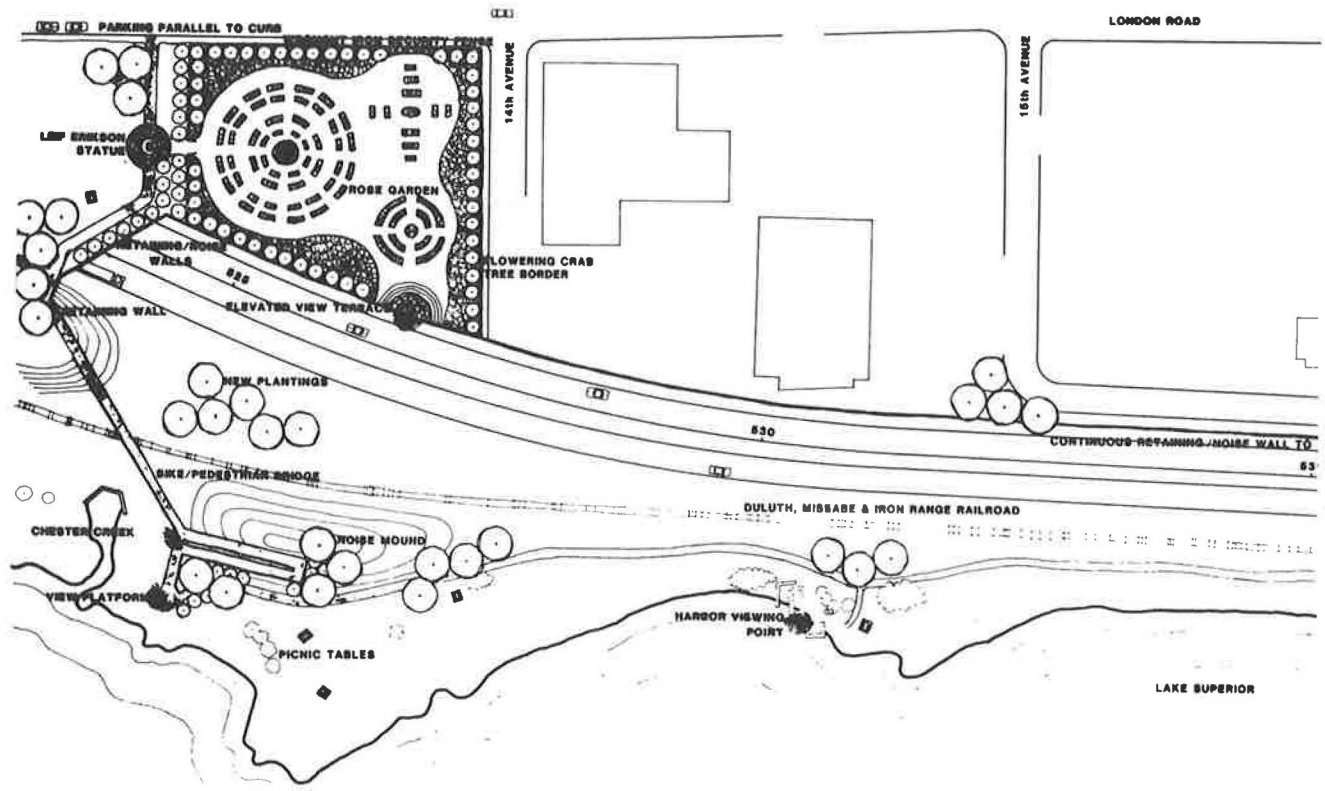


FIGURE 1 Proposed scenic overlook.



FIGURE 2 Test tunnel, view 1.



FIGURE 3 Test tunnel, view 2.

(i.e., Sites 5, 6, 7, 8, 9, and 10) have a drop-off in noise level less abrupt than that of the sites on top of the tunnel, but still rapid. Increased noise at the tunnel portal due to reverberation within the tunnel for these sites is insignificant beyond 60 to 70 ft (18 to 21 m). The noise levels and site descriptions are given in Table 1. For measurement sites in front of the tunnel, the variability of the traffic noise increases with distance from the portal. For the sites on top of the tunnel, the variability of the traffic noise decreases with distance from the portal. This is indicated by observing the values in the column labeled L_{10} - L_{50} in Table 1. Table 1 also indicates that Site 5 is under the influence of the tunnel noise reverberation. Sites 9 and 10 are beyond the effects of the tunnel noise reverberation. The difference in L_{10} between Sites 5 and 9 is approximately 7 dBA. The tunnel noise reverberation increases traffic noise by 7 dBA. By observing the L_{90} -values in Table 1, it can be seen that at Site 5 the level is above 83 dB 90 percent of the time. At Site 10 it is above 74 dB 90 percent of the time.

CONCLUSION

The increase in noise at a tunnel portal due to reverberation within the tunnel decreases rapidly for receivers on top of the tunnel with distance behind the portal. An acceptable traffic noise-mitigation technique may be a band of dense foliage 40 to 50 ft (12-15 m) wide, which would prevent receivers from approaching the noisy area directly behind the portal.

It may be concluded that the L_{10} - L_{50} difference (noise variation) decreases as the distance behind a tunnel portal increases when the listener is on top

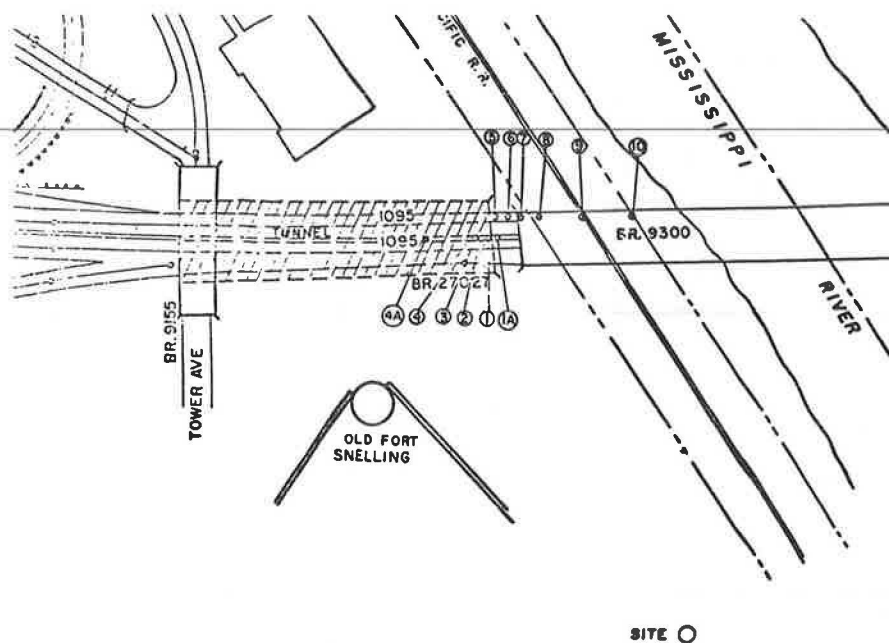


FIGURE 4 Measurement sites.

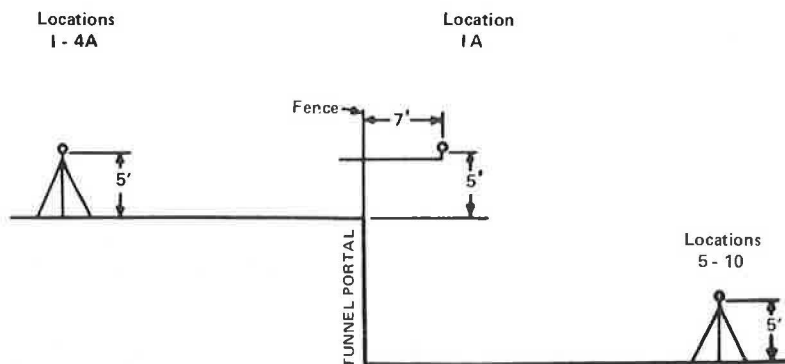


FIGURE 5 Instrument set-up.

TABLE 1 Site Location, Sound Pressure Levels, and Traffic

Location and Site	L ₁₀ (dBA)	95% Confidence Limits	Corrected L ₁₀ (dBA)	L ₅₀ (dBA)	L ₉₀ (dBA)	L ₁₀ -L ₅₀ (dBA)
On top of tunnel						
1A ^{a,b} : 7 ft north of north portal	85	+3 1/2 -1 1/2	86	79		7
1: 2 ft south of north portal	79	±2 1/2	79	73	68	6
2: 10 ft south of north portal	73	+2 1/2 -1 1/2	73 1/2	69		4 1/2
3: 15 ft south of north portal	69	+2 1/2 -1 1/2	69 1/2	66	62	3 1/2
4: 20 ft south of north portal	67	+2 1/2 -1 1/2	67 1/2	64	61	3 1/2
4A: 70 ft south of north portal	64	±2 1/2	64	60		4
West walk of Mississippi River Bridge						
5: 7 ft north of north tunnel portal	91	±1 1/2	91	87	83	4
6 ^a : 20 ft north of north tunnel portal	88	±2 1/2	88	83	77	5
7 ^a : 32 ft north of north tunnel portal	85	+2 1/2	85 1/2	81	73	4 1/2
8: 57 ft north of north tunnel portal	84	+2 1/2	84 1/2	81	77	3 1/2
9: 107 ft north of north tunnel portal	84	+2 1/2 -1 1/2	84 1/2	80	76	4 1/2
10: 160 ft north of north tunnel portal	83	+2 1/2	83 1/2	79	74	4 1/2

Note: Average speed (mph): automobiles, 48.1; standard deviation, 5.4; trucks, 46.2; standard deviation, 6.8.

^aThese sites were measured on a different day than the other sites.

^bThis measurement was made by holding the microphone, mounted on a range pole, out over the top of the tunnel.

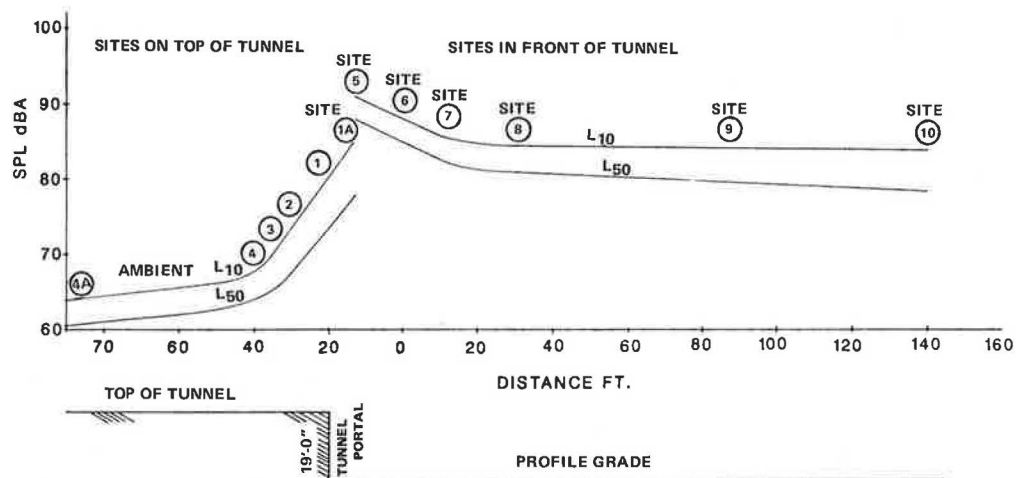


FIGURE 6 L_{10} and L_{50} sound level versus distance.

of the tunnel until ambient conditions exist. When the listener is in front of the tunnel and adjacent to the traffic flow, the L_{10} - L_{50} difference increases as the distance from a tunnel portal increases until the free-field traffic noise exists. When the L_{10} - L_{90} value at the free-field site is compared with the L_{10} - L_{90} value from just immediately outside the portal, it may be concluded that even though the variability of the noise decreases in the tunnel, the noise pollution level (L_{NP}) (2) increases because of the large increase in the L_{50} inside the tunnel. It may be concluded that the increase in traffic noise due to reverberation within a tunnel is of no particular consequence to receivers 60 to 70 ft beyond the portal.

REFERENCES

1. Sound Procedures for Measuring Highway Noise, Section 3. Report FHWA-DP-45-1R. FHWA, U.S. Department of Transportation, Aug. 1981.
2. L.L. Beranek. Noise and Vibration Control. McGraw-Hill, New York, 1971.

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