AN OVERVIEW OF THE ROADWAY SURFACE-TIRE PATTERN INTERACTION NOISE SYSTEM

MICHIGAN
HIGHWAY RESEARCH LABORATORY SECTION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

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G. H. Grove

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E. V. Erickson, Chairman; Charles H. Hewitt,
Vice-Chairman, Carl V. Pellonpaa, Peter B. Fletcher
John P. Woodford, Director
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ABSTRACT

The transverse grooving applied to the concrete surfaces described for our test sites did not appreciably effect the overall noise level for the tire types tested, although the snow tire did exhibit an increased frequency shift in its noise spectrum.

On the average, the noise level increased directly as the fourth power of vehicle speed.

Introduction

In answer to a request by M. N. Clyde (January 15, 1974), noise level measurements were conducted at selected site locations that have recently had grooves cut into the approach pavement of the signalized intersections. The objective was to determine if the grooving, added for the purpose of improving skid coefficients, changed the noise level generated by the tire-roadway surface interaction system.

This tire-roadway interaction system is one of the major sources of automotive noise. Tire-roadway noise is generated by all motor vehicles in motion. For some vehicles and operating conditions, it is the dominant source of noise. For example, late model passenger cars driven at freeway speeds radiate sound that is produced mostly by this tire-roadway interaction system. Many characteristics of the tire, the roadway, and the vehicle suspension are important in producing this type of noise, although the specific mechanisms are not clearly understood or easily measured. The amount of tread depth, the tread pattern, the roadway roughness, the pavement moisture content, the tire loading, and the tire-vehicle body coupling are all important in determining the amount of noise radiated.

Previous Research Studies

In the past few years, a number of research studies (1 - 7, 9) have been conducted in which the effects of the tire tread-roadway surface interface system on noise levels were evaluated.

The field measurements of Galloway, et al (1), on different roadway surfaces led to the following noise level versus speed relations for passenger cars.

Surface	Noise Level (dbA)
a	$18 + 30 \log_{10} V$
b	$23 + 30 \log_{10} V$
c	$28 + 30 \log_{10} V$

The surface (a) equation resulted from random drive-bys on very smooth, nearly new compact asphalt with very little surface roughness. Surface (b) data were from a moderately rough asphalt surface and a rough concrete surface typical of freeway construction. Surface (c) was a rough asphalt pavement with large voids, 1/2-in. or more in diameter, at the surface.

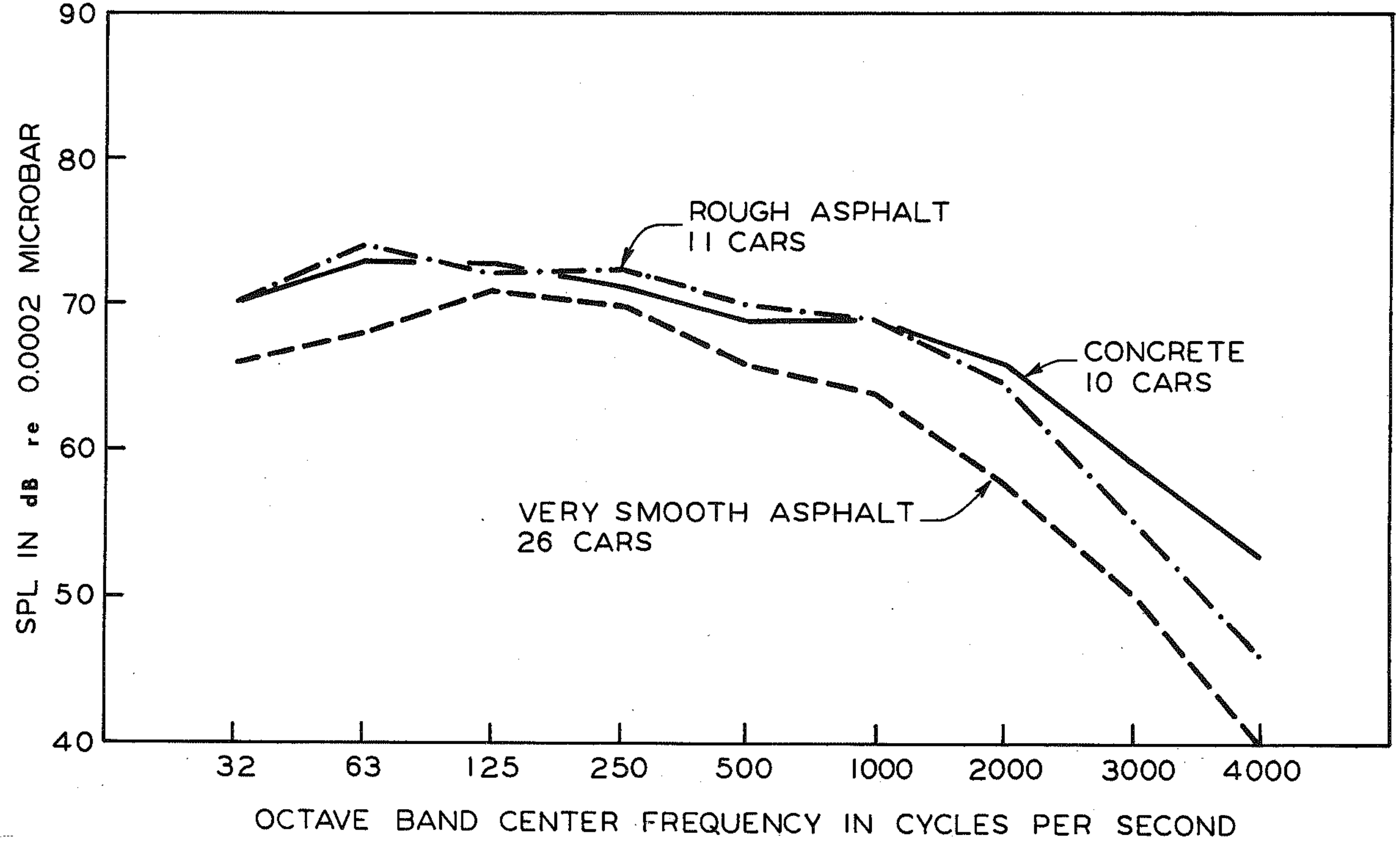


Figure 1. Noise spectra for passenger cars on three roadway surfaces (25-ft distance, 43- to 57-mph).

Galloway found that the difference in noise levels between very smooth asphalt and moderately rough concrete is greatest for frequencies greater than 2,000 Hz. Figure 1 illustrates the noise level spectra for three surfaces.

In a later study, Gordon, et al (2), provided a table of corrections (Table 1) to account for deviations from the "normal" roadway surface applicable to both automobiles and trucks.

TABLE 1

CLASSIFICATION OF ROAD SURFACE AS IT RELATES TO SURFACE INFLUENCE ON VEHICLE NOISE

Surface Type	Description	Adjustment (db)
Smooth	Very smooth, seal-coated asphalt pavement	-5
Normal	Moderately rough asphalt and concrete surface	0
Rough	Rough asphalt pavement with large voids 1/2 in. or larger in diameter, grooved concrete	+5

Tetlow (3) tested three sets of truck tires -- retread, crossbar, and rib -- on each of three roadway surfaces -- smooth, medium coarse, and coarse. He noted that the roadway surface effect was most pronounced (8 db at 40 to 50 mph) for the retread tire. This tire was noisiest on the smoothest surface and quietest on the roughest surface, due to the formation of a better air seal on the smoother surface. The differences for the crossbar and rib tires was less than 5 db for any speed.

Leasure, et al (4), Wallops Island tests on truck tires confirmed Tetlow's observation about pocket retreads producing more noise on a smoother surface. They found that crossbars exhibited higher noise levels on a smooth concrete surface than on a rougher asphalt. The rib tires produced a maximum difference of 3 db due to roadway roughness; being noisier on new asphalt and half worn concrete.

Close (5) reported that truck tires on the smoothest and roughest roads produce the highest noise levels while surfaces constructed with medium sized aggregate generally exhibited the lowest levels.

Anderson, et al (6, Ch. 2), commented on Galloway and Gordon's earlier work (Table 1) explaining that the application of the roadway surface adjustments should be left to the discretion of the user. They questioned the use of the -5 db correction since any surface smooth enough to justify -5 db for automobile noise would most likely be unsafe, especially when wet. In addition, the roadway surface was not considered, in general, to significantly affect truck noise levels. Their recommendations appear in Table 2.

TABLE 2
PASSENGER CAR TIRE --
ROADWAY SURFACE NOISE CORRECTIONS

Surface	Adjustments
Very rough	+5 dbA
Medium rough	+2 dbA
Average	0
Medium smooth	-2 dbA

However, in Chapter 4 of the same report, the previous results of -5, 0, +5 db for smooth, normal, and rough pavements (Table 1) were again suggested. They also noted that occasionally an old surface, worn by tire studs or a grooved surface warrants a +5 db adjustment.

Richards (7), in his study on automobile tire noise, noted that both road texture and tread pattern contribute to tire noise but not necessarily in an additive manner. He also made the following generalizations:

1. Smooth Tire - Smooth Road. A relatively quiet condition.

2. Smooth Tire - Rougher Surface. Noise levels generally increase with surface roughness.

3. Aggressive Tire - Smooth Road. Louder than smooth tire and generally tonal, depending greatly on the tread pattern.

4. Aggressive Tire - Rough Surface. Noise levels are nearly independent of the surface -- to the point at which the road roughness overshadows tread amplitudes. From this point on, the noise levels again increase with road roughness. Some aggressive tires (such as cross-lug truck tires) may become quieter on a coarse surface since the random texture of the road serves to disrupt the regular impacting of the tread blocks on the road.

Rentz and Pope (9) discussed tire - pavement noise in great detail for both cars and trucks. They presented actual noise level equations which are a function of speed, pavement wetness, and a tire tread-pavement type base value for cars; and speed, load, number of axles, and a tire tread-pavement type base value for trucks. These equations, given for 50 ft distances are:

$$L_A = 40 \log \left(\frac{V}{40}\right) + 10\,S + B_A$$

$$L_T = 40 \log \left(\frac{V}{40}\right) + 10 \log \left(\frac{L}{4430}\right) + 10 \log N + B_T$$

where: V = vehicle speed in mph

L = load in pounds

N = number of loaded axles.

$$S = \begin{cases} 1 & \text{if pavement is wet} \\ 0 & \text{if otherwise} \end{cases}$$

B_A = automobile tire base value (Table 3)

B_T = truck tire base value (Table 4)

TABLE 3
AUTOMOBILE TIRE NOISE BASE VALUES B_A (dbA)
AT 50 ft, 40 mph

Pavement Type	Straight Rib Tire	Snow Tread Tire	Smooth Tire
Open graded and smooth asphaltic concrete; new portland cement concrete	64(66.5)*	67.5(72)	63
Dense graded medium coarse asphaltic concrete	68(70.5)	71(75.5)	67
Old pitted portland cement concrete and rough asphaltic concrete	70(72.5)	75(79.5)	69

*First value is for new tire tread, value in parentheses for worn tread.

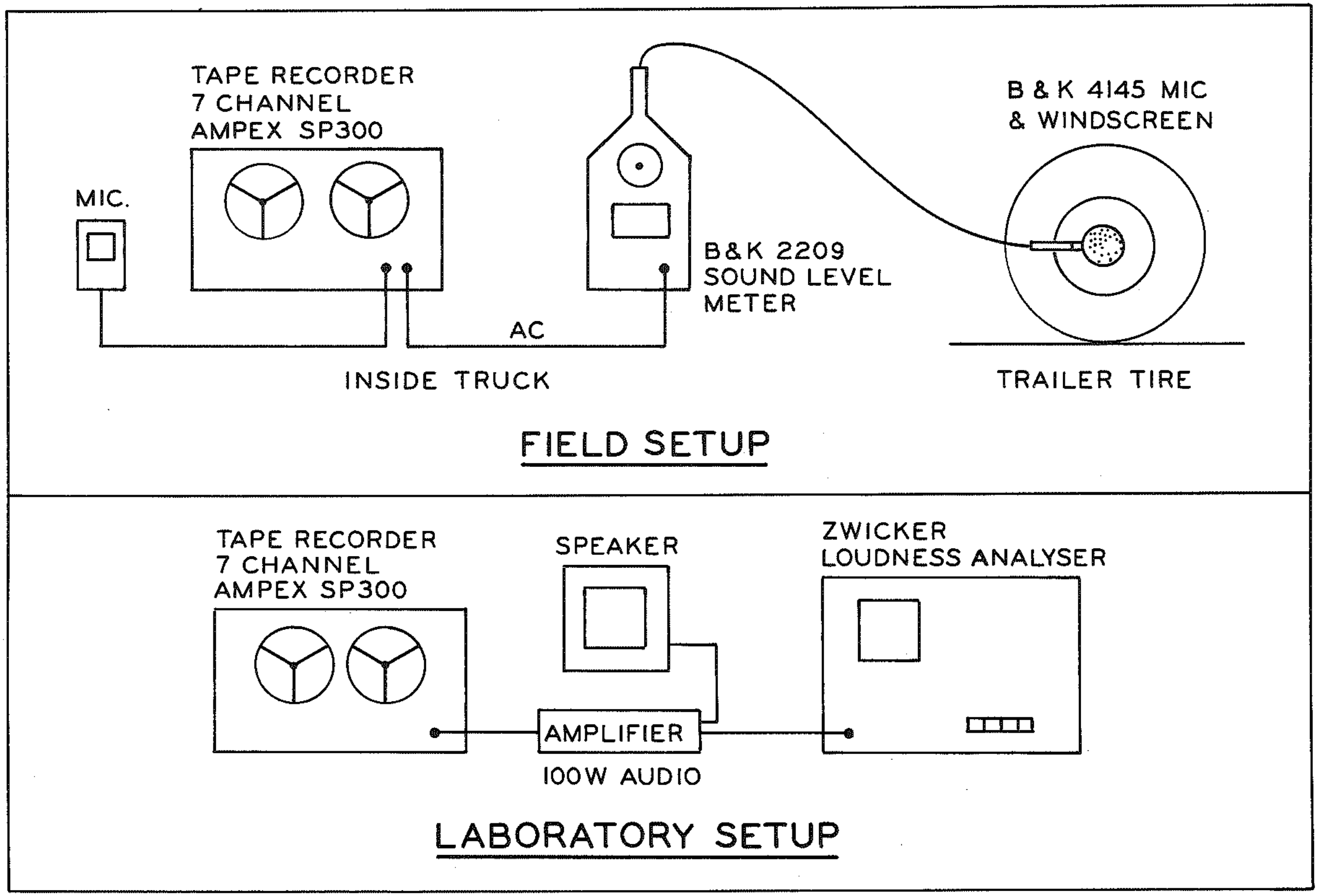


Figure 2. Equipment Setup.

TABLE 4
TRUCK TIRE NOISE BASE VALUES
B_T (dbA) AT 50 ft, 40 mph

Tire Tread Type	All Pavement Surface Types
Neutral rib	69(--)*
Rib	70.5(73)
Cross lug	75(79.5)
Pocket retread	86(86)

*First value is for new tire tread, value in parentheses for worn tread.

Procedure

Several difficulties were encountered both in the planning and actual measurement phases of this project.

1. Some of the lengths of the grooved sections were relatively short thus rendering very limited data for analysis purposes.

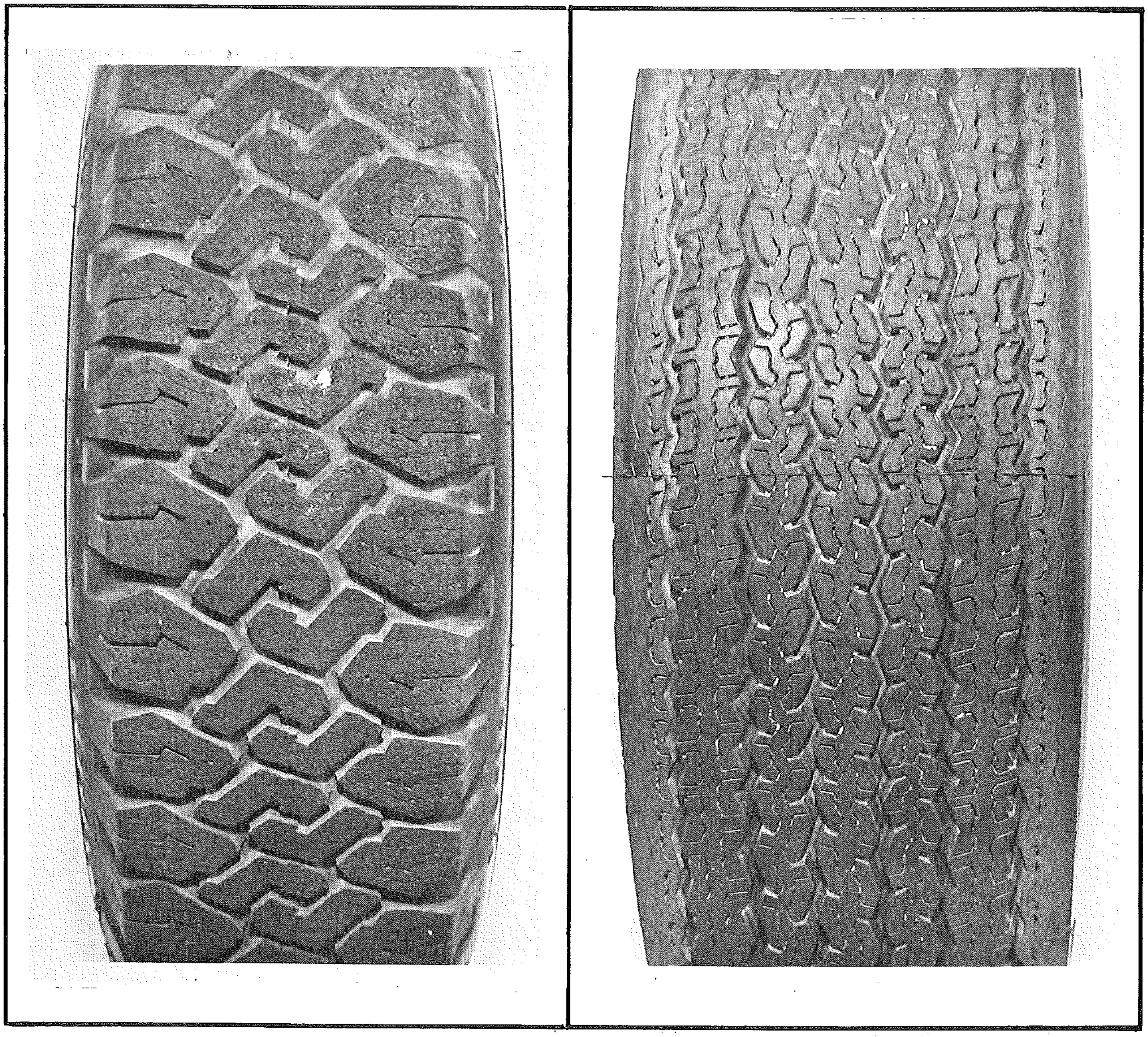
2. The grooved sections were always either on curves or on the approach lanes to a signalized intersection. Some signals such as the US 27-Waverly Rd intersection were vehicle actuated, making it impossible to prejudge the length of green time during a test run. Also, since these sites were generally higher volume intersections, cross traffic could not be held without creating traffic jams.

3. During test runs, vehicles would pass the test vehicle thus masking out data.

4. Since the microphone was mounted on a vehicle moving 30 to 45 mph, considerable wind noise also contaminated the recordings.

For these reasons, several straight, at-grade sites (listed below) located reasonably close to Lansing were selected, where the signal timing was not demand actuated and the test runs were made during off-peak traffic conditions.

The microphone, fitted with a windscreen, was mounted on the trailer near the roadway-tire interface facing opposite the direction of travel in order to minimize the effects of the pulling vehicle's engine noise and wind noise (Fig. 2). Calibration was performed prior to and after each set of



Glass Belted Suburbanite
(Ypsilanti Sites)

Steel Belted Radial
(Perry Site)

Figure 3. Test tires used at Ypsilanti and Perry.

recordings. Test runs at 35 and 45 mph at each site were recorded unweighted, so as not to lose any frequency effects.

Figure 3 illustrates the tire-tread pattern of the tires used at each test site while Figure 4 indicates the transversely grooved surface at Test Site 1.

Grooved Pavement Sites

1) Temporary I 69 at M 52, near Perry, 500 ft of the eastbound approach, through and turn lanes.

2) M 17, at Golfside, near Ypsilanti, 400 ft of the westbound approach, through and center lanes and 800 ft of the eastbound lanes.

3) M 17 at Hewitt, in Ypsilanti, 400 ft of the through and center lanes.

At each of these test sites, about 400 ft of ungrooved pavement preceding the above grooved sections acted as the control section used in determining the relative change in noise level due to the grooving.

Results

Because of the fairly low speed limits at each of the sites (40 to 45 mph) and the possible hazards caused by the slow moving test vehicle (more than 15 mph less than the posted speed) only two speeds were run at each location.

The field-recorded tapes were analyzed in the Laboratory (Fig. 2) on a modified Loudness Analyzer based upon the Zwicker method (8). It was found that at Test Site 1, transverse grooving did not produce a measureable change in noise level but did exhibit a shift in the frequency spectrum near 1 KHz. At Test Sites 2 and 3, no perceivable change was noted in either noise level or frequency.

Based upon the limited amount of field data, the direct dependence of noise level upon vehicle speed was determined from the field data given in Table 5. Using $\Delta L_{avg} = K \log_{10} (\frac{V_2}{V_1})$,

$$K = \frac{4.6}{\log_{10} (\frac{45}{35})} = 42.2,$$

which is very close to the value of 40 claimed by Rentz and Pope (9).

Figure 4. Transverse grooved concrete, eastbound temp I 69 at M 52, Perry.

TABLE 5
ZWICKER NOISE LEVELS

Site Number	Peak L (db)		ΔL (db)
	V_1 35 mph	V_2 45 mph	
1 east	92	96	4
2 east	96	101	5
2 west	96	100	4
3 east	96	101	5
3 west	96	101	5

Conclusions

Based upon the many detailed studies and our spot check tests, the following generalizations concerning the tire tread pattern-roadway surface interface system were made:

1) Roadway surface and tire tread pattern both contribute to tire noise but not necessarily in an additive manner, thus exhibiting the fact that the surface and tire patterns relative to each other is an important factor. The transverse grooving applied to the concrete surfaces used for our test sites did not appreciably effect the overall noise level for the two tire types used. The two tires chosen were felt to be representative of most common passenger car tires in use today. However, this does not imply that some other combination of tire pattern and pavement grooving will not cause a change in noise level.

2) The speed dependence appeared to agree closely with Rentz and Pope's suggested fourth power relationship.

3) The blanket statement of allowing a certain relative db adjustment factor for a vaguely described surface condition does not appear to be justified. First, a widely accepted index of roadway surface roughness must be established. Second, more research in this area needs to be conducted to effectively model the roadway surface-tire pattern interaction system.

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