

The Wall Journal™

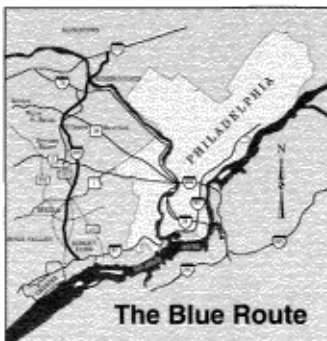
The International Journal of Transportation-Related Environmental Issues

8

July/August
1993



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The Wall Journal

The International Journal of Transportation-Related Environmental Issues

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Subscription and advertising information are shown on the back cover page 20.

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EDITOR'S CORNER

by El Angove

Well, I think I have finally decided what I want to do with the front cover. The back cover was easy; you have to leave a big space for the postal permit and the address label, and someone will always want a back-cover half-page ad, so there are not many options left. And then the government has all these regulations about the size of the label, where it has to go, and what kind of typeface it has to have. That takes care of the back page, and I guess that's all right, because the back page is usually the first thing you, the reader, gets to see if the person who delivers the mail to your desk throws it on the desk with the mail label side up. It's always nice to see your own name on your desk first thing in the morning; that way, you know you're in the right place.

Now, the front cover is a whole other story. First, you can forget about ad space, because they tell me it is gauche to put ads on the front page; only the Toonerville Gazette is dumb enough to do that. And our name, "The Wall Journal", doesn't take up much space at the top of the page (in the publishing business, they call that the "Nameplate" or the "Banner"). I call it the answer to the question, "What's the name of your paper, Bud?"

That leaves pretty much the whole front page to worry about. Well, one thing I always like to see first is what's in the paper today? Who knows? — I may not even want to read the dadburned thing. It takes a lot more to catch my attention than it used to. I like pictures. I don't have much time for reading the small print. I want a few fast pictures to give me some idea of if I want to read this. So, I figured a column or a space at the bottom of the



page showing what's "In This Issue" with some pictures would be a grabber.

Now, that still left a lot of white space on the page. What to do? Well, for the same reasons as the first column, the obvious choice

was: pictures. Front page articles may be nice, but they need headlines like "Huge Sinkhole Swallows I-95 Traffic" if you want to get someone to read the front page. You have to stop them cold before they have a chance to thumb idly through, looking for the goodies.

And logically enough, if a picture is good, a bigger picture would be better, and the biggest picture would be best. So, I dug down deep in my Florida file and I found an aerial photo of one of the Fanwall noise barriers erected on I-95 in North Miami in 1987-88 (these walls are included in Win Lindeman's "Florida Noise Barrier Status Report" which was condensed in our Issue No. 7).

This photo does a lot of story-telling. Just a few of its components: (1) It shows an existing, heavily-traveled highway; (2) It shows HOV lanes under construction on both sides; (3) It shows the noise barrier erected right up to the right-of-way line and (4) It shows that the wall's usual zig-zag layout was utilized to save as many trees as possible. [Maybe we can get Win to write that story for us one of these days].

This is the **kind** of photo we would like to feature on the front page of every issue. The photo should convey a sense of the barrier's place in the community, the kind of transportation noise it is attenuating, and its construction and aesthetics characteristics. We look forward to publishing **your** photos and reports. ■

NEXT ISSUE: No. 9, SEPTEMBER/OCTOBER

The Fundamentals of Sound – Part II - By Dr. Roger Wayson

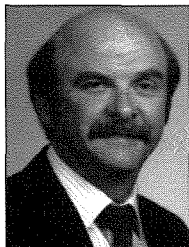
Summaries of Professional Papers – Part I

Presented at the TRB A1F04 Summer Meeting, July 11-14

A New Regular Reporting System on Upcoming Noise Barrier Projects

Assorted Wetlands and Air Quality Project Reports

And More ...



Ed. NOTE: A number of readers have asked whatever happened to Bob Armstrong's column. Well, Bob stays in touch with us, but says he has just been too busy to sit down and put together some items of interest. A few days ago, he told me that he had some good material he was trying to organize, and that he would do his best to make the next issue.

I've shaded this area in just to let him know that we are all waiting for the latest from the feds.

Press Release...June 1993 Silver Spring, MD.

Scantek, Inc. announces a breakthrough in graphic level recorders: The LR-06 Level Recorder from RION Company has capability as level recorder, data-logger and interface. The small and rugged unit is powered by AC or rechargeable or automobile batteries. The data stored on the PCMCIA 1MB memory card are instantaneous level data. The sampling rate for digital conversion depends on the paper speed. The unique recorder has a sample rate/recording time fixed at one roll of paper so that one roll is equivalent to the memory in one card. The slowest is 10.0s, the fastest is .003s. Data can be compressed or expanded to allow replay of long-term data in a short time.

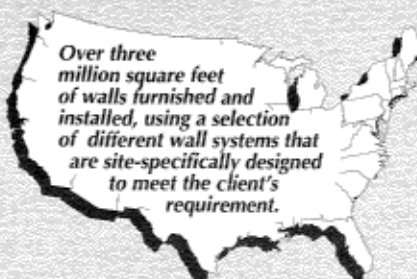
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Wanted — New Technologies and Concepts for the Highways and Intermodal Systems of the Future

The National Cooperative Highway Research Program (NCHRP), which is managed by the Transportation Research Board (TRB) and funded by the FHWA, state highway agencies and AASHTO, has a new "IDEA" — A program for Innovations Deserving Exploratory Analysis.

NCHRP-IDEA seeks to introduce new technologies, methods or processes for application to highways and intermodal surface transportation through the development and testing of nontraditional and innovative concepts, including application of those from other technology sectors that have not yet been tested in the highway sector. NCHRP-IDEA will consider deserving innovations in any technology area for highway and intermodal surface transportation systems. Technology emphasis areas for the first 2-year project cycle from October 1992 to September 1994 are identified in this solicitation.

Investigators wishing to participate in the IDEA program are required to sub-

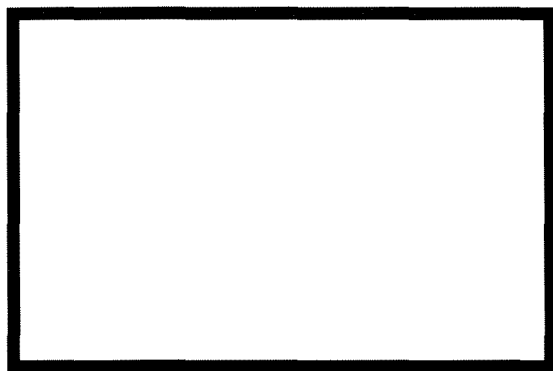
mit to NCHRP-IDEA a three-page concept proposal describing the innovation proposed for investigation and the potential impact of the innovation on current practice in accordance with the guidelines described in this project announcement. NCHRP-IDEA will review the concept proposal and, if it is found appropriate and promising, will invite the proposer to submit a more detailed proposal. The two-step proposal preparation process is designed to permit guidance and feedback from TRB on appropriate concepts before the detailed proposal is prepared. All IDEA awards are fixed-price contracts not to exceed \$100,000 and must be completed within 12 months.



IDEA concepts will be characterized by one or more of the following features:

1. Engineering and scientific innovations that offer significant promise for developing into usable and cost-effective technologies, processes or products.
2. High-risk but credible technical concepts that offer potential for significant technological breakthroughs and large payoffs.
3. New concepts that offer the potential for advancing the state-of-the-art highway and intermodal surface transportation technologies or those that may emerge into new technology areas for highway application.

(Continued next Page)



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Wanted – New Technologies, from page 4

4. Advanced concepts and products developed for other engineering applications but not as yet tested or applied to highway practice.

5. Advanced technologies tested or used in overseas practice but as yet not tested or proven useful in U.S. practice.

Feasibility Phase (Type I)

An IDEA investigation in the feasibility phase (Type I) would generally be an evaluation of an innovative technical concept for which adequate knowledge, technical information, or data are not currently available to ascertain its feasibility. The purpose of the Type I investigation is to determine the scientific and technical validity of the concept through appropriate small or bench scale experimentation and/or analytical verification. The results should demonstrate proof of concept for (1) subsequent design and fabrication of a prototype to perform field scale experimentation or (2) development of guidelines for the application

of a new method, process or technology to practice.

Advance Testing Phase (Type II)

NCHRP-IDEA will consider a Type II investigation to perform larger scale or field testing of deserving and feasible IDEA concepts. Concepts proven feasible by Type I investigations or innovations developed and tested from outside the NCHRP-IDEA project are eligible for Type II proposals. These include testing of new technological developments from overseas and other industrial technologies, such as from the aerospace and computer and information technology sectors.

Products that are currently available, marketed, used, or tested for U.S. highway application are not eligible for investigation.

A typical Type II investigation would consist of developing prototypes of *proven innovations*, evaluating the product under actual or simulated highway operating conditions, and estimating the efficacy of the product

for highway application. The results of a Type II investigation should provide adequate information on the cost effectiveness and potential application or acceptance of the product to practice.

Budget and Duration

The IDEA award amount, not to exceed \$100,000, will be based on the technical tasks required. All IDEA investigations must be completed within 12 months. Cost sharing is recommended but is not a requirement for Type I proposals. Substantial cost sharing is a requirement for all IDEA Type II proposals.

If you would like more information on applying for the IDEA program, give me a call at (609) 530-2834. ■

Domenick Billera is Manager, Air and Noise Section, Division of Project Development, New Jersey Department of Transportation, 1035 Parkway Ave., CN600, Trenton, NJ 08625.



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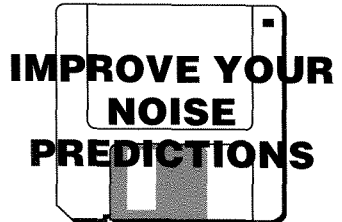
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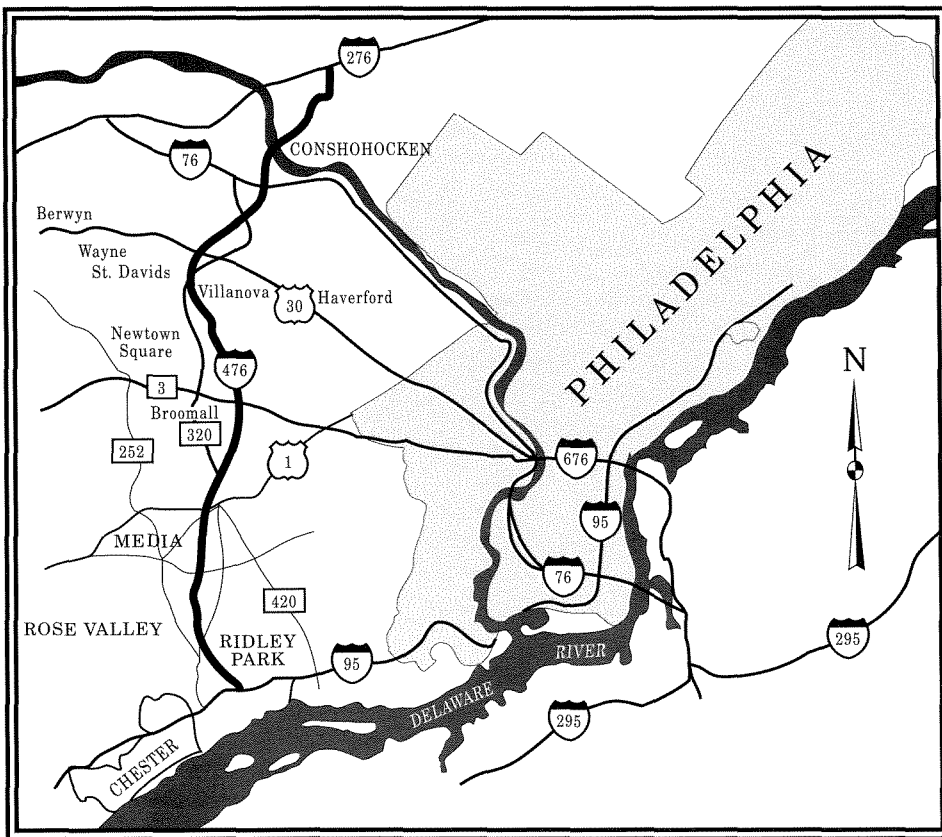
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The Making of PennDOT's 'Blue Route', I-476

A Thirty-Five Year Journey, Including 11 Years in the Courts



Interstate 476 in Pennsylvania is an unusual highway. Its 35 years in the making have had more twists and turns than the highway itself. It is the most environmentally-sensitive expressway ever built by the Pennsylvania Department of Transportation. The co-existence of man, nature and the automobile is reflected in the many miles and varied design of the noise walls and in the extensive landscaping which has been planted throughout the project. Even more so, it is reflected in the creation of approximately 11 acres of new wetlands and the enhancement or restoration of approximately 22 acres of existing wetlands which countless birds, waterfowl and small animals now call home.

The highway's origins can be traced as far back as 1929 when planners first recognized the need for a north-south expressway through the middle of Delaware County. But the journey really began in 1956 when the concept of a "mid-county" expressway was included in the U.S. Interstate and Defense Highway System which was

just beginning to take shape. Four years later, the State Department of Highways (now the Department of Transportation) had prepared a preliminary plan to build a six-lane, 21.5-mile "mid-county" expressway connecting I-95 in Ridley Township, Delaware County, with the Pennsylvania Turnpike (I-276) and its Northeast Extension (PA 9) in Plymouth Township, Montgomery County. The new road was given the designation I-476.

"the most environmentally-sensitive expressway ever built by the Pennsylvania Department of Transportation."

The plan was presented at a public hearing in January, 1961 at which four proposed alignments were discussed. The alignments were outlined in red, yellow, green and blue on a large map of the region. The one colored blue was the most preferred, hence the name "Blue Route". But it was not a unanimous choice; opposition to

building any highway had been evident at the meeting.

The "Blue Route" was estimated to cost \$50 million and construction began in July 1967 on a 2.5-mile section from approximately Darby Road in Haverford Township to where Tower Road now exists in Radnor Township. The section was completed in October 1969, the same year the National Environmental Policy Act was passed.

Five more sections of I-476 between Upper Merion Township and Plymouth Township in Montgomery County were started between 1970 and 1974. By 1978, almost nine miles of the highway had been built, but only three miles were opened to traffic in January 1979. During those eight years of construction, opponents of the highway had found a way to try to stop the project.

Using the 1969 environmental act, a citizens' group successfully sued in 1974 to force additional environmental studies, and in the interim all design and new construction were halted. The legal battle had begun.

The battle continued for 11 years, effectively stopping further construction until 1985 when the U.S. District Court denied an appeal to prevent resumption of work while plaintiffs challenged the process by which the Supplemental Environmental Impact Statement (SEIS) had been approved. The SEIS had been done to fine-tune the redesign of I-476 in order to make it more environmentally sensitive.

In December 1985 a groundbreaking ceremony was held to celebrate the start of work on the I-95/MacDade Boulevard Interchange in Ridley Township. Still more lawsuits followed, this time centered around the need for the Department to acquire a "Section 404 Permit" from the Army Corps of Engineers in order to build in wetland areas.

While the lawsuits made their way through the legal system, the Department was able to resume work on the expressway in February 1988

and had all six of the remaining sections under construction by July.

The litigation officially ended May 1, 1990 when the U.S. District Court issued its order effectively dismissing all cases. The 35-year journey of one of America's last interstate highways to be built was almost over. I-476 was a little more than a year and a half away from completion. Total construction cost....\$581.3 million.

Noise Barriers Account for \$34 Million of Total Construction Cost

The 25.9-mile long I-476 (The Blue Route) has a total of 21.9 miles of noise barriers. Seven and one-half miles of roadway have noise barriers on both sides of the highway. There are 1,440,000 square feet of noise barriers at an average installed price of \$23.67 for a total cost of \$34,080,880.

The majority of the ground-mounted barriers are constructed of precast concrete panels with precast concrete posts. Generally, the color and texture of the posts matches that of the adjacent panels. Structure-mounted noise barriers are predominantly precast concrete panels which are attached directly (without posts) to the outside face of the structures' parapets.

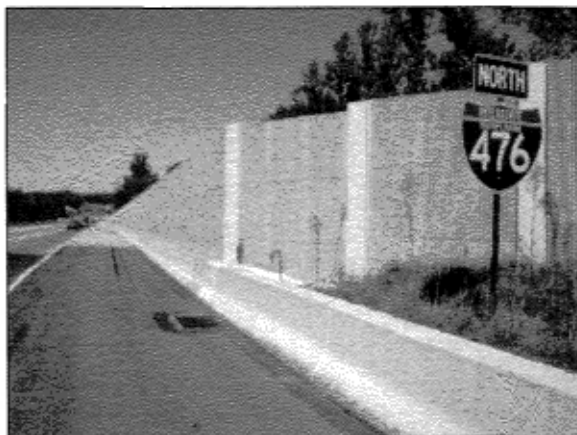
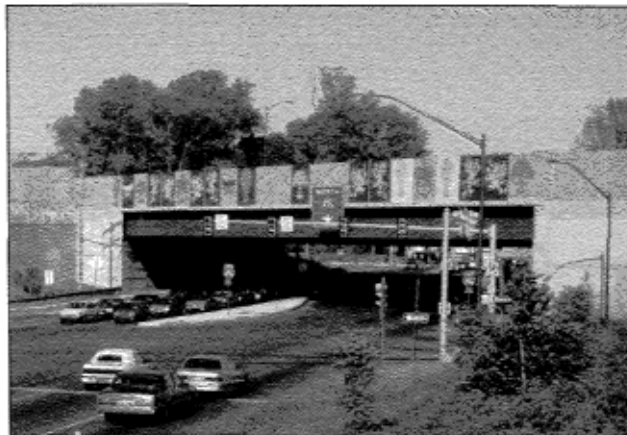
The textures chosen by the citizens for the community sides of the noise barriers were light exposed aggregate, dark exposed aggregate, and several types of textures created with formliners (grapestakes, horizontal planking and simulated stone).

One noise barrier has steel posts with concrete panels, one is constructed in an undulating pattern without posts ("Fanwall"), and two barriers are experimental "Evergreen" retaining wall/noise barrier systems, consisting of precast concrete elements which are stacked, filled with soil and planted.

In instances where sound-absorption is required on the highway side of the noise barrier, such is obtained with a "Durisol" sound-absorptive face on a precast concrete panel. The Durisol has a ribbed formliner texture and earth-tone color.

For the noise barrier surfaces having

Blue and beige 8' x 10' precast concrete panels adorn bridges in the Radnor Township area. The panels depict the Township seal, which incorporates a tree, a Conestoga wagon, a wheat sheaf, a lion, railroad tracks and a griffin. The Sound Zero panels not only provide abatement from the highway noise but also offer an interesting and aesthetic "face" to the community.



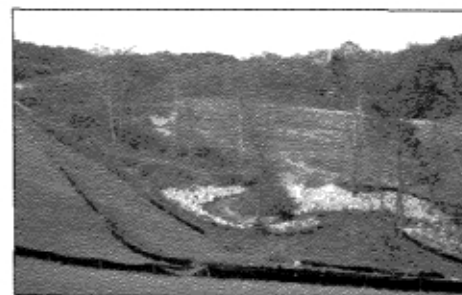
"Durisol" sound-absorptive faced precast panels with precast concrete posts. Durisol has ribbed texture face and is colored with earth tone penetrating stain.



"Evergreen" Retaining Wall/Noise Barrier under construction.



Noise Barriers being installed in the early phases of road construction. The hilly terrain is fairly typical of the area, which has affected construction cost.



The area through which the Blue Route passes required extensive wetlands conservation and restoration. This slide shows one such project.

the formliner textures, a variety of earth tone colors were selected by the various neighborhood groups. With the exception of the simulated stone and the Durisol surfaces, colors are obtained by the use of a pigmented three-coat urethane anti-graffiti coating system.

The simulated stone texture has its color integral with the concrete and

has an applied clear anti-graffiti coating. The Durisol surface have an earth tone color accomplished by application of a penetrating stain, since application of the urethane coating would negate the absorptive qualities of the surface. All exposed aggregate surfaces receive the clear anti-graffiti coating system. ■

The Blue Route (More on page 12)

Gore Hill Freeway: Sydney, Australia

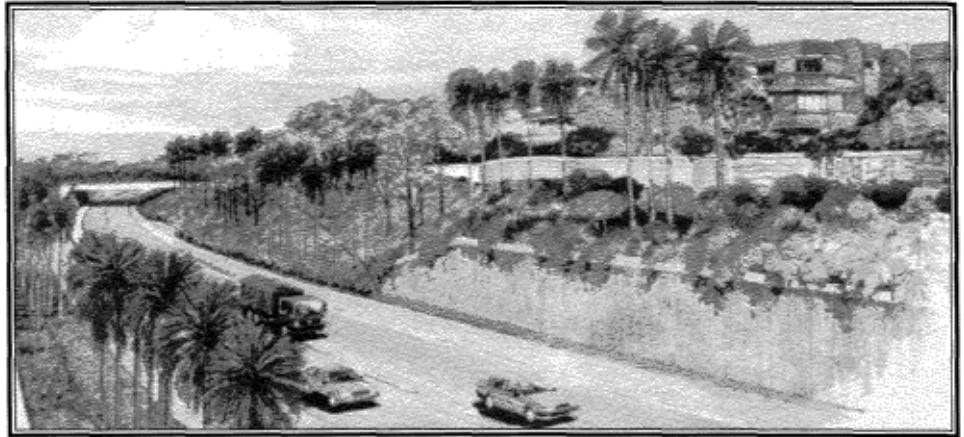
Keeping Australia Beautiful Council Award

By Karl Mezgailis

The Gore Hill Freeway is a 3.1km section of roadway which passes through Sydney's lower North Shore and carries traffic between the centre of Sydney and the North and North West sectors (see *Figure 1*). The building of freeways in an urban area such as this requires care to minimise the effect on the environment.

Two critical features of the finished roadway are the landscape and noise barrier designs. The Roads and Traffic Authority (RTA) of New South Wales used its own landscape designers, in conjunction with consultants Land Systems EBC for the landscape design and, a first for the Authority, an artist/architect Richard Goodwin, for artistic ideas and designs for the noise walls. Working collaboratively with the Project Management Team of Major Projects in its Sydney Region, led by Mr. Ray Brown, an integrated Landscape/Noise Barrier System was produced which marries engineering with art.

A panel 3.8m high and 7m long was chosen by the artist once the acoustic height was set. This rectangular shape accentuates the sense of architecture



The Roads and Traffic Authority decided that it was important to use indigenous plants in the landscape design, and engaged Willoughby City Council to collect seeds from native trees in the area prior to construction start of the roadway. The 70,000 trees and shrubs which have been planted represent 50 times the number removed for construction, and create a pocket of the type of planting that was once widespread in the area. The prominent species used were Sydney redgum, banksia, blackbutt turpentine, casurina native kangaroo grass and ferns. All landscape areas are mulched with 100mm of hardwood mulch. The final landscape created should be ecologically sustainable and relatively maintenance free.

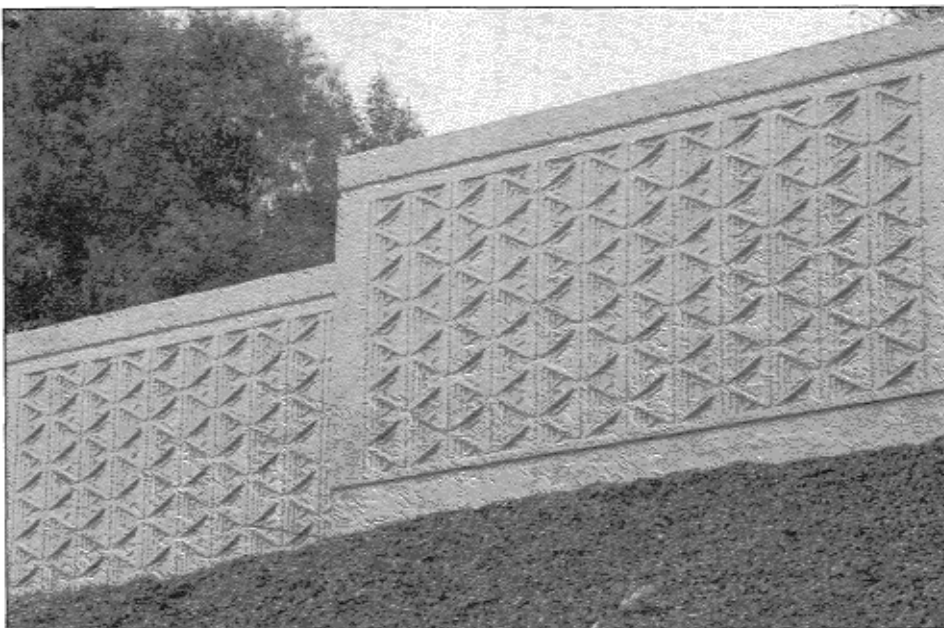
and wall over the more common notion of a panel. The relief motif chosen for the panels is a representation of the local area including the freeway. The Gore Hill Walls attempt to make significant architecture out of the necessity for noise attenuation (see *photos next page*).

The builders of walls, Obnova on cut and fill, and James Hardy Pty. Ltd. on

viaducts, have done an excellent job in reproducing the wall designs. The attention to detail was found to be very important, particularly the truss and support detail on the viaducts.

The proposal was assessed against the RTA Noise Level Criteria at the time of construction, 63dBA L_{10} (18 hours) and 55dBA L_{eq} night-time between 10pm and 6am. Future noise predictions were undertaken by Environmental Planning Section of the RTA using the UK CORTN method (with variations for local conditions) calibrated for anticipated traffic patterns and by acoustic consultants using the FHWA method. This acoustic analysis gave an overall barrier minimum height of 3.8m. Noise attenuation measures, in addition to 3.8 metre walls on the viaduct, included walls on cutting, earth mounding up to 6m high and "quiet" open-graded asphalt surfacing for the full length.

Before and after noise measurement studies have been undertaken and indicate that the noise attenuation measures are clearly effective. The noise levels meet the Noise Level Objectives for new roads in the RTA's recently released Interim Traffic Noise Policy for 'daytime' and 'night-time'



Precast concrete noise barrier panels with bas-relief designs originated by a famed local architect and used in many structures in the area are used to help establish a historical perspective to the walls.

Gore Hill Freeway, from page 8

noise. These are 60dBA Leq (24 hours) and 55dBA Leq (night-time) between 10pm and 6am, together with restricting noise level rises to 12dBA.

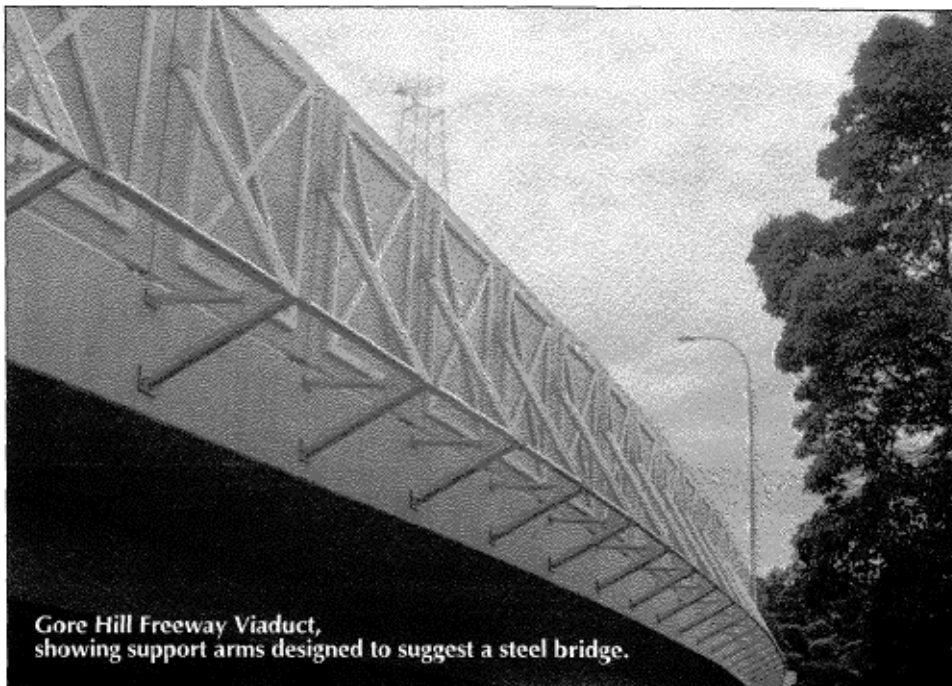
During the design, development and construction of the project, information flow to the community was maintained by the preparation of an Environmental Impact Statement, local workshops, open days and progress brochures.

By way of recognition of the creation of a roadscape which should be ecologically sustainable, which intertwines landscape with roadway and which minimises the effect on the acoustic environment, the project won the Keeping Australia Beautiful Council "1992 Vision for Australia Award".



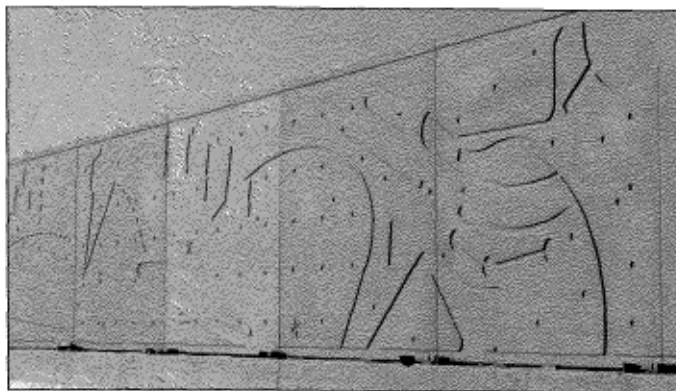
Karl Mezgailis is Manager, Research Development and Noise, in the Technical Services Directorate of the Roads and Traffic Authority of New South Wales, Australia. He

may be contacted by phone at 61-2-662 5125, by fax at 61-2-662 5215, and by mail at the Roads and Traffic Authority of NSW, GPO Box 28, Sydney, NSW 2001, Australia. ■



Gore Hill Freeway Viaduct,
showing support arms designed to suggest a steel bridge.

At right: Lightweight concrete panels with "Roadscape Design", an abstract made from fragmented plans of the freeway itself. It suggests landscape intertwined and structured by a controlling geometry. It has the effect of mapping and encapsulating the body of the freeway in abstract design.



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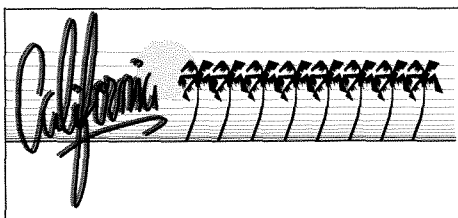
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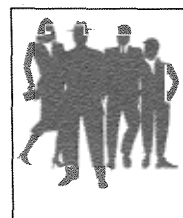
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THE PROGRAM OF PROFESSIONAL PAPERS

Presented at the TRB A1F04 Committee Summer Meeting in Berkeley, California, July 11-14, 1993



The Summer Meeting of the TRB Committee on Transportation-Related Noise and Vibration was hosted this year by acoustical consultants Wilson, Ihrig & Associates, Inc. of Oakland. Listed below are the professional presentations which were made at the conference. Summaries of each of these papers will be published in subsequent issues of The Wall Journal.



Managing the Flood of Data in Airport Noise Monitoring Systems, by Dan Ingold and Mark Karmelich, The Flood Group; and Paul Dunholter, Mestre Greve Associates

LaGuardia Airport Ground-Noise Abatement Study, by Douglas E. Barrett, Harris Miller Miller & Hanson, Inc.

Comparison of INM and NOISEMAP Results, by Ara Gharabegian, Engineering-Science, Inc.

Analysis of Vibration and Acoustics Using VAPEPS, by Albert Lee and Vance Anderson, Lockheed Missiles & Space Company, Inc.

Construction Noise Control Program of a Transit Tunnel, Portland, Oregon, by Steven Wolf, Parsons Brinckerhoff

Comparison of Rail Project Noise and Vibration Criteria; Absolute Values vs Community Ambient Levels, by James L. Sowell, Rail Construction Corporation

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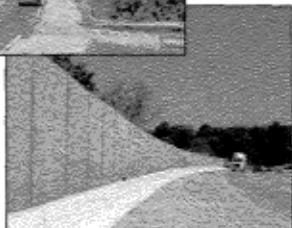
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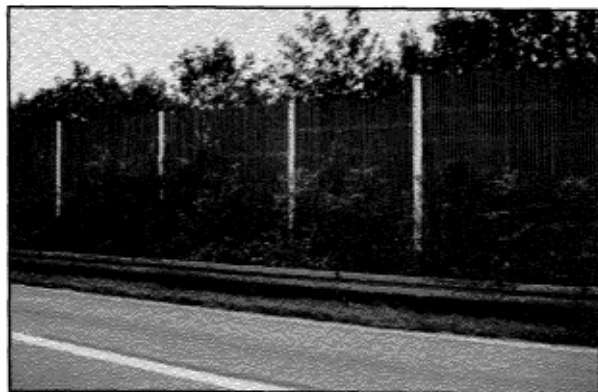
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Sound Fundamentals Part 1

Presented by:

The A1F04 Institute On Noise (ION)



Author:
Roger L. Wayson, Ph.D., P.E.
University of Central Florida

In this "course" we will not attempt to become theoretical acousticians. Instead we will concentrate on understanding the basic concepts of sound as it relates to receivers, propagation and sources. This first session will start with looking at what sound is and then concentrate on some fundamental nomenclature.

The first question we might ask has been around for a long time. "If a tree falls in the forest and no one is there to hear it, will there be a sound?" The answer of course is no. Let's investigate why.

Sound, as defined by Webster, is "The sensation of hearing, produced by stimulation of the auditory centers of the brain by vibratory waves propagated through the atmosphere or other elastic medium." So, if the tree falls, vibratory waves are created and propagate through the atmosphere, but there is no auditory center of the brain to be stimulated if no one is there. So, the answer is no. Consider also that the answer would be "no" if someone were there but deaf.

The human ear is a remarkable sensor. From any sound source, whether it is a pure tone from a tuning fork or the complicated spectra from traffic sounds, your sense of hearing and the concurrent thought that occurs is an amazing process. The human ear can hear a large range of pressure variations and frequencies. In fact, Baron von Helmholtz, a noted 19th century German physiologist and physicist, once stated that we could hear eight octaves but only see one. It is distinguishing these differences in sound that permit us to determine what the source is and its importance.

When you hear a sound, you decipher the input based on at least four distinct criteria: Loudness, Frequency, Duration and Subjectivity. A discussion of each follows.

LOUDNESS

The loudness or intensity of the sound is directly related to the amplitude of the pressure fluctuations transmitting through a medium, usually air. These small pressure fluctuations around barometric pressure (sometime called over-pressure) are traveling waves of molecular energy causing a compression and then a rarefaction of the air (see Figure 1). The pressure fluctuations in turn cause your ear drum to be flexed and the sensation of sound occurs.

Description of the pressure fluctuations requires more than just a simple average since the compressions and rarefactions would average to zero and represent atmospheric pressure. To overcome this difficulty, a mathematical approach called the root-mean-square is used. First, the pressure variance about atmospheric pressure is squared, making all values positive. Next, the average is calculated (mean). Finally, the square root is taken to compensate for the original squaring process. The result is a useable form of measurement for

problems (range of pressure fluctuations and the response of the ear), we use a man-made unit to describe loudness called the decibel. The decibel is usually abbreviated by using the nomenclature dB. When the dB is used, we no longer refer to the sound intensity as sound pressure, but as the sound pressure level (SPL).

The Bel, as defined, is the logarithm (base 10) of the ratio of the measured pressure fluctuations to a reference pressure (p_0), which is normally selected as the threshold of hearing. The equivalent num-

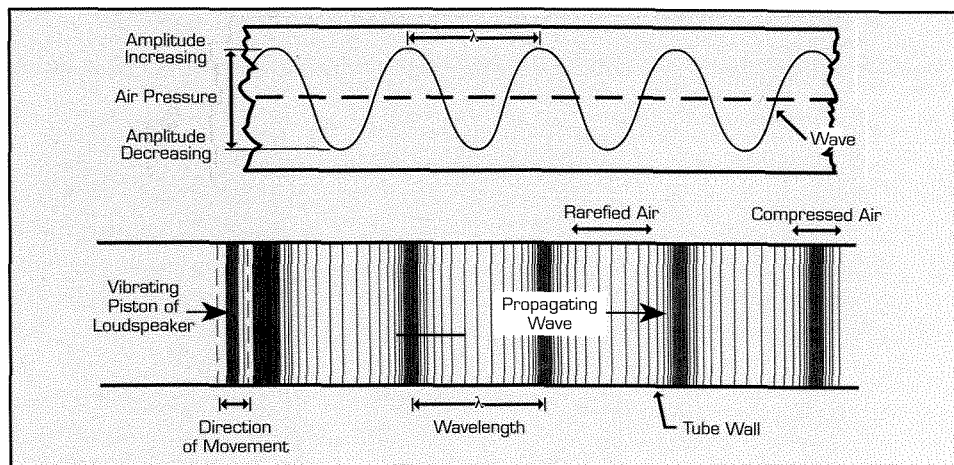


Figure 1

ber of decibels would be ten times a Bel. Mathematically:

$$\text{SPL (dB)} = 10 \log_{10} (p^2/p_0^2).$$

Using simple mathematics, this could also be written:

$$\text{SPL (dB)} = 10 \log_{10} (p/p_0)^2$$

or

$$\text{SPL (dB)} = 20 \log_{10} (p/p_0).$$

The use of the logarithm not only reduces the large range of values we must deal with (see Figure 2), but also corresponds more closely to the way our ears perceive sound. The range now extends from 0 dB (threshold of hearing) to about 130 dB (threshold of pain).

Because dB are on a logarithmic scale, they do not add in a linear fashion. This means that an increase in the sound power by a factor of two, would only result in an increase of 3 dB. Put another way, if we had two sources, each at 70 dB, the sum of the two would be 73 dB. It can also be proven that:

$$1 \text{ dB} + 1 \text{ dB} = 4 \text{ dB}$$

This can be easily calculated mathemati-

the small pressure fluctuations called the root-mean-square pressure and abbreviated by p_{rms} . The intensity of sound has been proven to be proportional to the square of p_{rms} or: $(p_{rms})^2$. The ear can sense pressure fluctuations as low as 2×10^{-5} Newtons per square meter which is usually considered the threshold of hearing for a normal healthy ear. Of course this leaves me out because I like rock-and-roll. The ear is also capable of sensing much greater pressure fluctuations until the ear is damaged (the threshold of pain is considered to be about 63 Newtons per square meter). It can be seen that the ear can detect pressure fluctuations changing over a range of 10,000,000!

The ear has a protective mechanism in that it does not respond in a linear fashion. If the ear did respond linearly, you could not hear the very soft sounds without losing your hearing when loud sounds occurred. In addition, this large range of pressure fluctuation values is hard to deal with mathematically. To overcome these two

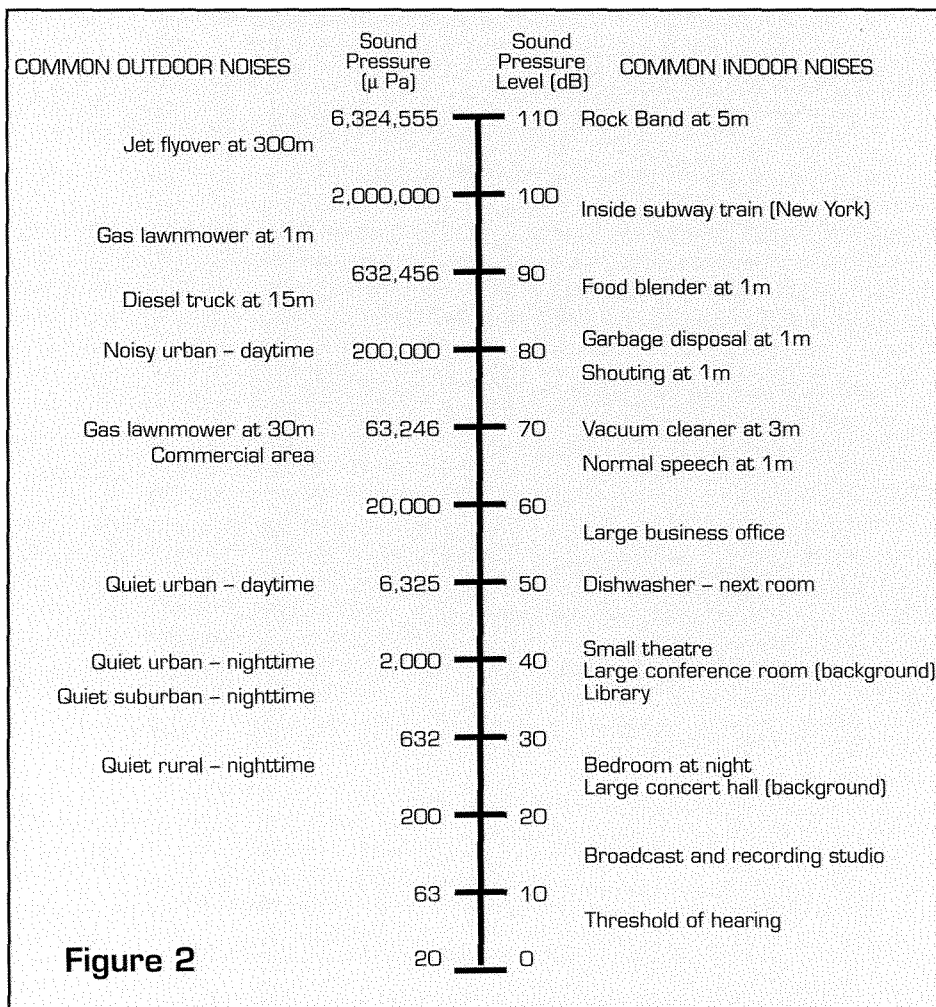


Figure 2

cally using the equation:

$$SPL_{total} = 10 \log_{10} \sum 10^{SPL/10}$$

What this equation does is changes the SPL back to sound power, sums all the sound power which is on a linear basis, and then changes the total sound power back into sound pressure levels, or dB.

Sometimes we just want to approximate the total SPL and our calculators are not handy. To overcome this non-linear problem we can use the simple chart shown in **Figure 3**.

QUESTION: If all traffic parameters stay the same, but traffic volume is doubled, how many dB will the sound level increase?

ANSWER: 3 dB.

QUESTION: If the traffic on a highway were to increase by a factor of 10, and everything else stayed the same, what is the increase in dB?

ANSWER: 10.

Under laboratory conditions, a normal healthy ear can determine a change in SPL corresponding to about a 3 dB change. In outdoor situations, a determination of change is usually greater than 3 dB. Also, in outdoor conditions, a change of 10 dB (10 times the sound power) is generally judged to be a doubling of the sound level.

This means that a significant change in traffic patterns or alignment must occur for individuals to objectively determine a change in sound levels.

FREQUENCY

The ear also shows an extraordinary determination of frequency. The healthy ear can determine sound pressure fluctuations occurring from about 20 times a second to 20,000 times a second. These occurrences per second (cycles per second) have the unit of Hertz (Hz). The Hz is a measure of the cycles per second, or frequency, of the sound wave.

The normal, healthy ear can hear from

about 20 to 20,000 Hz. It is the frequency that provides the tonal quality to sound. A flute has a much higher frequency than a bass guitar and we are adept enough to easily tell the difference.

Again, as a protective mechanism, our ears do not hear all frequencies equally well. Low frequencies (less than 500 Hz) are greatly attenuated while higher frequencies (greater than 10,000 Hz) are also attenuated. A sound is not described just by loudness (intensity), but the frequency spectra must also be described. We could measure the intensity of each frequency to completely describe the sound, but this would be unwieldy. Sound levels could also be reported in octave bands or one-third octave bands, and this is commonly done for research but would be difficult to control with regulations in an urban environment. Octave bands will be discussed in a later 'session'.

To overcome these difficulties and still allow complete reporting of a sound, three basic scales have been developed. The **A** scale is the way our ears respond to moderate sounds, the **B** scale is the response curve for more intense sound, and the **C** scale is the way our ears would respond to very loud sounds.

To be complete in reporting, a sound level should be defined for loudness (dB) and frequency components and this could be accomplished by adding the total contribution from each frequency band on an A-weighted basis and reporting a single number. This is normally done for community noise regulations, description and measurement. Sound level analyzers typically incorporate these weighting factors directly during measurement. Correct reporting would be "## dB (A-weighted)", where ## represents a numeric value.

The above reporting is still not complete. The duration of the sound must also be accounted for.

DURATION

The duration that a sound occurs is very important. A firecracker may be loud, but

(Continued on page 16)

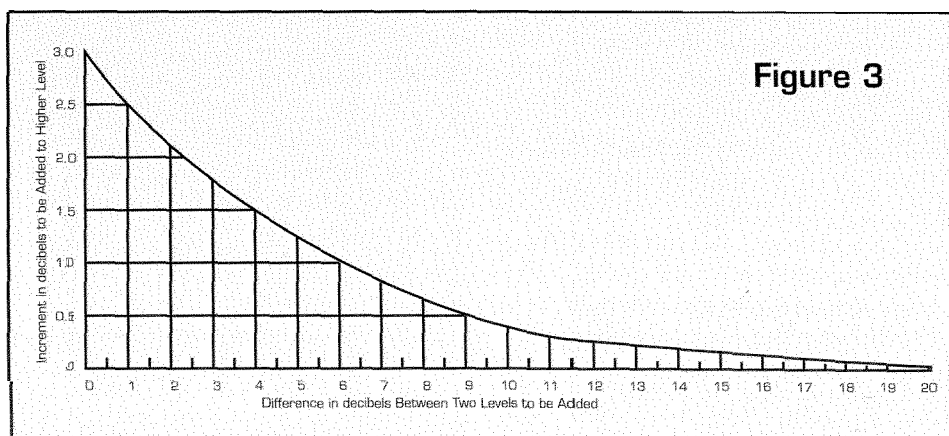


Figure 3

Sound Fundamentals, from page 15

lasts only a fraction of a second. Traffic sounds may not be as intense, but are continual. To account for the duration of the sound and allow for the effective description of how intensity varies with time, various descriptors are used. Some of the more important descriptors in regard to traffic sounds are: $L_{\max}$ (1hr); L_{xx} (1hr); L_{eq} (1hr); and L_{dn} .

In each of these descriptors, the capital L represents that each is a sound pressure level, and is an abbreviation of SPL. Accordingly, we know the units to be dB. For $L_{\max}$, L_{xx} , and L_{eq} , the designation of (1hr) shows that each is for a one-hour time period, which is typical of standards and criteria. It should be noted that any time period could be specified. The time period for L_{dn} is 24 hours by definition and will be discussed later.

$L_{\max}$ represents the maximum sound level that occurs during a defined time period. Accordingly, $L_{\max}$ (1hr) would be a descriptor that defined the maximum sound level that occurred during a one hour time period. For example, "60 dB (A-weight); $L_{\max}$ (1hr)" would completely define the sound level and represents a one hour time period when a maximum sound pressure level of 60 dB on an A-weighted scale occurred.

L_{xx} is a statistical descriptor, where the subscript xx represents a numeric value. The numeric value represents the amount of time in a defined time period that the reported level is exceeded. For instance, a reported sound level of "60 dB (A-

weight); L_{10} (1hr)" would mean that a sound pressure level of 60 dB on an A-weighted scale was exceeded 10 percent of the time in a one-hour time period. The numeric value may be any percentage, but L_{10} , L_{50} and L_{90} are most commonly used. L_{90} is the sound pressure level exceeded 90 percent of the time and is commonly used as the background level.

L_{eq} is the equivalent sound pressure level. L_{eq} is a single number metric that represents the value of a non-varying tone over a defined time period that contains the same acoustic energy as a varying tone. One might think of L_{eq} as an average acoustic energy descriptor. It should be noted that the average energy is not an average of SPL over the time period because of the logarithmic nature of the dB. We will look at L_{eq} in more detail in later "classes".

The Federal Highway Noise Abatement Criteria are listed as L_{10} and L_{eq} (but only one can be used in a report) and will be discussed in a later **ION** "class". These descriptors have also been used in Europe, Asia and Australia.

The descriptor L_{dn} , the day/night level, is by definition a 24 hour metric. L_{dn} is sometimes shown as DNL (day/night level). L_{dn} takes into account that not only is duration important, but the time of day the sound occurs is also important. If your neighbor has a visitor who continues to honk a car horn at 2 p.m., the sound may not bother you tremendously, but at 2 a.m., as you try to sleep, you might become quite annoyed.

To account for this fact, L_{dn} consists of hourly

L_{eq} (A-weighted) values, energy averaged over the entire 24 hour period, with a 10 dB (A-weight) penalty added for the time period from 10 p.m. to 7 a.m.. This means that to meet standard or criterion using L_{dn} , the sound pressure must be 10 times lower in the nighttime hours. The U.S. Department of Housing and Urban Development (HUD) and the Federal Aviation Administration (FAA) use L_{dn} .

QUESTION: If an airport has a constant sound intensity of 65 dB (A-weight); L_{eq} (1hr), what percent would the nighttime flights have to be reduced to not violate an FAA criterion of 65 dB (A-weight); L_{dn} ?

ANSWER: 90 percent.

SUBJECTIVITY

Until now we have discussed characteristics of sound that may be quantified. However, individuals have different responses to various sounds and as such, whether the sound is desirable or not is quite subjective. Rock music to one listener may be a refreshing sound, but to another listener, only noise. **Unwanted sound is commonly referred to as noise.**

In regard to traffic sounds, some consider the sounds to be more intrusive than others, and hence noise. It may not be possible to please all highway neighbors. Even if criteria and standards are met for highway projects, some individuals may still be irritated by the noise. This will be discussed as we continue our "classes". ■

(To be continued in Issue No. 9)

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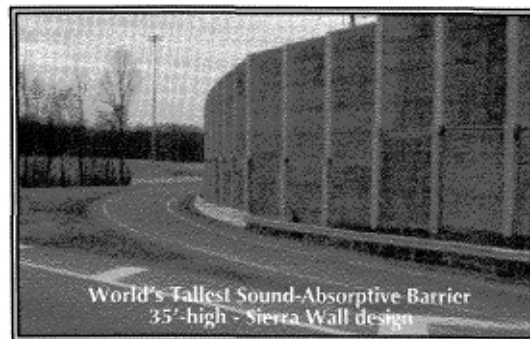
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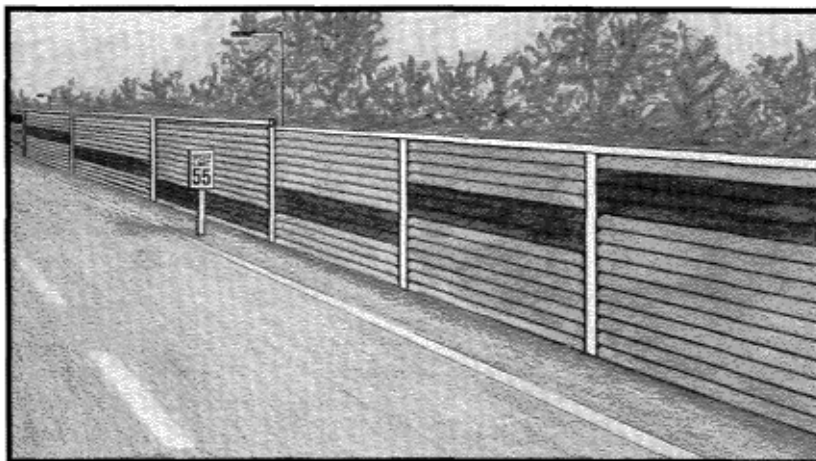
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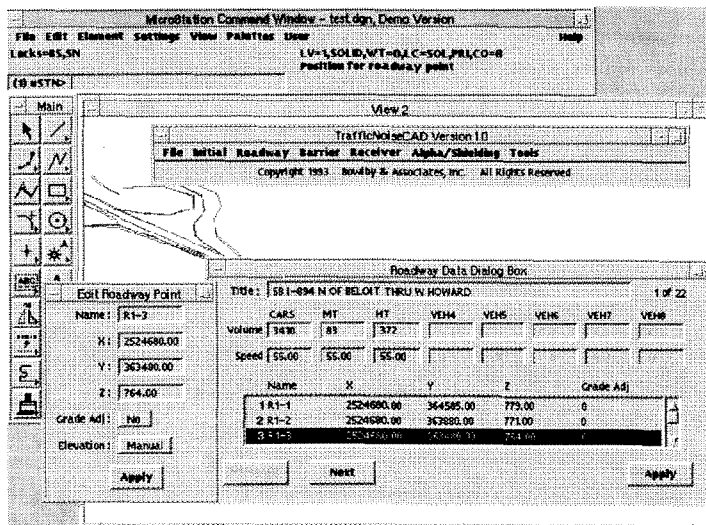
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