The Wall Journal™

The International Journal of Transportation–Related Environmental Issues

9

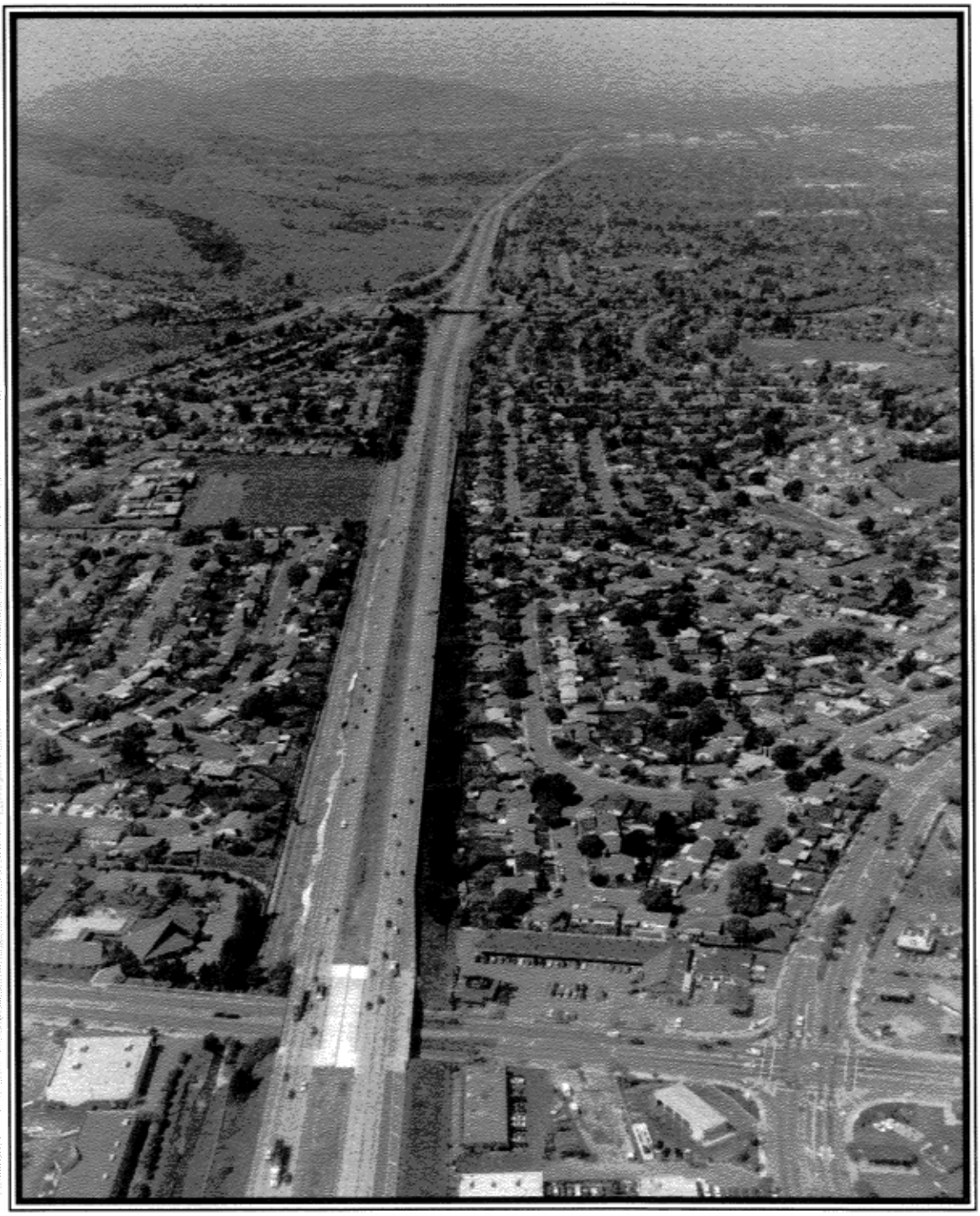
September/
October
1993

This Issue: More Pages...More Features...More Photos...

Cover: Caltrans' Contra Costa County Freeway (I-680)

(Story on page 6)

Also In This Issue:



The Wall Journal

The International Journal of Transportation-Related Environmental Issues

Volume Two, Number 9
September/October, 1993

The Wall Journal is published six times a year. Issues are mailed bi-monthly on or about the middle of the first month in the two-month issue date.

The Wall Journal is a publication of AcoustiCom Publishing Corporation. Editorial, subscription and advertising offices are located at 3011 Voyage Drive, Stafford, Virginia 22554. Tel: 703 720-0282, FAX: 703 720-0598.

Submissions of papers, articles, letters, and photographs for publication should be addressed to The Wall Journal, P.O. Box 1286, Stafford, VA 22555-1286.

Editor
El Angove

Director of Publications
John G. Piper

All material submitted becomes the property of The Wall Journal, and may be edited for length, clarity and accuracy. Material will not be returned without special arrangements prior to submission. The Wall Journal will not be responsible for lost or damaged materials.

Published articles, comments, letters, papers and advertisements do not necessarily represent the views and/or endorsements of The Wall Journal. The authors of submitted material are solely responsible for the truth and accuracy of their submissions, and The Wall Journal cannot be held liable for any damages suffered by our readers as a result of their use of published material.

Circulation is made to government agencies, consulting engineers, scientists, universities, contractors, vendors and others with an interest in transportation-related environmental issues.

Subscription and advertising information are shown on the back cover page 24.

* * * * *

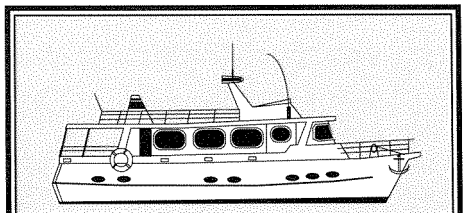
The Wall Journal is composed in its entirety on Apple Macintosh computers using Quark**XPress** electronic publishing software.

Printed in the U.S.A.

Editor's Corner

by El Angove

When I retired from selling highway noise barriers a couple of years ago, my wife and I had plans for selling our house and all our worldly possessions, and buying this nice big boat. We had already picked out this beautiful cruiser, on which we were going to visit various ports-of-call at our leisure.

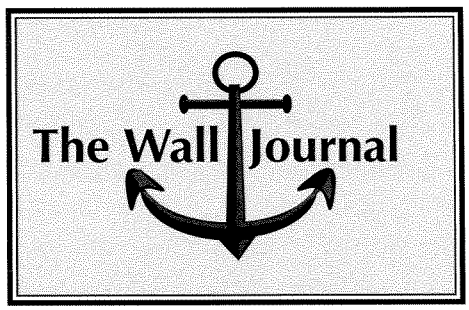


Our Boat

There would be no mortgage to pay, no real estate taxes, no utility bills, no pressure. The world would become our oyster.

However, that was not to be, My dear wife passed away the day after I retired, and the great plan melted away. Now, all I have is this nice big picture of my nice big boat hanging on my nice big wall.

But, at least I have the anchor:



A very good friend of mine somehow convinced me that it would be in my best interest to publish a journal on transportation-related environmental issues. That sounded like a splendid idea to keep me busy and out of the bars. Well, it has kept me extremely busy and several bars have closed since I can no longer get out to visit them. I can only watch Cheers on television and suffer.

I don't like to whine, but this is not my idea of retirement. I'm working a lot longer hours than I ever did selling noise barriers, and I can't retire from **this** endeavor. Also, I make a whole lot less money than I used to; Social Security doesn't go very far.

And, I have discovered that desktop publishing is more financially punishing than it is rewarding. I haven't yet found out what I am doing wrong. The subscriptions have been very disappointing. The Journal appears not to be of much appeal to consulting engineers. If it weren't for the advertisers (and my nest egg), I would be out of business.

Therefore, I have begun culling non-paying private sector subscribers from our mailing list, and adding more and more government employees to the list of those receiving free subscriptions.

I would like all of you readers in government to encourage your associates who have interest in matters such as are discussed on these pages, to fill out a registration (see page 23) and join in our activities. Register the names of your superiors who are instrumental in your career advancement and salary increases.

With a little help, we'll be around for a long time. ■

In the Next Issue:

Caltrans' $6 Billion HOV Lane Program

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

Update on New FHWA Model (Part II)

The Winners of Caltrans' Innovative Sound Design Contest

Summaries of Professional Papers – Part II

And More ...

NEW FHWA MODEL AND SOFTWARE — A CONTINUING SERIES

By: Gregg G. Fleming (US DOT)
Robert E. Armstrong (FHWA)
Steven A. Ronning (FHWA)
Grant S. Anderson (HMMH Inc.)

This article is the first in a series of articles to appear in The Wall Journal addressing the continuing development of the Federal Highway Administration's (FHWA) next generation of highway noise prediction model and implementing computer software (model/software). The new model/software, scheduled for release in middle to late 1995, will ultimately replace the current FHWA model (report No. FHWA-RD-77-108) and software (STAMINA 2.0). This article presents the developmental status of the new model/software along with a brief discussion of its planned components and capabilities. Future articles will update the status of the project and present a more detailed discussion of the components and capabilities of the model/software.

On June 18, 1993 the United States Department of Transportation, Volpe National Transportation Systems Center (Volpe Center), in support of the FHWA, awarded Technical Task Directive (TTD, i.e., contract) VA3203, "Development of Highway Noise Prediction Model and Implementing Computer Software", to Foster-Miller, Inc. (F-M) and Harris Miller Miller and Hanson Inc. (HMMH). F-M's role in the project is primarily administrative, while HMMH will take the lead technical role. Grant S. Anderson of HMMH has been assigned as Principal Investigator for the development of the model/software. Christopher W. Menge, also of HMMH, is the Assistant Principal Investigator.

Development of the database for the model/software, including all field measurements, will be performed by the Volpe Center under an expansion of the National Pooled-Fund Study, "Evaluation of Performance of Experimental Highway Noise Barriers" (NPFS). Specific data to be measured will include: (1) vehicle noise emission level data for both constant-flow and interrupted-flow traffic, on level grade and upgrade; (2) one-third octave-band subsource height data; and (3) multiple barrier diffraction data.

Funding for the project is from two sources: (1) the FHWA, Office of Environment and Planning, is funding the development of the model/software, estimated at $1.2M, through Research and Development funds; and (2) the state transportation agencies, through the FHWA, Office of Engineering and Highway Operations Research and Development, are funding the development of the database for the model/software, estimated at $300K. To date, the following states have contributed Fiscal Year (FY) 1993 funds to the NPFS totaling $45K: California, Florida, Georgia, Iowa and Pennsylvania. Only one state has contributed FY 94/95 funds — Michigan has provided $50K ($25K for FY 94 and $25K for FY 95). With the cost of the field measurements estimated at $300K, a significant amount of additional support from the states is required to insure the success of the project.

Model/software design and development is proceeding according to schedule. To facilitate the design process and insure public acceptance of the model/software, a technical "brainstorming" session has been scheduled for October 12-14, 1993. The session will take place at the Volpe Center in Cambridge, Massachusetts. All members of the model/software technical review panel are expected to attend. The review panel consists of members of the FHWA, the Volpe Center, and several state transportation agencies. All deliverables

(Continued on page 14)

TRB COMMITTEE A1F04

By Domenick Billera, Chairman

The Summer Meetings of the A1F04 Committee on Transportation-Related Noise and Vibration have been growing steadily in attendance since their inception in 1978. This year's meeting in Berkeley, California surpassed all with a record 140 attendees. The meeting was co-hosted by the California Department of Transportation and the consulting firm of Wilson, Ihrig and Associates of Oakland.

The prime reason for the increased attendance is the format combination of formal meetings, field tours and the after-sessions informal gatherings where highway officials, consultants and vendors all have ample opportunity to meet each other and exchange ideas and information. Not to mention that spouses and member guests are also invited.

The hard work of preparing and presenting professional papers at these meetings is 'mitigated' by the great comradeship established among the attendees both in session and after the work is over for the day. Long-time personal friendships have developed from these great meetings, which has done much to increase the interest in the activities of the A1F04 Committee and to maintain the high professional quality of the papers. The members of A1F04 are among the nation's leaders in research, planning and engineering of transportation noise and vibration mitigation.

I wish to extend my personal thanks and congratulations to all the persons at Caltrans and Wilson, Ihrig and Associates for their dedicated work in putting together all of the elements for a very successful meeting.

Special thanks to President George Wilson, Vice President James Nelson, and Technical Coordinator Kash Gill of Wilson, Ihrig Associates , and to Dianne Steinhauser, Branch Chief of Environmental Engineering for Caltrans District 4. Your hard work paid off handsomely.

A final word before you look at the random snapshots on the next page — The 1994 Summer Meeting will be held in the Philadelphia area. Start making your plans now. We want a new record attendance. Further information will appear in this column in future issues. ■

MEETING HIGHLIGHTS

The Professional Papers

The Agenda for Presentations was printed in the last issue. See page 10 of this issue for Part I of the summaries.

The Working Tours

Lockheed Missiles & Space Company Structures/Dynamics Test Lab
San Francisco BART Pittsburg-Antioch Extension
Oakland Airport Noise Monitoring System
I-680 Soundwalls (see article on page 6)

After-Sessions Social Gatherings

Pre-Session Welcoming Reception
Dinner Cruise of San Francisco Bay aboard the Hornblower Yacht
Dinner Party with an Alcatraz Theme

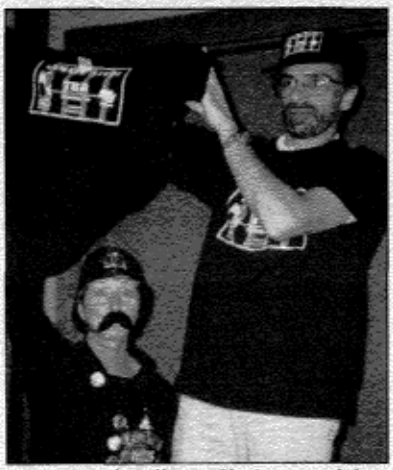
PHOTO OPS FROM THE A1F04 SUMMER MEETING

James Nelson, Vice President of Wilson, Ihrig & Associates, inc., and Dianne Steinhauser, Caltrans Bureau Chief of Environmental Engineering, compare notes on the Speakers' Agenda

Group re-entering one of the two Caltrans buses after one of numerous stops on I-680 Tour of Soundwalls

Part of the happy crowd at the 'Alcatraz Theme' Dinner Party

George Wilson, President of Wilson, Ihrig & Associates, Inc. welcomes Attendees at Opening of the Presentation Sessions



Domenick Billera, Chairman of the A1F04 Committee, shows one of the ticket lottery prizes (a 'prison guard' coyly peeks out at the camera).

Caltrans' Contra Costa County Freeway (I-680)

A Story of Environmental Issues in Conflict

By Dianne Steinhauser

Stretching from Walnut Creek to San Jose, Interstate 680 carries over 200,000 vehicles per day to business parks, manufacturing sites and shopping malls. Nearly half of this section of I-680 through Contra Costa County is scheduled to be widened by one additional lane, a High-Occupancy Vehicle (HOV) lane. This transit/carpool lane will provide an important link to the over 400-mile HOV system being built in the San Francisco Bay Area.

Driving this stretch of freeway 12 years ago, you would have been on a four-lane freeway instead of the eight- or even ten-lane freeway it is now. Most of the traffic then could then have been handled by one lane each way for much of the day. You would have looked out your car windows to see the rolling green hills that turn golden brown in the summer, dotted by ranches and an occasional residential area. More recently, however, as you drove south from Walnut Creek, you would see only an occasional open area, as the Contra Costa (CC) Corridor has experienced an incredible boom in growth, with huge business parks, compact housing developments, and burgeoning commercial areas occupying nearly the entire Corridor.

Faced with the HOV widening project, as well as the likely addition of another general purpose lane in the near future, Caltrans District 4, the California Department of Transportation in the Bay Area, performed both a federal and state environmental impact study. Part of that effort was the assessment of the need for soundwalls, as the project would cause a traffic increase and move the traffic closer to residences, parks, churches and schools along the Corridor. Following Federal Aid Program Guide 7.7.2, as well as guidance developed by Caltrans' Office of New Technology, Materials, and Research (NTM&R, the research and development arm of Caltrans in their Sacramento headquarters), District 4 prepared a noise report on the Corridor calling for 10 miles of soundwalls to be built. These soundwalls served as mitigation for the existing traffic noise as well as the future project-caused noise.

Land values are some of the highest in the nation in the Bay Area. Due to this, Caltrans achieved the widening of CC-680 almost entirely within existing rights of way, widening out to the edge of the State-owned freeway. This necessitated building many of the soundwalls on top of concrete barrier, the familiar vehicle-redirection "Jersey" barrier, or "Type 50" barrier as it is known in California.

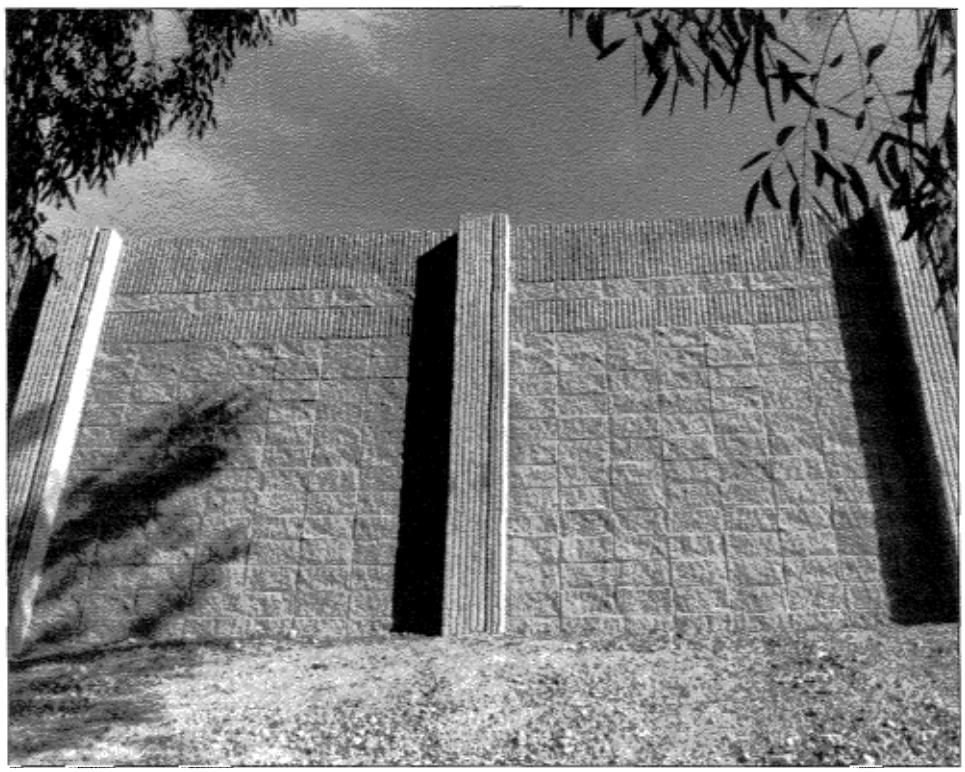
In an attempt to reduce the cost of the soundwalls, estimated at $1 million per mile currently (or $200/linear foot for a typical 12- to 14-foot high wall), Caltrans undertook an extensive value engineering study. This effort showed that if precast concrete panel walls could be built, and the panels could be relocatable, then the project to widen CC-680 in the late 1990s could reuse the panels. An early estimate showed up to a 40 percent savings if the panels could be successfully reused.

Caltrans began meeting with local governments and citizens when the environmental clearances were near completion, continuing consensus-getting through the design phase of the project and even into construction. The Soundwall Committee that was formed worked to select details of the walls, such as form, pattern and color. The panels that finally went up were the most intricately detailed panel walls ever built in the Bay Area, with a wall pattern on the roadway side meant to replicate existing masonry block walls in the Corridor, colors meant to match architectural color themes in each city, and the community sides of walls meant to match existing property walls and be aesthetically pleasing to homeowners.

CC-680 from Highway 24 in Walnut Creek to the Alameda/Santa Clara County line is a designated California Scenic Highway. California began its Scenic Highway program in 1963, with the intention of protecting certain roads from advertising signs and other features marring the natural landscape. When addressing the scenic values of CC-680, Caltrans debated on the effect the walls would have. The consideration of noise barriers was a requirement in order to qualify for federal funding.

On the other hand, the miles of noise barriers would no doubt have an effect on the viewscape when driving the route. Caltrans chose to proceed with the soundwalls, judging that the original natural scenic aspects of the Corridor were already gone, due to the massive residential, commercial and business development. Attention to the details of the walls was paid in an attempt to make the walls themselves more aesthetically pleasing.

The walls started going up in the Fall of 1991. As would happen every Fall along



The panel surfaces on the roadway side of the precast concrete walls are textured to replicate the appearance of existing masonry block walls in the Corridor, using a machine called "The Impressor," described elsewhere in this issue, and are colored in earth tones to match colors in the community.

the CC-680 Corridor, temperature inversions would occur, forming layers of air that abruptly change in temperature as you increase height above ground. Wind shear was also likely as weather systems consistently move in off the nearby Pacific Ocean and are carried over the East Bay hills, swirling down into the valleys bordering the freeway. As the fate of timing would have it, the new walls were seen by the citizens as causing tremendous increases in noise at receptors 1,000 feet to two miles from the freeway. Twenty-four-hour field measurements taken after construction of the walls yielded readings well below the Federal Noise Abatement Criterion of 67 dBA [L_{eq} (h)] at the noisiest hour. Measurements taken immediately behind the walls indicated decreases of up to 10 dBA. Despite these readings, communities became divided as to whether the walls really worked.

A second outcry went up over the appearance of the walls. In order not to have to buy any more costly right of way, walls were often erected right along the edge of the shoulder. Sections of CC-680 remained open to view, yet citizens decried the fact that scenic viewscapes were now walled off, that driving the Corridor was monotonous, that the walls were downright ugly. On an adjacent project in Walnut Creek, masonry block walls received only praise. Yet the relocatable panel walls, designed to replicate the masonry walls, received adverse comment from the community.

Caltrans immediately stopped the wall construction, and went back to the local governments and the citizens along the Corridor. Picketing of public meetings by anti-wall coalitions and even an attempt to blow up a soundwall occurred. Local jurisdictions quickly abandoned their pre-project acceptance of the walls. However, when the final vote was cast by the Contra Costa County Board of Supervisors, the vote was for soundwall construction to continue. It was at these critical Board of Supervisors meetings that those residents whom the walls were protecting from worst case future traffic noise as high as 80 to 85 dBA finally made their voices heard. The remaining walls are now under construction.

Meanwhile, Caltrans is conducting further research into what might be happening at receptors 1,000 feet to two miles away from the freeway, assessing in detail meteorological affects and potential shifts in frequency. As well, on all future soundwall projects, the local government will be asked for their concurrence in advance. They will be made aware of the issues of public concern such as views being blocked and the character of the community being changed by measures to be taken to protect the community from highway traffic noise.

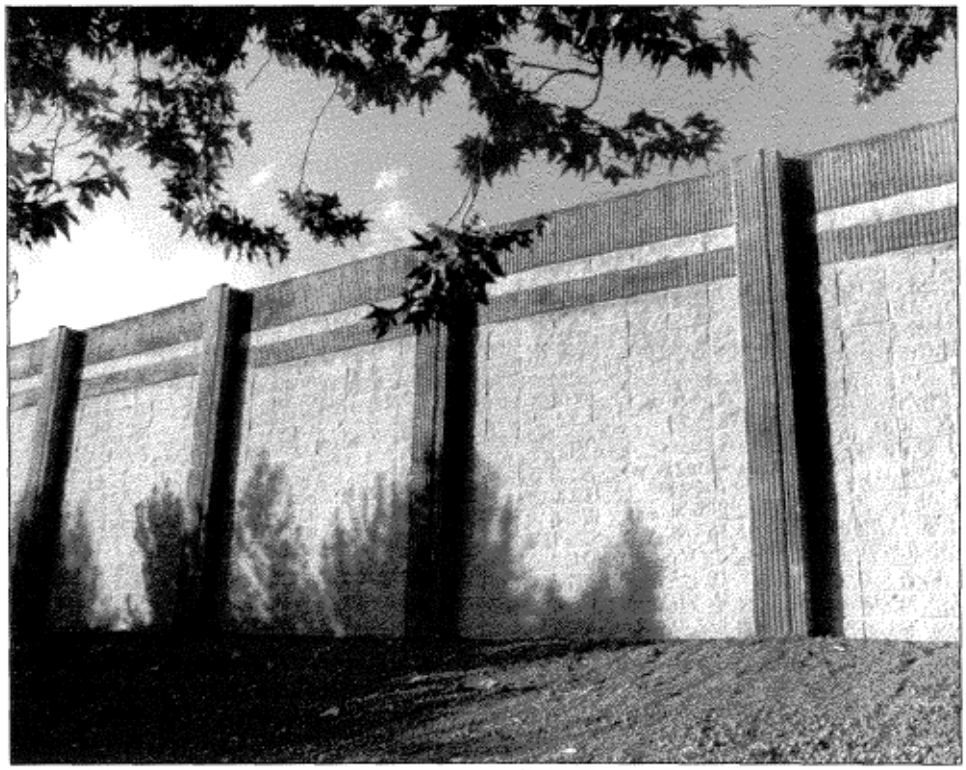
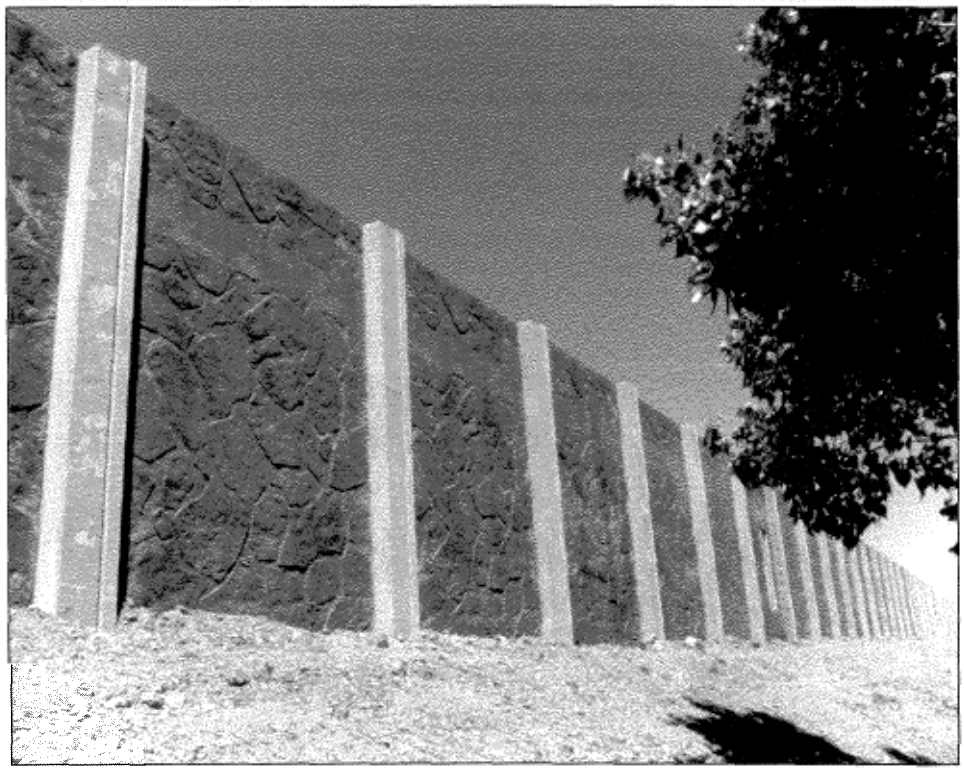


Photo above: Contrasting earth tone colors are used to enhance the aesthetics of the soundwalls, again to replicate the appearance of existing masonry block walls in the Corridor.
Photo below: The residential side of the walls are textured to match existing property walls in the community, to make them more aesthetically pleasing to the homeowners.



And, finally, Caltrans is attempting to walk that fine line between reducing the costs of the walls and providing more aesthetically pleasing soundwalls. What must always be kept in mind, however, is that in earthquake country, the walls being seismically safe is a top concern.

For even more information on this experience and future efforts, you are welcome to contact Dianne Steinhauser, Branch Chief of the Environmental Branch, Caltrans District 4, 111 Grand Avenue, 14th Floor, Oakland, CA 94612. Telephone (510) 286-5678, fax (510) 286-5642. ■

New Product Announcements

The Impressor

In October of 1991, Concrete Products, Inc. of Redmond, Washington was awarded a contract to construct 500,000 square feet of precast concrete soundwall along Interstate highway 680 in Contra Costa County, California. At that time, Concrete Products' Northern California plant in Tracy, California was producing precast concrete items such as highway median barriers and earth retaining wall panels. To facilitate a job of this size would require a major upgrading of forming tables, maintenance and finishing areas, and stockpile areas.

The design of the precast walls was unusual in that Caltrans specifications called for nine different combinations of painted textures of fractured rib, fractured granite, and smooth bands for the freeway side of the soundwalls. For the community side of the walls, they specified a masonry block or stone textured pattern utilizing pigmented surface hardener for coloring.

Doug Meyers, an engineer for Concrete Products, working in association with Gary Fjelland at Helser Industries in Tualatin, Oregon, began investigating methods for producing the imprinted textures on the community side. The main concern was finding a method to imprint a texture on a large exposed surface area of approximately twelve feet wide by eighteen feet long. To be cost effective and meet project schedules, Concrete Products figured they would have to produce approximately 3,000 square feet of panel per day of the imprinted precast panels. Meyers developed an idea for imprinting the panels in a way similar to using a printing press. This method had not been replicated in the industry before. He developed a machine called "The Impressor", which could imprint up to 300 square feet at a time. Concrete Products has since patented this device.

The basic idea behind The Impressor was that precast concrete panels would be poured on rubber lined steel casting tables laid out similar to an auto assembly line with tracks on both sides to allow machines to pass over the tables performing different functions. The Impressor itself would be the last machine and would imprint the panels with either the masonry block or stone texture using a large steel form lined with the appropriate rubber liner. The Impressor sweeps through a controlled profile in a rocking motion parallel to the panel, engaging the wet, color-hardened concrete and imprinting the proper texture on each panel. This process would be repeated as The Impressor continued down the line, imprinting up to 20 panels per day, each with near identical results.

The Impressor process opened up many product possibilities in the precast concrete industry. Wall surfaces with textures on both sides, beyond

your most basic finishes (rake, broom, exposed aggregate), had been very costly to produce, due in large part to a vertical double form and double liner cost. By using interchangeable liners, a single Impressor machine can adapt to various sizes and patterns to produce nearly any type of wall at a cost effective price.

The precast panels for the I-680 project had an average surface area of approximately 170 square feet and weighed, on average, 14,500 pounds. Loaded onto trucks vertically, three panels per truck were shipped on double drop trailers with an attached A-frame to the job site. The panels were off-loaded on the freeway by the general contractor, Ball, Ball & Brossamer of Alamo, California. Using a crane, they were able to set an average of 51 panels in an eight hour shift. Each panel had a steel baseplate connection which would be attached to a concrete pile at each end of a panel by four anchor bolts embedded in the pile. The anchor bolts slide up through the baseplate and are nutted above and below. The installation at that point is complete, and this bolt and baseplate connection allows each panel to be removed or relocated if necessary, with very little time or expense involved.

Concrete Products completed the I-680 project in approximately 10 months, including yard set-up, production, and panel delivery. They currently produce residential and highway soundwalls using The Impressor technology at their permanent facilities in California, Oregon and Washington. A company called Concrete Impressions, Inc. of Denver, Colorado is actively pursuing precast projects across the country and marketing The Impressor to other precasters for sale or franchising. Phone Joe Cornell at (303) 455-1717 for more information. ■

SUMMARIES OF PROFESSIONAL PAPERS

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

The Summer Meeting of the TRB A1F04 Committee on Transportation-Related Noise and Vibration was co-hosted this year by Caltrans and acoustical consultants Wilson, Ihrig & Associates, Inc. of Oakland. Listed below are the professional papers in the order in which they were presented at the conference. Twenty papers were presented; the remaining papers will be published in the November/December issue of The Wall Journal.

MANAGING THE FLOOD OF DATA IN AIRPORT NOISE MONITORING SYSTEMS

Over the last few years, airport noise monitoring systems (NMS) have evolved from systems producing simple acoustical reports to complex networks integrating noise, flight tracks, complaints, land use, and other data. While the additional data provided could help an airport manage noise more effectively, in many cases it simply overwhelms them. For an NMS to become a useful tool rather than a millstone of data and procedures, the NMS vendor must ensure that its system truly integrates into existing operations, intuitively facilitates the investigation of noise-related problems, and clearly communicates the NMS's findings.

Although airport noise offices share common NMS requirements, each has specialized needs to which the system must adapt. One approach to adaptability is a generic NMS which encompasses all airports' needs. New features evolve slowly, when sufficient demand arises to define the common requirements and to implement them in the system baseline. A more responsive alternative employs a "building block" approach, where each installation is assembled from standardized modular components to meet the airport's unique requirements. To succeed in this approach without adding unacceptable cost and risk, the components must be tailorable without software development, and standard inter-component communication must allow new features to be added without jeopardizing existing functions. These features permit the vendor to integrate its system with the established work flows of the airport noise office, rather than forcing the noise office to adapt to the NMS.

To enhance communications with surrounding communities, airport management, and regulatory agencies, an NMS must supplement its on-line analyses with printed reports. It is important to distinguish these presentation report requirements from simple record-keeping reports. As with on-line analyses, presentation reports need to distill an overwhelming amount of data into cogent high-level summaries. Since the audiences for these reports are often non-technical, these reports must present their results graphically for ease of interpretation, while accurately representing the underlying data. The NMS must facilitate the creation of these reports, while the vendor must provide strong technical guidance to ensure the reports' clarity and veracity. When an NMS clearly communicates its findings, it achieves its goal of educating and informing the public.

Authors: Dan Ingold and Mark Karmelich (310) 539-9555
Organization: The Flood Group, Inc., Torrance, CA
Author: Paul Dunholter
Organization: Mestre Greve Associates Newport Beach, CA

LAGUARDIA AIRPORT GROUND-NOISE ABATEMENT STUDY

In response to community concerns regarding noise at LaGuardia Airport during the nighttime, the Port Authority of New York and New Jersey (The Port) commissioned Harris Miller Miller and Hanson Inc. (HMMH) to conduct a noise study along the airport's western boundary. The purpose of the study was to identify major noise sources affecting residents and to assess the feasibility of noise barriers to reduce noise levels. The loudest events were jet aircraft departures, but other significant events included thrust reverses and vehicles on local streets.

Barriers to reduce highway noise in communities are common across the United States; airport noise barriers are less familiar for a variety of reasons. Foremost, community noise exposure near airports is often dominated by airborne aircraft for which noise barriers are ineffective. Even in situations where ground-based noise sources significantly affect noise exposure, the design of a feasible and effective barrier can be limited by long sound propagation distances that reduce barrier effectiveness and increase the opportunity for degradation of performance by weather conditions. In addition, excess ground attenuation often must be confronted due to large expanses of "soft ground" near airports.

The LaGuardia study involved many of these technical issues as well as a public-relations challenge due to the contentious history between the Port and the active, well-organized community. HMMH predicted potential barrier performance by first recording noise sources and then performing 1/3 octave band analyses using methods appropriate to each prediction location. These included the algorithms of STAMINA 2.0, Foss's double barrier algorithm where existing buildings provided shielding, and Piercy and Embleton's DIFRCT model to account for the presence of soft ground. HMMH compared measurement results to output from the frequency-dependent DIFRCT model to calibrate the ground impedance and to predict the loss of ground effect and, therefore, decreased noise reduction that would result from noise-barrier construction. Failure to account for existing sound attenuation due to ground effect would have resulted in overprediction of the barrier's performance.

Following the development of barrier design alternatives, HMMH portrayed the potential visual impact and acoustic benefits of the various alternatives at a public meeting using renderings and calibrated tape recordings. The community supported the construction of a 20-foot high barrier in one area, but initially rejected construction in another area. Following construction of the first portion of the barrier, however, the community requested that the second portion be built. The Port commissioned HMMH to conduct post-measurements to evaluate the effectiveness of the barrier and the measurements confirmed the predicted barrier performance, including the anticipated loss of ground effect.

Author: Douglas E. Barrett (Sacramento, CA) (916) 568-1116
Author: Christopher W. Menge (Lexington, MA) (617) 863-1401
Organization: Harris, Miller, Miller & Hanson, Inc.

COMPARISON OF INM AND NOISEMAP RESULTS

After a partial U.S. Air Force base closure, there will be both civilian and military flights. NOISEMAP computer model was used to predict noise impacts from various alternatives. In addition, to L_{dn} noise contours SEL values from various aircraft were calculated at sensitive receptor areas. These values were used to evaluate sleep disturbance from future airfield operation. Later, it was decided to use INM computer model instead of NOISEMAP because all military operations will be by transient aircraft and there will be no based military aircraft. Unfortunately INM data base has only six military aircraft. Therefore, the results produced by the OMEGA 10 module of the NOISEMAP were used to prepare noise curves for various military aircraft as required by INM. The procedures used for preparing INM noise curves will be presented. In addition, the differences between SEL values at the sensitive receptor locations and noise contours produced by INM and NOISEMAP will be discussed.

Author: Areg Gharabegian (818) 685-6047
Organization: Engineering-Science, Incorporated, Pasadena, CA

ANALYSIS OF VIBRATION AND ACOUSTICS USING VAPEPS

Vibration and acoustic predictions can be made using the Statistical Energy Analysis (SEA) method. LMSC has developed VAPEPS (VibroAcoustic Payload Environmental Prediction System), a statistical energy analysis computer code to make prediction for the vibration levels of structural members and sound pressure levels in enclosures. The VAPEPS code has been successfully applied to the vibroacoustic design and analysis of many aerospace systems and has been verified with test results. This method can also be applied directly to the vibration and acoustic design and analysis of transportation systems.

Authors: Albert Lee and Vance Anderson (408) 742-5021
Organization: Lockheed Missiles & Space Company, Inc., Sunnyvale, CA

CONSTRUCTION NOISE CONTROL PROGRAM OF A TRANSIT TUNNEL

The existing Westside Light Rail transit line in Portland, Oregon is being extended by Tri-Met from downtown Portland to downtown Hillsboro. As part of the alignment, a three mile, twin-tube tunnel will extend through the West Hills of Portland. The construction of these tunnels will require the excavation of 700,000 cubic yards of rock and dirt. To allow for the round the clock conveyance of the tunnel excavation materials, Tri-Met has applied for and been granted a noise variance by the City of Portland and Washington County to construction 24 hours a day for the full four year and three month project schedule.

This paper describes the Noise Control Program that was developed as part of the 24-hour variance applications. The Noise Control Program is based on an effective noise monitoring plan developed and implemented by the construction contractor and by field verification procedures which will be coordinated by Tri-Met. The following are the Program's objectives:

- To ensure that the contractor is adhering to plans and specifications;
- To evaluate the success of implemented mitigation measures;
- To identify unanticipated construction conditions which would warrant new mitigation measures;and
- To enforce compliance with the Project Noise Criteria.

The information, procedures and guidelines of the Program were aimed at implementing a comprehensive noise monitoring plan which would adequately address public and community concerns related to construction noise of this three mile section of the Westside Corridor Project.

The key elements of the Noise Control Program are based on the following three step implementation procedure:

1. Require the contractor to take noise level measurements, during different stages of construction, to demonstrate compliance with the Project Noise Criteria.

2. A Program of quality assurance to be implemented by Tri-Met. The quality assurance program will require Tri-Met to conduct noise measurements to verify that the noise level measurements taken by the contractor are representative of the noise generated during the construction activity. The program will also serve as verification that the contractor is in compliance with the Project Noise Criteria.

3. Evaluation, tracking and resolution of public complaints regarding construction noise.

Author: Steven Wolf (714) 973-4880
Organization: Parsons Brinckerhoff Quade & Douglas, Inc., Orange, CA

LONG RANGE SOUND PROPAGATION IN A SUBURBAN ENVIRONMENT UNDER THE PRESENCE OF AN INVERSION: A CASE STUDY

The propagation of highway noise in a suburban environment and its correlation with key meteorological variables over distances of up to a mile has been studied by means of continuously logging sound level meters deployed at several locations for periods of up to one week. The statistical information on the noise environment provided by these units, where the effects of atmospheric lapses and inversions can easily be seen, has been correlated with hourly meteorological information readily available from a local airport's weather station. The result of the analysis is given and conclusions are drawn on the usefulness of airport meteorological data in the prediction of CNEL and L_{dn} due to transportation noise in quiet neighborhoods at long distances from the sources.

Author: Pablo A. Daroux (510) 658-6719
Organization: Wilson, Ihrig & Associates, Inc., Oakland, CA

A SUMMARY OF MEASURED SEISMIC WAVE ATTENUATION COEFFICIENTS FOR SOILS

Ground vibration from a variety of sources including transportation vehicles and industrial equipment has been, and will continue to be, a potential problem for buildings. The need to develop and to improve prediction schemes which will determine the expected vibrational excitation of a building is evident. One of the parameters used in any ground vibration prediction methodology is the seismic energy attenuation coefficient of the soil.

Several projects over the last 15 years have provided the opportunity to measure, in situ, the ground propagation properties of seismic waves. Data, from a variety of vibration sources and soil types, has been summarized in the form of the coefficient of attenuation versus frequency in the range 5 Hz to 250 Hz. Also included in the summary are data from the published literature. Although the data exhibits a wide scatter, it is felt that its availability will enhance the effort to predict building vibration.

Authors: Jose C. Ortega and Dr. Hooshang Khosrovani (310) 450-1733
Organization: Paul S. Veneklasen & Assoc., Santa Monica, CA

SOME RECENT UK EXAMPLES OF BUILDING ISOLATION FROM RAILWAY VIBRATION AND STRUCTUREBORNE NOISE

The paper outlines Arup Acoustics experience of an unusual range of building isolation projects in the UK. Criteria for control over railway vibration and structureborne noise are briefly referred to and the approach to isolation is discussed. Although Finite Element and Statistical Energy Analysis are available and are used for railway vibration and noise, the noise of most interest falls over a frequency range where neither is operating well. In response to this, Arup Acoustics has carried out extensive measurements of both substructure and superstructure responses to enable experience and interpolation to support the analysis.

Survey work often involves use of measurements at the base of boreholes. These have been compared with unloaded and loaded pile responses and the pattern of superstructure response has also been evaluated. By using also the established formulae for estimating noise radiated from the structure, the need for building isolation is assessed. Seven examples are referred to. In each case the isolation material and system frequency are referred to, with notes of findings of interest.

America Square is a major office development in Central London, located over Fenchurch Street Station. Isolated conventionally on 10 Hz composite bearing arrays, results are close to target. Data relating to loaded and is unloaded piles and suspended floor responses is of particular interest.

Langham Hilton Hotel involved retention of some existing accommodation behind a listed facade, but also new accommodation behind it. Both sit over London Underground lines and we have interesting comparison of the exposure in unisolated and isolated constructions.

Embankment Place is built over and

(Continued on page 12)

under Charing Cross Station and uses a structural arch as a 2 Hz spring, isolating floors suspended from it. Below the station, an entrance hall is also isolated and some residue of railway noise is masked by a water feature designed for the purpose.

Birmingham ICC includes a Concert Hall designed to meet noise limits close to the threshold of hearing, located within 35 meters of a major Intercity railway. Voided piles are used with natural rubber bearings operating at 9 Hz. Special detailing of services links is extensive. The railway also has under sleeper isolators for which "before" and "after" comparison is available.

Offices, Victoria This project uses 5 - 7 Hz natural rubber bearings set at the base of column and a locally isolated floor.

Offices, Ludgate makes use of 3.5 Hz springs designed to attenuate railway vibration. Vibration residue is so low as to be insignificant. Current rail traffic is not yet worst case.

British Library Meeting Room is a small box in box construction and is designed for long life. Arrangements for bearing replacement are of interest.

Arup Acoustics current acoustic consultancy for the new Concert Hall in Manchester (for the Halle orchestra) includes measures for isolation from the Hall from the adjacent light railway.

Author: Richard Cowell 44-71-636-2853
Organization: Arup Acoustics, London

PREDICTION OF RAIL TRANSIT GROUNDBORNE NOISE AND VIBRATION A CASE STUDY

The prediction procedure for groundborne noise and vibration from rail transportation systems developed by Wilson, Ihrig & Associates, Inc. has been utilized at a number of new and expanding rail transit systems. Along the Metro Red Line in Los Angeles, groundborne noise and vibration from transit train operations have been a major concern at the recently built Jewelers Mall, which contains office/work spaces for wholesale jewelers. These spaces are located directly over the top of two subway bores. Since neither the subway nor the building were built at the time of the initial investigation, a number of assumptions were made to determine whether there would be excessive levels of groundborne noise and vibration from Metro Red Line train operations. Three series of field tests were performed to verify the conclusions and validate the prediction procedures. The first series of tests utilized impulse response testing procedures with boreholes, performed in the fall of 1988 prior to completion of the building and boring of the tunnel. The second series of tests utilized impulse response testing procedures in the completed tunnel with vibration measurements in the building. These tests were performed in February 1991 prior to any train operations in the tunnel. The final series of tests were performed in July 1992 with a 2-car transit train operating through one of the tunnel bores. Details of each test series are presented along with conclusions and information learned which may be applicable to other rail transit systems.

Author: Steven L. Wolfe (510) 658-6719
Organization: Wilson, Ihrig & Associates, Inc.. Oakland, CA ■

Papers, *(continued on page 15)*

Noise Barrier Construction Forecast

The database has been compiled by a polling of state highway officials and other research. This material is intended for use only as a general guide to upcoming noise barrier construction projects. For consultants, contractors and vendors, we recommend that you contact directly the appropriate state highway officials for verification and further information. We assume no liability for the correctness or completeness of any data presented here. The following represent data gathered from 14 states. In subsequent issues, data will be presented covering all 50 states, as well as updates and expanded details.

The Forecast will be provided on a regular basis through the courtesy of LEAP Associates, Inc., consulting structural engineers to the precast concrete industry.

Location	State	Highway	Linear Feet	Wall Height	Square Feet	Bid Month	Bid Year
Colorado Springs	CO		1,100			December	93
Pueblo	CO		2,500			Aug-Sep	94
Colorado Springs	CO		15,000			October	94
Silverplume	CO		1,400			Early	94
Fountain	CO		1,500			Summer	94-95
Denver	CO	I-70				Summer	94-95
Denver	CO	Sheridan Blvd.					95-96
Denver	CO	I-25					95-96
Denver	CO	State Hwy 121					95-96
Denver	CO	Sheridan Blvd.					96-97
Denver	CO	I-25					97-98
Denver	CO	6th Avenue					97-98
West Palm Beach	FL		26,000				93-94
Orlando	FL		3,104	12-14	40,000	January	94
Sumter County	FL		2,100	12-14	27,300		94-95
Orlando	FL		540	12-14	7,000		98
Eagle	ID		1,600			October	93
Eagle	ID		?			October	94
Wood River	IL		2,000				94-95
Hopkinsville	KY						94-95
Covington	KY						94-95
Shreveport	LA		4,500	10-12	50,000	Summer	94
Shreveport	LA		2,000	10	20,000	Summer	94
Shreveport	LA		1,300	16	20,800	Summer	94
Shreveport	LA		6,700	20	134,000	Summer	94
Shreveport	LA		1,000	10	10,000	Summer	94
Shreveport	LA		19,000	10		Summer	94
Shreveport	LA		1,400	10		Summer	94
Shreveport	LA		1,800	10		Summer	94
Baltimore	MD	I-97	10,000			December	93
Baltimore	MD	I-95/495	4,500			December	93
Baltimore	MD	I-95/495	9,000			December	93
Baltimore	MD	I-95	3,200			December	93
Albuquerque	NM	I-40				Spring	94
Reno	NV	US 395	1,300			August	93
Akron	OH		2,870			Late	93
Akron	OH		6,200			Late	93
Beavercreek	OH		2,200			Late	93
West Carrolton	OH		3,400			Late	93
Cleveland	OH		29,831				93-94
Brookpark	OH		4,925				93-94
Cincinnati	OH		35,000				94
Harrisburg	PA		1,500			Oct-Dec	93
	PA	N Cross Valley Expwy	4,500	4-16	45,000		93/94
Park Road	PA		15,000	10-20	225,000	December	94
Northampton County	PA			10-20	?		94
Summerset	PA				?		94
Cranberry Interchg	PA						94-95
Hollidaysburg	PA		?				94-95
Warren St. Ext.	PA		?	10-20			95
Lehigh River East	PA		?	10-20			95
Houston	TX	Beltway 8	3,000			October	93
Houston	TX	I-610	7,500			December	93
Dallas	TX	Hwy 190				September	94
Houston	TX	US 59	10,000			April	94
Austin	TX	Hwy 71				November	95
Salt Lake City	UT	Bangerter Blvd	11,000				94-95
Provo Canyon	UT		800				94-95
Salt Lake City	UT	90th South	300				94-95
Culman Bridge	VA		800	16-18	13,600		94
Prince William County	VA	I-95	6,400	20-30	160,000		94
Chesapeake	VA	I-64	3,500	18-20	66,500	Middle	94
Fairfax	VA	I-66	6,200	20-25	140,000		95

New FHWA Model *(from page 3)*

received under the project will be subject to review and approval by the panel.

The brainstorming session is also open to other interested individuals. If you would like to attend or are interested in providing comments to the technical review panel as a corresponding member, please contact either Robert Armstrong of the FHWA at (202) 366-2073 or Gregg Fleming of the Volpe Center at (617) 494-2876. An agenda for the upcoming session will be distributed to interested individuals in the next couple of weeks. The objective of the brainstorming session will be to discuss the most effective methodologies for implementing all aspects of the user interface with the software.

The next generation highway noise prediction software, scheduled for release in middle to late 1995, will be developed for use on an IBM-compatible personal computer. The target hardware platform will be a 486DX-based, 33 MHz, personal computer with 8 MB of RAM and at least a 100 MB hard drive. The software will be programmed to run under the Microsoft Windows environment and coded in the C++ programming language. The design of the program will follow the object-oriented, C++ design philosophy. A modular program architecture will be maintained to allow components and capabilities to be added or updated in the future when technological advancements occur. The following are major components and capabilities to be included in the new software:

User-Friendly Graphic User Interface (GUI): The new format will contain a user-friendly GUI developed in the Microsoft Windows environment. In addition to automating the input file creation process through the use of pull-down menus and built-in digitizing capabilities, among other things, the GUI will have an on-line user help and guidance facility, and an upgraded barrier design facility. The GUI will also maintain on-line graphic and plotting capabilities as well as automatic input error checking.

Contours: The new software will have the capability of computing, displaying, and printing/plotting various contours, including noise level contours and noise level difference contours (e.g., barrier insertion loss contours).

Intergraph Microstation CAD Environment: Included with the new software will be an entirely self-contained Intergraph Microstation CAD Environment. This environment will be callable from within Microsoft Windows and will allow for two-way information flow between the new software and the environment via disk access. Note: To utilize this capability within the new software, the user must have Intergraph Microstation.

Vehicle Noise Emission Levels: the new software will be structured to utilize constant-flow vehicle noise emission levels (10-70 mph) stated in the one-third -octave frequency bands from 50 to 10,000 HZ. In addition, the new software will contain the capability to account for the effects of interrupted-flow and grades.

Propagation Components: The new software will maintain the capability to account for the following propagation components: (1) stack-height check for heavy trucks; (2) divergence and atmospheric absorption; (3) effects of ground and absorptive/reflective barriers (Note: The specific algorithms for including this capability are entirely different from the alpha theory currently employed by the FHWA's STAMINA software); (4) effects of multiple barriers in sequence, i.e., multiple diffraction; (5) effects of parallel barriers, i.e., multiple reflections; (6) effects of tilted barriers; (7) effects of rows of buildings; and (8) effects of heavily-wooded areas.

The above outline is intended to be a brief summary of the major components and capabilities to be included in the new model/software. A more detailed discussion will be presented in future articles. For those individuals interested in obtaining copies of the Statement of Work for the development of the new model/software, copies of the minutes from any of the meetings to date, or other information pertaining to this development project, please contact either Messrs. Armstrong or Fleming at the telephone numbers given above in this article. ■

Papers, *(from page 12)*

COMPUTER MODELS FOR THE ANALYSIS OF VEHICLE/GUIDEWAY VIBRATION PROBLEMS

Railway vehicle induced groundborne vibration has been the subject of increased study in recent years. This is due to greater freight car weights and speed, and the growth of high speed, light and commuter rail service. Questions often arise as to the impact such systems have on people and structures that exist within a certain proximity to the right-of-way. These questions underscore the need for accurate, portable tools to perform timely analysis. Among these tools are comprehensive and interactive computer models that describe with reasonable accuracy the mechanical and dynamic behavior of a wide variety of vehicle/guideway systems. The first half of this paper describes existing vehicle/track models that have been developed by the Association of American Railroads (AAR) to study localized vehicle/track interaction.

The second half of this paper then describes the framework of a more elaborate model in which the interactive rail/vehicle model is only one component. Additional components are introduced for modeling the response of structures within the track's domain of influence to the resulting mechanical vibrations. A component is introduced for modeling the connective medium between the track and the structure through which vibrations are transmitted. The outlined frame work is demonstrated through the solution of a hypothetical vibration problem. It involves a two-story industrial building within a short distance of a commuter railway line. The goal of this theoretical case study is to identify means of filtering or attenuating vehicle driven vibrations to an acceptable level.

Author: John F. Leary (719) 584-0572
Organization: Association of American Railroads, Transportation Test Center, Pueblo, CO
Author: Magdy El-Sibaie (312) 808-5842
Organization: Assn. of American Railroads, Chicago Technical Center, Chicago, IL

IDENTIFICATION, ANALYSIS & PREDICTION OF NOISE RADIATED FROM A LIGHT RAIL VEHICLE

This paper presents a case study of a combined analytical and experimental approach for identifying, analyzing and predicting the noise radiated from a light rail vehicle during high speed operation on tangent track. The work was conducted as part of a noise control program which considered excitation control measures, vibration control measures, airborne noise control measures and the analysis of a sound wall. Various aspects of the measurement surveys are discussed including pass-by noise measurements, frequency response measurements and modification tests. Frequency response measurements were used to identify wheel web, wheel tread and rail resonances as well as to predict the effectiveness of applying tuned dampers to the wheel treads. The modification tests included absorption treatments, side skirts and rail barriers. The results of one excitation control measure, rail grinding, is also presented. A three dimensional, analytical/geographical site model was created which included the rail line, an adjacent residential community and the intervening topography and obstacles. A propagation model, based upon the Austrian Guidelines, OAL Richtlinie 28 & 30 and acoustic ray tracing techniques was

Papers, *(continued on page 16)*

Papers, *(from page 15)*

used to predict the noise radiation into the adjacent community. The noise model was verified by field measurement and then used in the design/analysis of a sound wall paralleling the LRV right of way.

Author: James B. Steedman, President (714) 441-3488
Organization: Navcon Engineering Network, Fullerton, CA
Author: William G. Halvorsen
Organization: Halvorsen Associates, Inc., Cincinnati, OH
Author: Hans Forschner 49-(0)7195-67631
Organization: Braunstein Und Berndt GmbH, D-7057 Leutenbach 3 (Nellmersbach)

NOISE AND VIBRATION BART A- AND B-CARS

This presentation by Jason Micklewright of PGH Wong Engineering seeks to address and discuss the noise levels generated by the Bay Area Rapid Transit A- and B-cars. The presentation will use data obtained in a recent series of noise tests, performed in conjunction with Wilson, Ihrig & Associates, Inc.

The BART cars were originally constructed 20 years ago and are now due for overhaul, one of the major objectives of which is to reduce the noise levels within the cars. Consequently, tests shall be performed before and after the cars are overhauled. The data to be presented represents the first half of the tests on two prototype cars scheduled for rehabilitation. Measurements, taken both inside and outside the car, provided a wealth of data on topics which include: (1) noise level variation along the car length, (2) noise level variation due to different truck types, (3) noise generated by on-board equipment, (4) effects of speed, and (5) environmental impacts.

In addition to the results as they stand, comparisons shall also be made with noise levels on BART in the 1970's when the cars were first introduced to the system, and with noise levels present on other transit systems throughout the country.

Author: Jason Micklewright (415) 566-0800
Organization: PGH Wong Engineering, San Francisco, CA

RAILROAD TRACK NOISE AND VIBRATION IMPACT STUDY AND SOUNDWALL DESIGN

This paper presents a case study in which the authors investigated the noise and vibration impact of a rail line which was to be relocated to within 60 ft of an existing mobile home park in Los Angeles County. The realignment was proposed to make the rail right-of-way available for a new arterial street.

The rail right-of-way was initially located about 700 ft from the mobile home park's boundary line and had a line-of-sight path to the mobile homes. Prior to realignment, the hourly L_{eq} at the nearest mobile homes was 63 dBA during hours with train passages; ambient sound level (excluding rail passages) varied between 37 and 45 dBA (L_{90}). Peak noise levels at the boundary line were predicted to be on the order of 68 to 75 dBA (hourly L_{eq}) up to 87 dBA (L_1) without mitigation. A sound wall was designed which reduced train noise levels at the park boundary line to less than they were prior to the realignment.

Prior to realignment, the vibration due to train passages were imperceptible. However, the vibrations after realignment were predicted to be perceptible, on the order of 20,000 micro-inches/sec (in

Papers, *(continued on page 17)*

Papers, *(continued from page 16)*

the 20 Hz 1/3 octave band) at 100 feet from the tracks. After the change, there were few complaints about train noise but mobile home residents began complaining about vibration they could feel and rattles they could hear.

Authors: Sean K. Bui and Hal Amick
Organization: Acentech Incorporated
Canoga Park, CA
Author: Amir M. Yazdanniyaz*
Organization: Arup Acoustics
Los Angeles, CA

* Work performed while at Acentech

(Ed. Note: This concludes Part 1 of the Summaries of Professional Papers Presented at the 1993 Summer Meeting of A1F04 Committee. The remaining papers will be printed in the next issue of The Wall Journal).

Noise Wall Construction Continues On I-95 in Broward County, Florida

Win Lindeman, Environmental Administrator with the Florida Department of Transportation, reports that another series of noise walls are now under construction along I-95 in Broward County. State Paving Corporation of Fort Lauderdale is constructing the walls along a 10.7 mile stretch of Interstate 95 between Sunrise Boulevard and Copans Road.

The $4.3 million job will complete the noise barrier wall projects in Broward County and climax an $11 million noise abatement effort along this portion of I-95.

According to FDOT Construction Engineer Bill Walsh, the wall construction is progressing well and includes some innovative construction techniques.

Over 280,000 square feet of wall are involved in this project, with the installed cost per square foot coming out to about $15.44. Further details on the status of this and other noise walls along I-95 and elsewhere in Florida will be reported as they become available. ■

(Win Lindeman may be reached in Tallahassee by phone at 904 488-2914 and by fax at 904 922-7292).

Call for Stories and Articles

We're certain you have enjoyed reading the fine story about environmental issues in conflict, written by Dianne Steinhauser of Caltrans, which appears on page 6 of this issue. This is the type of story or article we wish to feature in The Journal. There **must** be more like this out there. Please send them in. If they are good, we'll put you on the front page. Let your fellow professionals know what you are doing. Publish and become nationally known.

Sound Fundamentals Part 2

Presented by:
The A1F04 Institute On Noise (ION)

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

Last time in The Wall Journal, terms and basic concepts were described. The discussion was presented not as rigid proofs or in textbook format, but rather as a general discussion. We continue along that same path this time as we discuss sources of transportation sound. Many of the terms used here have been defined in the first article and so will not be defined again.

The source is of course the originating location of the sound. The sound is caused by vibrations in the air that are produced by the transportation vehicle. The source is one of three general locations or topics usually associated with sound, the other two being the sound path and the receiver location. Whether we are discussing highway vehicles, off-road vehicles, aircraft or trains, the total sound energy emitted from transportation sources can be categorized in four discrete categories or sub-sources: wheel contact, aeroacoustic disturbance, exhaust, and drive train. The total acoustic energy emitted is then a summation of each of these four sub-sources. A brief discussion of each follows.

WHEEL CONTACT

Wheel contact with pavement, rails, or other surfaces (e.g., gratings) causes vibrations as the wheel turns and slides across the surface. The intensity and frequency components of the emitted sound depend primarily on the wheel design, type of surface, speed of the vehicle, and vehicle loading. Testing has also shown that wheel condition (e.g., new or worn) can also change the emissions with time.

For highway vehicles, "quiet" tread is considered to be when the air inside the tread "can escape as the tread blocks come into contact with the road surface."[1] Of course this makes tread design (wheel design) an important consideration. As tires become worn, air can not as easily be evacuated and sound emissions increase.

Roadway surfaces are also important. The type of surface (e.g., asphalt or concrete) and the pavement condition determine the "impact" of the wheel on the surface. As such, the intensity and frequency components of the sound emitted are largely determined by the surface. Smoother surfaces tend to produce less noise. However, recent research has shown open-graded asphalt to be quieter! How can this be true for such a rough surface? We will discuss this concept next time during our "session" on sound propagation path. Increased speeds cause the tire to "strike" the surface with greater impact. Accordingly, wheel contact sound is very speed dependent. How much force is applied to the tire/surface contact, a function of vehicle loading, also affects the impact and causes a change in acoustic emissions.

For rail vehicles a very smooth surface and round, balanced wheels become very important. As such, jointed rail will have more acoustic emissions than continuous rail and a distorted wheel will be louder than a well machined, round wheel. As with highway vehicles, the acoustic emissions are speed and load dependent. Of course as we move into the high speed ground transportation (HSGT) era, magnetic levitation (maglev) must be considered. With this technology there is no wheel contact or reduced wheel contact dependent upon design, but as we will find out later, this does not mean that maglev is quiet.

We generally ignore wheel contact sound from aircraft because it does not add to the total sound level because of the dominant engine noise during idle. (Remember how decibels must be summed!)

AEROACOUSTIC DISTURBANCE

As vehicles move through the atmosphere, air must be displaced. At higher speeds, this displacement can result in significant acoustic emissions. We generally ignore these emissions from highway, off-road, and normal rail operations, but they cannot be ignored for aircraft or HSGT. Indeed it is these aeroacoustic emissions that dominate for maglev systems or aircraft on final approach. For these high speed sources, streamlining has been used to reduce the acoustic emissions. New technology, based on the skin of the shark, has also been found to greatly reduce these acoustic emissions.

EXHAUST

We have all experienced the loud, intrusive noise from a faulty muffler. The "explosions" taking place in the internal combustion engine cause violent gaseous emissions from the engine and this in turn creates an acoustic disturbance. Mufflers greatly reduce the disturbance and quiet the exhaust so that at highway speeds the exhaust does not add significantly to the total SPL. Improvements in truck mufflers over the last twenty years have decreased the acoustic emissions from trucks. However, exhaust noise is still a concern from trucks and adds to the total.

As with heavy trucks, locomotives with large diesel engines also have significant contributions to the total acoustic emissions from the exhaust. Mufflers have again proven to be quite effective in reducing the sound.

Turbine engines, used in commercial jet aircraft cannot be muffled and the turbulent flow from the exhaust creates a large acoustic disturbance. Streamlining the flow from the exhaust is one way to reduce the acoustic emissions. The newer, quieter aircraft use high air bypass engine designs to achieve this streamlining of the exhaust and have significantly reduced the acoustic emissions.

DRIVE TRAIN

The drive train sounds from highway vehicles come from bearings, air intakes, fans, turbochargers, clutch plates, gears, structural vibration, etc. These variety of sources occur along the entire vehicle, but are more concentrated near the engine. In automobiles, under-the-hood insulation helps to muffle the sound. Trucks tend to not be as well insulated.

Trains tend to have more drive train emissions because of more moving parts and larger engines. Aircraft of course are dominated by the engine exhaust sound.

SIGNIFICANCE OF THE SUB-SOURCES

Which of these sub-sources dominates is dependent upon the vehicle type, configuration, and use. As previously discussed, automobile drive-train and exhaust acoustic emissions have been greatly reduced as vehicle technology has progressed. The aeroacoustic disturbance phenomenon is small for normal driving speeds. Accordingly, at freeway speeds, it is the wheel contact sound (tire/pavement interaction) that dominates for automobiles. For jet aircraft the exhaust sound dominates during taxi and takeoff, but the aeroacoustic disturbance may dominate upon final approach. Locomotives are a combination of exhaust, drive-train, and wheel interaction sound, while the trailing cars are of course dominated by the wheel contact sound. For magnetically levitated trains, wheel contact does not occur and at the very high speeds attained, the sound is dominated by the aeroacoustic disturbance which can be quite loud (e.g., similar to an airliner on final approach). Off-road vehicles tend to be dominated by the exhaust sound.

Because of this varying sub-source contribution, and the characteristics of each

type of mobile source, different spectra are generated. Of course we know this because our ears can perceive the different tonal quality and it is an easy task to distinguish a locomotive from an automobile by the unique sound produced. But what do these spectra look like and how do they vary?

In order to present these spectra we must first discuss a concept which was touched upon in the last "session"; octave bands.

OCTAVE BANDS

We know from experience that if a guitar string is plucked a dominant frequency or note is created. If we shorten the effective length of the string by pressing on the string at the midway point, the same note occurs, but one octave higher. The vibrations are twice as fast, so the frequency is doubled. This is the same concept used in octave bands. An octave band is a range of frequencies designated by the geometric mean frequency of the range. The designator, or geometric mean frequency, is sometimes referred to as the center frequency. Each progressive octave band is designated by a frequency twice the last, or one octave higher. Octave band ranges and the geometric mean designation (center) frequencies are listed here.

Range (Hz.)	Geometric Mean (Hz.)
22-44	31.5
44-88	63
88-177	125
177-355	250
355-710	500
710-1420	1000
1420-2840	2000
2840-5680	4000
5680-11360	8000
11360-22720	16000

Notice how the designator frequency (geometric mean) is twice the previous frequency in the progression. The use of this convention makes it easy to discuss frequency contributions. For example, if the contribution from the 500 Hz. octave band is known to be 70 dB, it is the total SPL from all frequencies, 355 to 710 Hz. A graph of a spectrum would only show the geometric mean frequencies, but it is understood that the sound energy is from the entire defined frequency range for that band.

Sometimes the ranges need to be smaller to better define or display the data. In this case, the ranges are divided into three smaller parts and we refer to them as one-third octave bands.

A, B, AND C WEIGHTING, REVISITED

Remember from last time that we used A, B, or C weighting to represent the entire range of frequencies. This is done by adjusting the SPL of each octave band or one-third octave band by a factor, summing the energy for all ranges (remember we cannot simply sum decibels), changing the energy back to dB, and then reporting a single number (dB) for all frequencies. The weighting factors for the A scale are:

Octave Band Designator (Hz.)	A-weighting Factor (dB)
31.5	-39
63	-26
125	-16
250	-9
500	3
1000	0
2000	+1
4000	+1
8000	-1
16000	-7

Notice as discussed last time that the ear does not hear low frequencies well (in 31.5 Hz. band a factor of negative 39 dB is applied) or in the high frequencies (at 16000 Hz. a factor of negative 7 dB is applied). Also remember that the final reported number in dB is the weighted sum of all contributions from each octave band. Figure 1 is a comparison of the A, B, and C scale weighting factors.

SOURCE SPECTRA

Now that we are armed with more tools, let's first consider the highway vehicles. Figure 2 is a graph of a typical spectrum from an automobile. Figure 3 is the spectrum from a typical heavy truck. These two vehicle types, along with a third type, medium trucks, are the three categories used in the FHWA Noise Prediction Model and it is easy to see why. The most obvious difference, as expected, is the intensity.

Trucks emit more acoustic energy than do automobiles. An old, rough "rule of thumb" for comparing automobiles and heavy trucks is that a heavy truck at the same speed emits about ten times the acoustic energy than an automobile. Or stated another way, each heavy truck equals ten passenger cars on an L_{eq} basis. Also apparent is the frequency contributions. The heavy truck contains more low frequency sound than does the automobile. This is as expected since the drive-train and exhaust sub-sources contribute more sound energy for a truck than for an automobile. Of note in Figures 2 and 3 are how the spectra change with A-weighting compared to the linear spectra.

The relative contributions for a heavy truck are shown in Figure 4. As shown, the three defined sub-sources contribute to the overall sound level somewhat equally. However, recent advances in muffler design have further reduced the exhaust noise contribution.

MODELING OF HIGHWAY SOURCES

Because of the different sub-sources, the effective height of acoustic emissions change with vehicle type. Figure 5 shows the three main sub-sources for a heavy truck (remember that the aeroacoustic dis turbance is small at normal traffic speeds). It is easy to see that the effective truck emission height is greater than that of an automobile which is dominated by the tire noise at higher speeds.

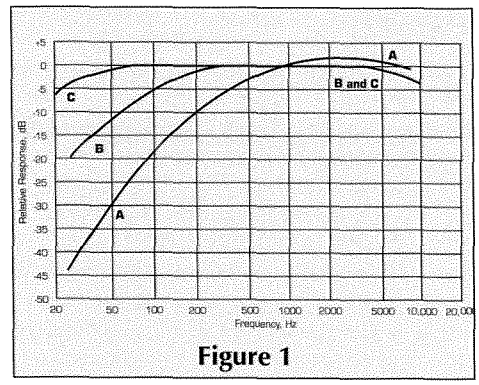


Figure 1

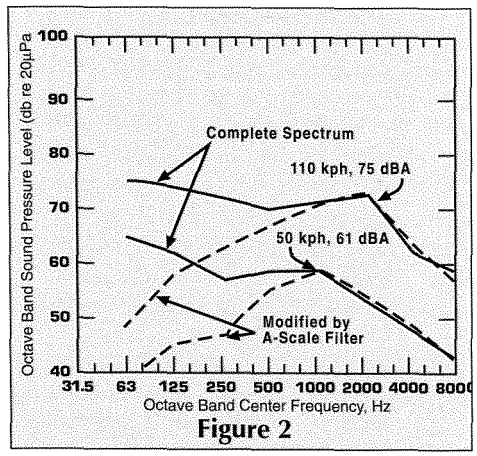


Figure 2

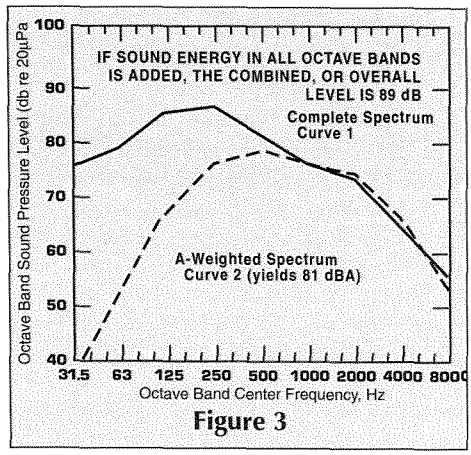


Figure 3

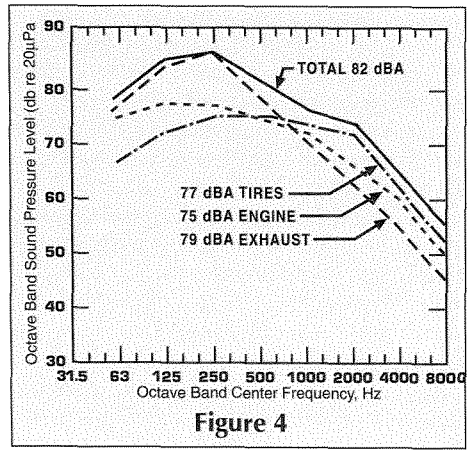


Figure 4

Because of this, FHWA has defined the

(Continued on page 20)

Sound Fundamentals *(from p. 19)*

effective source heights of automobiles to be 0 feet (dominated by tire emissions), medium trucks to be 2.3 feet (average height of drive train and exhaust contributions), and heavy trucks to be 7.9 feet (again the average height of drive train and exhaust contributions. Recent research has shown these may be incorrect and will be changed in the new model (replacement for STAMINA 2.0). In addition, the new model may include source heights for the sub-sources.

In predictive modeling of highway sources, it is important to define the source strength at a known distance as a minimum. Past models have done this on an A-weighted basis. Figure 6 shows the national average values used by the FHWA and the appropriate equations. These are called the Reference Energy Mean Emission Levels (REMELs) and are at the "heart" of all modeling efforts. The REMELs are the maximum levels of a single vehicle passby, fifty feet from the centerline of the vehicle track, with 0.115 times the standard deviation (sigma) of the sample base added in. Mathematically:

REMEL (by defined vehicle type) = $(L_o)_i = L_{max} + 0.115$ (sigma)

Details of the mathematics are included in the FHWA Traffic Noise Prediction Document.[2] A review of Figure 6 reveals a strong speed dependence. Many States, concerned that the national average data that the REMELs were based on may be dated, have developed new values for their State as we have done here in Florida. The general trend that has emerged is that the national REMELs are a little low for automobiles and a little high for both classifications of trucks. The on-going model work intended to replace STAMINA 2.0 will use one-third octave bands instead of single A-weighted values and will provide a more accurate modeling methodology. This is not only because of the increased acoustic emissions with speed, but also the changes that occur to the spectra with speed and the effects that must be modeled during propagation (our topic next time).

The spectra from off-road vehicles is similar to those of highway vehicles because of the similarity of design. Of course the sound from wheel interaction is minimized in the dirt and mufflers are generally not as effective. For aircraft and trains the spectra is considerably different. Aircraft have a much greater intensity and include much more sound energy in the higher frequencies. Trains again have a greater intensity when compared to highway vehicles and have more energy in the lower frequencies. While typical spectra are not shown because of copyright concerns, considerable data is present in the ASCE Journal of Transportation Engineering and the Journal of the Acoustic Society of America. Modeling efforts for aircraft and trains are again based around the concept of using a reference value, most often A-weighted. The FAA Computerized Integrated Noise Model for airports uses this concept. Both FRA and FAA use A-weighting for their criteria.

Well, it is time to end for now. In the next issue, we will discuss the propagation path of the sound and how it may be affected. I hope you have enjoyed this installment. If so, please let The Wall Journal know. ■

(Dr. Wayson may be reached by phone at 407 823-2480, by fax at 407 823-3315)

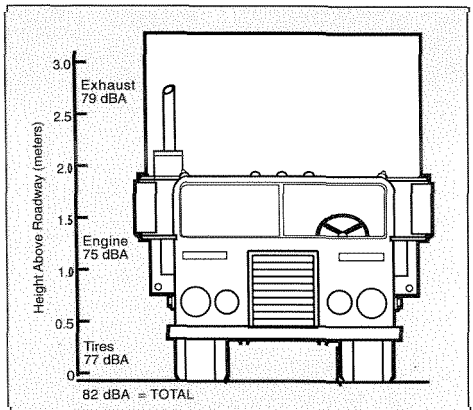


Figure 5

Author's Reference Notes

Ref. 1: G.S. Anderson, L.N. Miller and J.R. Shadley, Fundamentals and Abatement of Highway Traffic Noise, Cont. No. DOT-FH-11-7976, FHWA, Wash., DC, 1973.

Ref. 2: T.M. Barry and J.A. Reagan, FHWA Highway Traffic Noise Prediction Model, Report No. FHWA-RD-77-108, FHWA, Wash., DC, 1978

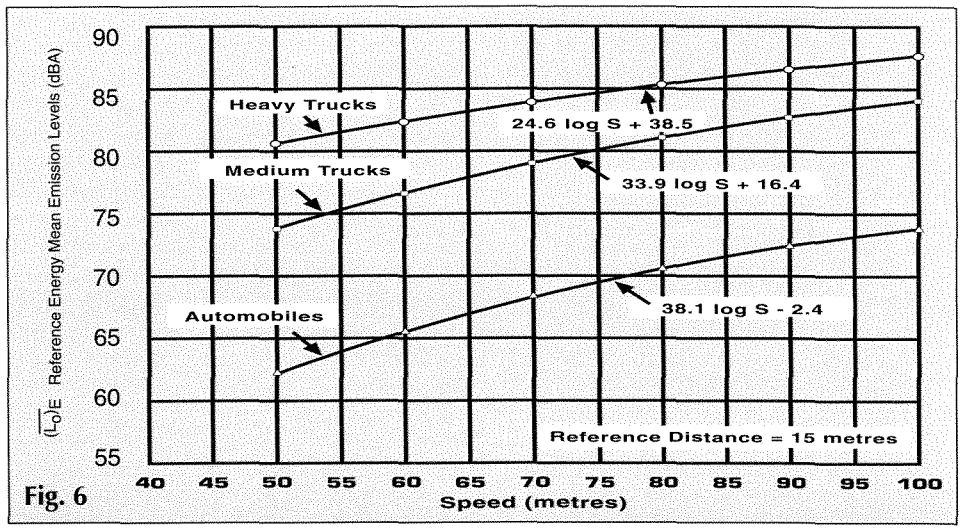


Fig. 6

CORRECTIONS

In our story in the last issue on The Blue Route, PennDOT's I-476, we stated, "Structure-mounted noise barriers are predominantly precast concrete panels which are attached directly (without posts) to the outside face of the structures' parapets."

We copied this from material provided by Harvey Knauer of PennDOT last year, but did not print it until this year, not knowing of changes made to the contract during construction.

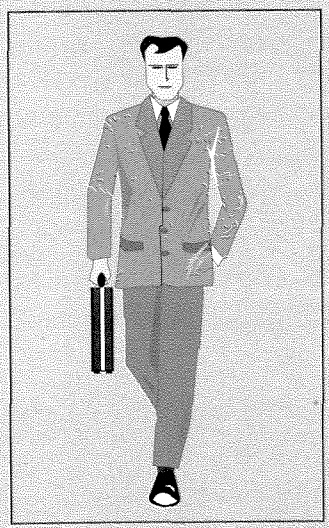
Our advertiser, Sound Zero, wrote us to inform that 19 structures on Sections 200, 500 and 600 of this project were changed to their product; a total of 78,000 square feet of structure-mounted barrier.

We apologize, Sound Zero.

We also apologize to Harvey for not supplying his telephone and fax numbers in the article for readers who wish further information.

Herewith: Telephone 215 964-6537, fax 215 964-2603. Sorry, Harvey.

Please Consider Our Advertisers



Without Them, we could not continue to publish The Wall Journal in the Style to which you have Become Accustomed.

Notice to Our New Readers

If this is the first copy of The Wall Journal you have received, welcome. This is your introductory copy. If you find The Journal interesting,and would like to receive further issues,please read about Reader Registration on page 23. It is important that you register your wish to continue your readership, since we are in the process of updating our mailing database. We hope you will stay with us.

Note: If you don't wish to cut up your Journal, just copy and fax.

Potential Advertiser's Form

Please send me a copy of your latest Ad Rate Schedule, which shows ad sizes, typical ad layouts, prices for 1, 3 or 6 insertions a year, publication schedules and information on art and copy submittals. No obligation, of course.

Name: _____

Company _____

Address _____

City, State, Zip _____

I understand that display advertisers get a free subscription for the year-period in which they advertise, and that additional copies of a particular issue are available in any quantity at the time of publication, provided notice is given prior to printing. Such additional copies are priced at $1.00 each postpaid, and must be shipped to a single address.

❑ Check here if you would like to receive at this time three previous issues of The Wall Journal without charge to assist you in making your evaluation of this publication as a potential advertising medium.

Our distribution averages 2,000 copies mailed per issue. Approximately 1,700 are mailed to specific readers in the United States, 250 to readers in Canada, and the remainder to Australia, Hong Kong, Denmark and France. We hold additional copies in inventory for back issue orders.

We are constantly updating our database to ensure that readers have paid their subscriptions (in the case of the private sector) and that government officials have registered their free subscriptions with us. New names are added to replace deleted names.

You may xerox this form and mail it to The Wall Journal, P.O. Box 1286, Stafford, VA 22555-1286, or fax to us at 703 720-0598, or simply call us at 703 720-0282.

INDEX OF ADVERTISERS

Our Advertisers are the Principal Supporters of The Wall Journal. We hope that you will favor them with inquiries.

If you would like to join them as an advertiser, please see the form at the top of this page.

Wall
is our middle name

That's because we print information on noise WALLs, sound WALLs, barrier WALLs, retaining WALLs, and also on other "walls" which are man-made to mitigate transportation-related impacts on the environment (such as air, noise and water pollution). Other "walls"include wetlands restoration, air quality control, land use regulation and HAZMAT transport safety controls.

The Wall Journal

Reader Registration

For Federal, State and Local Government Officials
For Government Associations
For Universities and Libraries

You are entitled to a **free** subscription to The Wall Journal. All you have to do is to register. And all that requires is that you provide us with the following information for our records:

Name _____

Title or Job Function _____

Department _____

Agency _____

Address _____

City, State, Zip _____

Tel. No. _____ Fax No. _____

You may fill out this registration and mail it to us at P.O. Box 1286, Stafford, VA 22555-1286. Or, you may copy this and fax it to us at 703 720-0598. But please don't telephone it to us. That's all it takes for you to get every issue. If you have already registered, please ignore this — you are safely in our database.

The Wall Journal

TWJ#9

Note: If you don't wish to cut up your Journal, just copy and fax.

Reader Subscription

For Consultants, Contractors, Manufacturers, Equipment Vendors and Others in the Private Sector

Please ❑ begin/ ❑ renew my subscription to The Wall Journal.

Subscriptions are for a one-year period (six bi-monthly issues).
New subscriptions start with next issue after receipt of check.
Renewals start following expiration of present subscription.

Single Copy Subscription (USA) ❑ 1 Year, $17.95
Single Copy Subscription (Overseas) ❑ 1 Year, $30.00
Corporate Subscription (5 copies each issue, one address) ❑ 1 Year, $56.00

Name _____

Title or Job Function _____

Department _____

Firm _____

Address _____

City, State, Zip _____

Tel. No. _____ Fax No. _____

Please fill out this subscription order (or a copy of it) and mail to The Wall Journal, P.O. Box 1286, Stafford, VA 22555-1286. Please enclose your check with order.

TWJ#9

Note: If you don't wish to cut up your Journal, just copy and fax.

Notice

Back Copies (Issues #1 through # 8) are available at a cost of $3.00 each including postage and handling

Keep your collection complete

Subscriptions

Subscriptions to **The Wall Journal** are free of charge to federal, state and local government agencies and their officials, to government associations, and to universities, provided they have registered in writing by sending name, department and complete mailing address. We would also like to have telephone and fax numbers for our referral records.

Subscriptions for the private sector (e.g.,consulting engineers, contractors, equipment manufacturers and vendors) are available at the costs per year (6 issues) shown below. Please include your check with your subscription order.

U.S. Subscribers: $17.95. Please send checks and subscription orders to The Wall Journal, P.O. Box 1286, Stafford, VA 22555-1286.

Canadian Subscribers: $26.00 (CDN, including GST). Please make checks and subscription orders payable to Catseye Services, Postal Outlet Box 27001, Etobicoke, Ontario M9W 6L0.

All Others: $30.00 (U.S.). Please send subscription orders and drafts payable in U.S. funds through U.S. banks to The Wall Journal, P.O. Box 1286, Stafford, VA 22555-1286, USA.

Advertising

Display advertising rates and sizes are contained in our Advertising Rate Schedule, available on request sent to The Wall Journal, P.O. Box 1286, Stafford, VA 22555-1286, or by fax to 703 720-0598.

The Wall Journal
P.O. Box 1286
Stafford, VA 22555-1286

BULK RATE
U.S. POSTAGE
PAID
PERMIT NO. 77
MANASSAS VA

PRINTED WITH SOY INK
Printed on Recycled Paper