The Wall Journal™ 4

The International Journal of Transportation-Related Environmental Noise Issues

Highway Traffic Noise in Denmark: Noise Barrier Design Considerations

By Hans Bendtsen, Road Data Laboratory

A three-meter high transparent glass noise barrier in Soborg Hovedgade in Gladsaxe, Denmark.

(Ed. Note: Mr. Bendtsen reports that the Road Data Laboratory in Denmark has completed a project on strategies for design and construction of noise barriers. The project is based on an analysis of 40 noise barriers and noise embankments in Denmark and Europe. In this article, he details some of the considerations which were explored and recommendations for design procedures).

The best solution for highway noise is always to lower the noise source. As regards road traffic, this would mean that something must be done about the noise emission from individual vehicles. Traffic and town planning can also be used as an effective means in this effort to reduce noise nuisance. This can be achieved by ensuring a sufficiently large distance between residential areas which are sensitive to noise from heavily trafficked roads, as well as moving traffic from those roads which are close to noise-sensitive areas.

*(See **Denmark**, page 8)*

California Noise Barriers Task Force Report - A Summary

The basic reason behind this study was the general perception that the costs of constructing noise barriers along State highways are too high. Prices to build noise barriers have been averaging more than ten dollars per square foot of wall surface. Annual maintenance costs, where graffiti is a problem, can amount to 10% of the initial construction costs. These costs are sapping resources which could otherwise be available for other transportation improvements, among them safety and congestion relief projects.

It is Caltrans' goal to reduce life-cycle costs and gain greater public acceptance for noise barriers. In order to accomplish this goal, a thorough study of our noise barriers policies, designs, materials, attitudes, and in particular the latest ideas and technology in the field of noise barriers, was undertaken. The basic thread woven through the fabric of the Noise Barrier study was to "leave no stone unturned" in our quest for better and/or less expensive ap-

*(See **California**, page 7)*

FHWA Mobile Noise Lab Is Available for Use

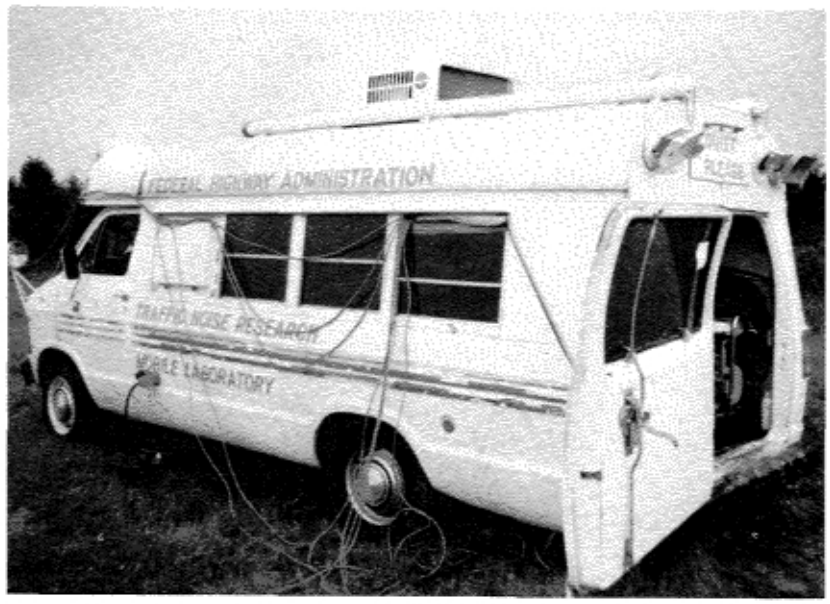
By Gregg Fleming and Edward Rickley,
US DOT/Volpe National Transportation Systems Center

In 1986, the Federal Highway Administration (FHWA) initiated the National Pooled Fund Study, "Evaluation of Performance of Experimental Highway Noise Barriers." The six-year study, conducted by the Noise Measurement and Assessment Facility (NMAF) at the John A. Volpe National Transportation Systems Center in Cambridge, Massachusetts, with funding support from 17 state transportation agencies, is nearing a close. Among the many residual benefits of the study is the FHWA's mobile highway noise measurement and analysis laboratory which was developed by the NMAF. The intent of this article is to briefly describe the components and capabilities of the mobile laboratory in the interest of stimulating potential users.

Laboratory Hardware

The acoustic data from up to eight General Radio Model 1962/9610 microphones and companion Cetec Ivie Model IE3P preamplifiers, which can be deployed in the field, are fed through several hundred feet of cable

*(See **Mobile**, page 5)*



The Federal Highway Administrations's mobile highway noise measurement and analysis laboratory is entirely self-contained and capable of making noise level "spot-checks" as well as extensive highway noise research studies.

The Wall Journal™

The International Journal of Transportation-Related Environmental Noise Issues

Volume One, Number 4
December/January, 1992-93

In This Issue:

Coming Issues:

- The 1993 Caltrans SILENT* Challenge... A Design Competition for Innovative Concepts for Abatement of Transportation-Related Environmental Noise
- "Big Blue"... The Story of PennDOT's 22 Miles of Noise Barriers on I-476, the "Blue Route"

The Wall Journal is published ten times a year. Issues are distributed monthly, with combined issues for July/August and December/January.

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

Publication offices are located at 617 Frederick Street S.W., Vienna, Virginia 22180. Telephone (703)938-6745, FAX (703) 938-5621.

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Submissions of papers, articles, letters, and photographs for publication, as well as requests for our advertising rate schedule should be addressed to The Wall Journal, P.O. Box 1286, Stafford, VA 22555-1286.

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Editor's Corner

by El Angove

About Our Deliveries...

As you may have surmised from the somewhat erratic delivery of our last two issues, we have had some problems getting our show on the road. We are new in the publishing business, and have experienced some unanticipated scheduling difficulties. First, our entire shipment of the September issue to our Canadian readers disappeared. The last we saw of it was when we delivered it to the Stafford, Virginia post office with the required first-class postage affixed. To remedy this unexplained problem, we included copies of the September issue in our Canadian mailing of the October issue (a spot check with some of our friends in Canada indicates that the mail went through).

Second, the addressed mailing labels for our October issue were apparently lost by the courier used by our label supplier. After a fruitless search for over a week, we purchased a label-addressing machine and now have internal control of that function. There were numerous other glitches we encountered which I will not describe here. It is sufficient to say that we believe we have plugged the leaks and that the mailing of this combined issue will permit us to get back on a regular monthly mailing schedule. Thanks for your forbearance in this matter.

About Our New Format...

Some of our problems were caused by our 11" x 14" tabloid format. Although we think it looks great, our printer has a loaded schedule on the particular press needed to run this size. A magazine size, 8 1/2" x 11", is much easier for them to run on a number of presses, and will speed delivery. Also, we had comments from a number of readers that their issue arrived in a battered condition. The post office assures us that the magazine size will fare much better in the mail sorting and handling processes.

It also allows us to go back to two-color issues as a standard, and the possibility of some four-color pages. We hope that you like this format. We will be adding more photos and graphics and different layouts to promote greater reader interest.

What We Need Now....

Is greater **reader participation.** We cannot invent material to print. We must have your technical articles, news of noise programs, research and development activities, projects in progress, field experiences and new concepts. Please help.

Request for Information

James P. Cowan is under contract with Van Nostrand Reinhold, the New York City-based publishing company, to write a book entitled *Handbook of Environmental Acoustics,* to be published toward the end of 1993. The book will be a basic reference in all areas of environmental noise pollution for people with little or no knowledge in the field. Anyone who would like to submit data (particularly noise level measurements which show the effectiveness of noise barriers in the mitigation of highway traffic noise) or interesting field experiences, to be included in the book, is welcome to do so. A letter of permission to use the information in the book must accompany all submissions. All material used in the book will be referenced to the appropriate authors. Submissions must be received by January 15, 1993 to be considered for inclusion in the book. Submissions should be sent to:

James P. Cowan
Cowan & Associates, Inc.
1 Opal Court
Newtown, PA 18940-2435
Telephone: (215) 579-9050

New Product Announcement

The SILATOR - A Small Volume Resonator

A new resonator element , called a SILATOR, has been designed for use as a noise control device. A SILATOR consists of an evacuated lentiform convex cap of sheet metal. The effect of a SILATOR is comparable to that of a Helmholtz resonator. Broad-band noise control may be achieved by tuning a set of SILATORs to different frequencies.

Helmholtz resonators are effective only in a relatively narrow frequency range centered around their resonant frequency, and are therefore used for suppressing discrete frequencies.Despite the physical advantage and technical ruggedness of a Helmholtz resonator, it is impractical to be used for attenuating broad-band noise because of the required installation volume. Reducing the stiffness component of the acoustic impedance requires a large resonator volume.

This constraint also limits the low frequency performance of the foil sound absorber described by Mechel and Kiesewetter. These foil absorbers consist of sealed plastic caps. The enclosed air acts as a spring, while

*see **Silator**, page 9*

FHWA Update by Bob Armstrong

Highway Traffic Noise Analysis Training

The Federal Highway Administration (FHWA) continues to offer a 32-hour National Highway Institute training course entitled "Fundamentals and Abatement of Highway Traffic Noise". The course is taught by FHWA staff and focuses heavily on FHWA noise policies. It is presented at the request of a host State highway agency (SHA) and is directed primarily to FHWA and SHA personnel who have responsibility for implementing FHWA's noise standards through the identification, analysis and mitigation of highway traffic noise impacts. The host SHA may invite local agency staff and private consultants to attend courses if space is available.

Two other known sources provide highway traffic noise training which focuses heavily on technical noise analysis. These training sessions are approximately a week in length and have a registration fee of $795 - $850, which includes an extensive set of microcomputer traffic noise analysis software (STAMINA 2.0/OPTIMA plus more). These sources are as follows:

Highway Noise Analysis Seminar
University of Louisville
Telephone: 502 588-6456

Advanced Traffic Noise Modeling
Vanderbilt University
Telephone: 615 327-8130

Microcomputer Versions of STAMINA2.0/OPTIMA. FHWA receives numerous requests for microcomputer versions of STAMINA 2.0/OPTIMA. Since FHWA has never developed such microcomputer software, we refer inquiries to the following known marketing sources:

Mr. Alex Veress
Towne, Richards & Chaudiere, Inc.
105 N.E. 56th Street
Seattle, Washington 98105
Tel: 206 523-3350

Ms. Shirley Lake
Trinity Consultants
Suite 1200
12801 N. Central Expressway
Dallas, Texas 75243
Tel: 214 661-8100

Dr. William Bowlby
Bowlby & Associates, Inc.
6403 Waterford Drive
Brentwood, Tennessee 37027

Dr. Louis Cohn or Dr. Al Harris
University of Louisville
Department of Civil Engineering
Louisville, Kentucky 40292
Tel: 502 588-6276

Highway Traffic Noise Research. The following information on highway traffic noise research has recently been compiled for the Nationally Coordinated Program of Highway Research, Development and Technology for the year ending September 30, 1992:

Significant Results During the Past Year

- "Determination of Traffic Noise Barrier Effectiveness: An Evaluation of Noise Abatement Measures Used on I-440" evaluated the reduction in traffic noise levels due to depressing the highway and the added effectiveness of both reflective and absorptive noise barriers constructed along the highway (Tennessee DOT).
- "Parallel Barrier Effectiveness Under Free-Flowing Traffic Conditions: evaluated the degradation in acoustic performance of a highway traffic noise barrier due to the close proximity of a parallel barrier on the opposite side of the roadway (FHWA Pooled Fund study).
- "Extension of Reference Emission Factors for the STAMINA 2.0 Model to include 55-65 MPH" determined highway traffic noise reference energy mean emission levels for traffic speeds of 55-65 mph on selected open, flat sites along major heavily-travelled Florida highways (Florida DOT).

Work Underway

- "Improving Highway Traffic Noise Prediction Procedures" has been improving highway traffic noise prediction procedures by reevaluating the reference energy mean emission levels and incorporating recent advances in traffic noise acoustics and computer technology. Phase 1 is producing an extensive literature review and resulting recommendations for improved procedures (FHWA).
- "Traffic Noise Attenuation as a Function of Ground and Vegetation" has been evaluating decreases of traffic noise levels with distance from highways due to various ground conditions (California DOT).
- "Determination of Truck Noise Levels for New Jersey" has been determining reference energy mean emission levels for heavy trucks on highway upgrades in New Jersey and has been developing a simple method for predicting the noise due to heavy trucks on highway upgrades (New Jersey DOT).
- "Evaluation of Innovative Noise Barriers" has been evaluating the effectiveness of two concrete post-and-panel highway traffic noise barriers. One barrier was tilted ten degrees away from the roadway; the other barrier was covered with a proprietary absorbing finish (New Jersey DOT).
- "Multi-Level Roadway Noise Abatement" has been evaluating the problem of traffic noise impacts from a multi-level viaduct and the potential of addressing the problem with the addition of acoustically absorbent material on the underside of the upper deck of the viaduct and the construction of traffic noise barriers on both sides of the lower and upper decks of the viaduct (Washington State DOT).
- "The Effect of Roadway Wear on Tire Noise" has been examining how vehicle tire noise changes with time as pavement ages and wears. Forty- one pavement sections are being studied biannually for a ten-year period; the sections include both asphaltic and concrete compositions (Washington State DOT).
- "Special Noise Barrier Applications" has been examining the technical and economic feasibility of special applications of highway traffic noise barriers, including absorptive barriers (both single and parallel), fully slanted barriers, barriers with slanted tops, T-top barriers, and barriers with dispersive faces and roughened textures (Washington State DOT).
- "Noise Mitigation Strategies" (WA HP&R) has been (1) reassessing feasible and cost-effective noise-reduction strategies for each noise-producing component of motor vehicles; (2) updating the estimates of the noise abatement potential and associated costs for motor vehicles; (3) reviewing the success of federal, state and local laws and ordinances for vehicle noise control; (4) evaluating the success of community measures to reduce the impact of highway traffic noise, including land-use strategies, zoning regulations and building design standards, and retrofit sound-insulation treatments; and (5) developing system-level noise abatement strategies, comparing the costs and benefits of reducing noise at the source, along the path, and at the receiver (Washington State DOT).
- "Update of Truck Noise Levels in New Jersey" has been developing new energy mean emission levels for medium and heavy trucks operating in New Jersey (New Jersey DOT).
- "Evaluation of Performance of Experimental Highway Noise Barriers" has been evaluating different noise barrier designs and the separation-distance to barrier-height ratio of parallel noise barriers (FHWA Pooled-Fund Study).
- "Design of Noise Barriers Using Artificial Intelligence" has been developing an artificial intelligence design procedure for highway traffic noise barriers (California DOT).
- "Specialized Noise Barriers for Use on Bridges" has been evaluating alternatives to include retrofit noise barriers on bridges, including better bridge supports and means to relieve wind loads (New Jersey DOT).

*see **Update**, page 9*

TRB A1F04 Committee by Domenick Billera, Chairman

Notice for 1993 Winter Meeting

The Winter Meeting of the TRB A1F04 Committee on Transportation-Related Noise and Vibration will be conducted at the Transportation Research Board Annual Meeting on January 10-14, 1993 in Washington, D.C. Details and schedules will be announced by the Transportation Research Board. Following is the agenda for the A1F04 Committee activities. The professional papers and presentations have been divided into two-part Super-Sessions.

Session 176A - 1/13/93 - 8:30 AM
"Type II Noise Abatement - Programs, Policies and Priorities"

Presiding: Kenneth Polcak

Maryland's Type II Noise Abatement Program
Ken Polcak (Maryland State Highway Administration)

Type II Program Priority System Development for Wisconsin DOT
John R. Jaeckel (Howard, Needles, Tammen and Bergendoff)

Type II Noise Abatement: The New Jersey Experience
Domenick Billera (New Jersey Department of Transportation)

Type II Noise Abatement Study for the New Jersey Turnpike
Bela Schmidt (Louis Berger and Associates, Inc.)

Barrier Priority Program for the Massachusetts Turnpike
Christopher Menge (Harris Miller Miller and Hanson)

Session 176B - 1/13/93 - 10:30 AM
"Evaluating the Noise Reduction Provided by Sound Insulation Modifications in Homes Near Commercial Airports"
Presiding: Eric Stusnick (Wyle Laboratories)

Results of The Residential Sound Insulation Program at Logan Airport
Carl Rosenberg and Frank Iacovino (Acentech, Inc.)

Use of a Synthesized Aircraft Noise Source for Measurements of Outdoor to Indoor Noise Reduction in a Reno Residential Development
Robert Brown and Jim Buntin (Brown-Buntin Associates, Inc.)

Comparison of Techniques for Evaluating Sound Insulation
Dana Hougland and Michael Barnhardt (David L. Adams Associates, Inc.)

User-Friendly Sound Insulation Programs
Andrew Harris (Harris Miller Miller and Hanson, Inc.)

The Use of Aircraft and Artificial Noise Sources in the Measurement of Residential Noise Reduction
Ben Sharp, Vijay Desai and Kevin Bradley (Wyle Laboratories)

Session 201A - 1/13/93 - 2:30 PM
"Highway Noise: Emission Levels and Abatement"
Presiding: David R. Still

Development of Reference Energy Mean Emission Levels for Highway Traffic Noise in Florida
Roger Wayson, et al

Reference Energy Mean Emission Levels for Riyadh, Saudi Arabia
Parviz Koushki, et al

Special Noise Barrier Applications
Louis F. Cohn, et al

Determination of Traffic Noise Barrier Effectiveness: An Evaluation of Noise Abatement Measured on I-440
Lloyd Herman, et al

Session 201B - 1/13/93 - 4:00 PM
"Rail Transportation Noise and Vibration"
Presiding: Carl Hanson

Sound-Absorptive Fence for Light Rail Transit in the City of Calgary
U. Gandhi, et al

The Effect of Rail Straightness on Wayside Ground Vibration
James Nelson

Radiated Aerodynamic Noise Generated by High Speed Tracked Vehicles
Dr. W. F. King III (Federal Republic of Germany)

Wayside Noise Generated by the German High Speed Transit Systems ICE and Transrapid
Dipl.-Ing Bernd Barsikow (Federal Republic of Germany)

The A1F04 Committee business meetings are all scheduled on the previous day, January 12, as follows:

2:00 PM - Aircraft Subcommittee Meeting

Highway Subcommittee Meeting

Rail Subcommittee Meeting

7:30 PM - Full A1F04 Committee Meeting

The Annual Committee Awards Dinner is set for Wednesday evening, January 13. This looks to be the Biggest and Best A1F04 winter meeting in recent years. Don't miss it !

Domenick Billera may be contacted at New Jersey Department of Transportation, telephone: 609 530-2834 or fax 609 530-3893.

Mobile, from page 1

to the data processing system inside the mobile laboratory. Raw data processing and storage is accomplished by eight portable Cetec Ivie IE-30A one-third-octave spectrum analyzers, interfaced with an on-board IBM PC-AT microcomputer.

Two analog outputs from the analyzers, the one-third -octave band level output and the sound level meter (SLM) output, are fed directly to the analog input of a Data Translations DT2821-16-SE analog-to-digital (A/D) converter board inside the PC. A third analog output, the sawtooth timing signal, is connected to a special interface card which converts the sawtooth signal into two TTL-compatible signals, a trigger signal and a timing signal. The converted trigger and timing signals are then connected to the 16 digital I/O ports on the A/D board.

During data collection, the A/D board in conjunction with the PC are programmed to sample, digitize and store in PC memory the 32 one-third-octave band levels using the associated trigger and timing pulses, as appropriate. After sampling the 32 one-third-octave band levels for each analyzer, the SLM signal level, which requires no timing alignment, is also sampled, digitized and stored.

Laboratory Software

All system functions are controlled by two NMAF-developed computer programs: a data collection program (HWINPUT) and a data processing program (HWNOISE). The HWINPUT program is used to collect acoustic data from up to eight analyzers in averaging times as short as one-eighth of a second for up to 120 individual measurements. Averaging times and measurement periods are user-defined and controlled by a clock board which is internal to the PC. After data collection is complete, the PC automatically downloads the raw data to a file on a user-selected disk drive. Reduction and processing of the raw data files is performed using the companion program, HWNOISE.

The HWNOISE processing program automatically applies calibration adjustments to the raw data and uses these data to calculate various noise level indices, including the equivalent sound level (L_{EQ}) and the sound exposure level (SEL) for individual measurement events. These data can then be displayed in various tabular and graphical formats. Detailed user's guides for both HWINPUT and HWNOISE have been prepared and are available to interested individuals.

Additional Laboratory Accessories

In addition, the mobile laboratory contains all pertinent support accessories needed to perform advanced highway noise research. They include: a Climatronics Model EWS weather station, capable of measuring and recording temperature, humidity, wind speed and wind direction; four portable measurement masts which can be set for heights up to 30 feet above the ground; calibrators, pink noise generators and microphone simulators; 10 reels of microphone cable, each 500 feet in length; and spare microphones, analyzers and preamplifiers.

Additional instrumentation which may be needed, depending on requirements, would include a doppler radar gun for measuring vehicle speeds, and a more advanced meteorological system capable of both downloading data directly to the PC and measuring meteorological conditions at multiple heights.

Summary

The FHWA's mobile highway noise measurement and analysis laboratory is entirely self-contained and capable of both quick "spot-checks" of noise levels, as well as extensive highway noise research studies. In addition to the thousands of hours of rigorous use the system experienced during the Pooled Fund Study, it has since been successfully used for highway noise studies by the University of Central Florida and by the Maryland State Highway Administration. It is a valuable resource which is available to interested state transportation agencies for both in-house research as well as state-sponsored research.

For additional information, contact Gregg Fleming at (617) 494-2372. Individuals interested in using the system for highway noise studies should contact Robert Armstrong of FHWA at (202) 366-2078.

Summary of Professional Papers

Presented at the TRB A1F04 Summer Meeting at Milwaukee: July 21-24, 1991 - **Part 1**

These summaries are the second in a continuing series which will provide a chronicle of all the professional papers presented at A1F04 winter and summer meetings, beginning in 1978.

The following, printed in order of presentation, are summaries of the papers presented at the 1991 summer meeting of the TRB A1F04 Committee on transportation noise and vibration.

A Comprehensive Software Library of Highway Noise Analysis

by Al Harris and Louis Cohn
Presented by: Dr. Al Harris
University of Louisville
Department of Civil Engineering
Louisville, KY 40292
(502) 588-6276

Summary: The development of computerized noise prediction and barrier design tools can be traced back to 1963. Through research funding efforts at the national level, improved prediction methodologies and models have subsequently evolved. Since the first research, various algorithms were developed and revised which were incorporated into SNAP 1.0, the first FHWA computerized model for traffic noise prediction. Later revisions led to STAMINA 1.0 and later, the Barrier Cost Reduction (BCR) procedure.

Along with advancements in highway noise analysis methods, various pieces of software have been developed to handle specific, but separate, issues associated with complex problems. While being developed to address specific tasks, there have been only limited efforts to integrate these separate packages into a single comprehensive library. As a result, the noise analyst is required to manually compile and execute data files while managing the location of all the data input and program output.

With the widespread availability of microcomputers and associated software, a significant problem has emerged relative to the varying skill levels of various users. In order to effectively and efficiently accomplish this complex task, the user must be very familiar with the operation of the computer, as well as the process of developing input data, generating output, and managing the location of both input and output files.

This presentation describes a powerful, flexible, but easy to use prototype system which is capable of managing analysis programs, as well as the location of input/output files. This system also provides a mechanism for electronically constructing input files as well as a plotting routine for checking input data and generating hardcopy plots. Other programs, in addition to STAMINA 2.0/ OPTIMA, are also available in the system for construction noise analysis, multiple reflections analysis from parallel walls, and a prototype expert system for automated noise barrier design.

Country-Wide Noise Mapping Terminals

Presented by: Robert Krug
Cirrus Research, Inc.
6818 W. State Street, Suite 170
Wauwatosa, WI 53213
(414) 258- 0717

Summary: This is a discussion of the noise monitoring terminals used to make a noise map of England. In1989, the United Kingdom Department of the Environment issued an invitation for companies to tender for a new National Noise Survey. The survey was to measure the noise climate at 1,000 sites across England and Wales over a 24-hour period. Each 24-hour period was to be during weekdays only. Measurements were to be made in reasonable weather conditions. The measurements required were to be L_{A1}, L_{A10}, L_{A50}, L_{A90}, L_{A95}, and L_{Aeq} for each hour during the 24-hour period. The CRL 702 Logging Integrating Sound Level Meter in a waterproof case equipped with an outdoor microphone was used for the survey. In addition to the required measurements, hourly Peak, L_{Amax}, L_{Amin} and 2-second short L_{eq} levels were acquired. Each day, 10 units were placed at 10 selected locations. The next day, data from each unit was downloaded into a TOSHIBA T1000 battery computer in the car. If the data was unusual, 2-second short L_{Aeq} levels for the 24-hour period were also downloaded to analyze the data in detail. The 10 units were then transferred to the next 10 sites. Using this method, the staff at AIRO Ltd. Hemel Hempstead Hertfordshire U.K. were able to analyze the environmental noise throughout an entire country.

Noise Analysis for Proposed Helistop - Shadyside Hospital (Pittsburgh, PA)

Presented by: David Coate
Acentech Incorporated
125 Cambridge Park Drive
Cambridge, MA 02140
(617) 499-8019

Summary: Shadyside Hospital has applied for a permit to construct an emergency medical-use helicopter landing facility on the hospital roof. This paper addresses the potential community noise impact of helicopter operations for the proposed facility.

The study consists of I) ambient noise measurements in the vicinity of the hospital; 2) computer projections of helicopter noise levels using the Federal Aviation Administration's Heliport Noise Model; 3) actual measurements of helicopter noise at a site comparable to Shadyside Hospital; 4) comparison of projected helicopter noise with relevant regulating criteria and existing ambient noise levels; and 5) measurement and analysis of hospital facade sound reflections.

Existing ambient noise levels influence the acceptability of the projected helicopter noise levels. Under the City of Pittsburgh Helicopter Regulations, ambient noise levels are not taken into consideration until the day-night level (L_{dn}) reaches 75 dB. Ambient noise levels were measured for 40 continuous hours at 5 locations near the hospital. A-weighted L_{dn} values ranged from 55 to 72 dB. The 72 dBA value was measured near the end of Colonial Place and ranged from 55 to 72 dB. The 72 dBA value was measured near the end of Colonial Place and was caused primarily by freight train activity in the area. During the course of 24 hours, 52 freight trains, 1,107 buses, 44 aircraft, and 13 helicopters were observed to pass by this location. Using federal noise criteria (ANSI, FAA, HUD), this area would be considered incompatible for residential use, irrespective of the proposed landing facility.

Helicopter noise levels were projected using FAA's Heliport Noise Model (HNM) as required by the FAA and the Pittsburgh Helicopter Landing Facility Ordinance. The model projects noise contours around the site for the purpose of evaluating compatible land uses within various noise contours. This analysis indicated that day-night noise levels in the community due only to helicopter operations would range from 40 to 53 dBA.

To supplement and verify the HNM results, noise measurements of actual helicopter operations were also made. Since helicopters cannot currently land on Shadyside Hospital, and since takeoff and landing operations play a major role in the noise generation, an existing helistop at Westmoreland Hospital (Greensburg, PA) with comparable geometry to Shadyside was used for the noise measurements. The noise measurements for this analysis were in close agreement (within 1 decibel) with results of the FAA Heliport Noise Model. This is significant since the computer-generated noise contours provide a comprehensive means of evaluating the potential noise impacts at all locations surrounding the proposed helistop.

Helicopter operations are projected to produce a day-night level of 53 dBA at the closest residence. This is well-below the ANSI, FAA, and HUD criteria of 65 dB L_{dn} for residential use. Helicopter noise levels will also be well-below the Pittsburgh noise ordinance of 75 dB Ldn. Additionally, the noise levels due

*see **1991 Papers**, page 12*

California, from page 1

proaches to providing noise attenuation along California's freeways.

The study was performed by a Task Force made up of Caltrans engineers and architects representing project development, structures design and architecture, landscape architecture, materials and research, and value engineering, from both Headquarters and the Districts, and included members of private industry representing the Precast Concrete and the Concrete Masonry Associations. In addition, information and advice was obtained from a variety of other Caltrans employees, wall manufacturers and builders, Federal Highway Administration reports and articles, and from newspaper or magazine articles.

The History of Noise Barriers

Caltrans first became interested in mitigating noise in the 1950s. Early research was aimed at controlling noise during highway construction. In 1968, in response to public concern, Caltrans built the first noise barriers to control everyday highway noise along freeways. These first two sound walls were built in San Francisco and near San Jose. It was also in 1968 that Caltrans established policy and procedures for freeway noise barriers, policy that has become more specific but not substantially different in intent over the years since.

The passage of both the National Environmental Policy Act (NEPA) in 1969 and the California Environmental Quality Act (CEQA) in 1970 required Caltrans to study and to consider noise effects, and to mitigate those effects when they could have been significant, in the building of highway projects. The Federal Highway Administration (FHWA) in 1973 adopted policy and regulations, now known as 23-CFR-Part-772 (formerly FHPM-7-7-3), that clearly defined when highway noise was considered to be high enough to require consideration of noise mitigation. These regulations apply to any project on which federal funds are used.

In 1974, Caltrans established a retrofit program to build noise barriers along freeways built before the noise barrier program, but where noise levels were sufficiently high to warrant a noise barrier under the current policies. A shortage of highway funds during the period from 1974 through 1976 prevented Caltrans from actually undertaking any retrofit noise barrier projects until 1977. By that time the Legislature, which was interested but was seeing little progress, placed into statute a requirement for a retrofit noise barrier program, with the California Transportation Commission to program projects consistent with available funding.

It is estimated that Caltrans has spent about $300 million on noise barriers to date, constructing about 330 miles of noise barriers along our urban and suburban freeways. About 50% of the noise barriers have been constructed in the Los Angeles area, about 30% in the San Francisco Bay area, and the remainder in other urban areas scattered around the state. Since the noise barrier program became well established, the cost of the program has represented about 5% of the Department's overall capital outlay for highway improvements.

Noise Barrier Costs

Up until now, the predominant material used for noise barrier construction has been masonry block. Of the noise barriers constructed to date, approximately 85% are masonry block, about 10% are precast concrete panels, and the remaining 5% are of other materials such as metal, reinforced stucco, wood or earth berms and mounds.

Over the years, the Department has made a conscious effort to increase competition and decrease costs by specifying the use of materials other than masonry block, and the use of different construction techniques. The effort has not been particularly successful. For instance, in 1991 the Department received bids on a precast concrete panel project utilizing a different and reportedly less expensive support system. The bid price for the precast panel project was $10.25 per square foot. During the same period, the average bid price of masonry block sound walls was $10.42 per square foot. Both prices are for sound walls to be located near the right of way line, and include the wall, foundations and footings, but exclude safety shape barriers, traffic handling, drainage, etc.

Also during the past 1991 year, the Department received bids for a project on Route 101 in Los Angeles, which specified heavy timber for the sound wall material. The low bid price was $16.00 per square foot. This compares rather unfavorably with an average bid price, during the same period, of $10.42 per square foot. Earlier, in 1985 the Department specified a timber wall on another project, in Santa Barbara, which resulted in a bid price of $11.00 per square foot. This would escalate to a present cost of about $15.00 per square foot.

The history of noise barriers in California does not lack in examples such as those noted above. More often than not, when alternatives to masonry block are specified, such alternatives are bid higher than normal block walls. Often, when the other materials are dictated, to insure that they are in fact constructed, the low bids come in higher than the usual masonry prices.

Framed plywood walls were recently constructed along Route 85 in Sunnyvale, under a Measure funded project, for about $10.00 per square foot. Since the first of this 1992 year, bid prices for masonry block sound walls (constructed at or near the right of way line) have ranged from $8.85 to $13.00 per square foot, with a median price of $11.02 per square foot. This is the cost only of the sound wall and footings, but does not include other associated costs such as clearing and grubbing, drainage, or landscape modifications.

Caltrans Action Program Recommended by the Task Force

1. Establish new design guidelines for noise barriers that stress simplicity.
2. Use plantings more freely as elements of noise abatement features to allow simpler barriers and to deter graffiti.
3. Review current structural design criteria for opportunities to obtain cost savings by developing more economical designs.
4. Develop a standardized column/post/footing support system to accommodate a variety of panel-type materials.
5. Establish a review group to evaluate new products from vendors that can be used for noise barriers, and develop a package of evaluation criteria and design standards for vendors.
6. Invite private companies to construct test sections of noise barriers, using their new construction and materials concepts to reduce capital and maintenance costs.
7. Use demonstration projects to evaluate those new noise barrier concepts which show promise, but have not yet been built in California.
8. Obtain industry ideas on lowering the cost of building noise barriers, and adopt those which are reasonable and practical.
9. Use life-cycle costs in the process of selecting the noise barrier solution.
10. Resolve the question as to whether construction of noise barriers increases reflected noise on the opposite side of the freeway.
11. Organize a contest among students interested in noise barriers as an endeavor to make use of the variety of talent that is available in California colleges and universities.
12. Issue instructions to Caltrans' designers to actively develop innovative noise barrier designs which incorporate salvaged materials, particularly highway hardware materials.
13. Study the concept of offering contractors a design/build process for noise barrier projects.

Ed. Note: The above are excerpted from the complete 85-page Task Force Report, which contains Sections on: Requirements of the Statutes/Policy/Programs; Fundamentals of Noise and Noise Barriers; Design Criteria; Aesthetic Considerations; Approved Caltrans Design Alternatives; Design, Construction and Bidding Processes; Cost Analysis; New Concepts; and the Action Program. For further information on the report, contact Robert Vogel at :

California Department of Transportation,
Sacramento,
telephone: 916 654-2477
fax : 916 654-3770.

Denmark, from page 1

Noise Barriers.

In areas where it is not possible within a short foreseeable period of time to reduce noise nuisance by planning action, it may be necessary to establish noise barriers or noise embankments. Unfortunately, these are frequently large and characteristic constructions, which can contribute considerably to leaving their mark on the road and community environment in which they are situated.

Starting Point for Design.

Seen from an aesthetic point of view, noise barriers will most frequently be unwanted. The visual environment will deteriorate, seen both from the road and the community. Therefore, it is important not only to reduce the environmental noise nuisance from the road but also to take into account the appearance and character of the surrounding area. The design of the noise barriers must be based on the area surrounding the road and the function and design of the area as well as the amount of traffic and its speed.

Speed of Traffic.

The noise barrier construction is viewed by various traffic user groups passing the construction at varying speeds. Residents living near the noise barrier have a direct and continuous view of it from their windows and open spaces. Pedestrians and cyclists pass the construction at low speed and are therefore able to note details and variations in the barrier shape and choice of color.

Drivers, passing the construction at low speed (30-50 km/h) are able to note the larger details. Drivers, passing at a speed of 80-100 km/h) are, however, only able to note general elements of design as shapes with different contrasts and colors.

Town and Country.

In areas of urban estates a great deal of thought should be given to make the noise barriers fit in with the type of constructions around them, since it is here that the local population has to live with these barriers and also since it is in urban areas that the road users moving at walking or cycling speed will note the details of the barriers.

The barriers should under all circumstances have two 'front sides'; one which faces the roadway and one which faces the surrounding areas. The acoustic demand for noise reduction must not be the only decisive factor for the height and shape of the barrier, since visual criteria can also be of importance for the choice of height.

Evaluation of the Local Inhabitants.

Investigations conducted in the Netherlands show that inhabitants behind a noise barrier very soon forget the former high noise levels and thereafter become dissatisfied with lost or reduced view, if the noise barrier has been constructed too close to their homes. This is a nuisance that the inhabitants will have to live with every day for many years.

Visual Impact.

Noise barriers can appear, due to their height, as dominating constructions. The following means can be used to reduce the visual effect of a high noise barrier:

- Use of colors, in which the barrier is constructed with horizontal color bars, having light colors on the upper courses and dark colors on the lower courses.
- Use of transparent panel materials.
- Constructing the barrier at a slight angle away from the road.
- Use of low plants in front of the barrier and high plants behind the barrier.

The higher a noise barrier construction is and the closer it is to the road or a residential area, the more effective is the noise protection. On the other hand, the influence on the surrounding area and the road environment is more dominant.

The Planning Process.

In the connection with the process where a noise barrier construction is planned and designed, it is important to consider the wishes and points of view of those people living in the area. It is important to ensure that a noise problem is solved, while a new visual problem is not created.

Furthermore, it is important to include the authorities and organizations which have an interest in the project in some way. This could be traffic safety people, architects, landscape architects/designers and road planners.

Other European Design Strategies.

In European countries, various points of view and principles for the choice of noise barrier construction are used. Some of these follow:

■ **Cologne.** Primarily a wish to make the construction fit into the area as a part of nature, based on the recognition that these constructions are a foreign element in the countryside and in towns.

■ **Hannover.** Noise barriers are constructed as a landmark.

Use of industry-designed barriers with marked, individual variations.

■ **Holland.** Variation and adjustment to the surroundings, seen from the understanding that when noise barriers and/or embankments are to be constructed, they may be equally well-used to create variation and possibilities of aesthetic interest alongside the road and its environment.

■ **Paris.** Not in favor of industry-designed constructions without direct adjustment to the urban environment. The result is that many noise barriers around Paris are independent, sculptural additions to the local environment.

The report, "Noise Barriers - An Idea Catalog", may be ordered from Ulla Hansen at the Road Data Laboratory, Road Directorate, Danish Road Institute, Stationsalléen 42, P.O. Box 40, DK-2730 Herlev, Denmark (fax +45 42 91 61 41).

The price is 355 DKK. The report is illustrated with many color photographs. A ten-minute videotape is available at a price of 500 DKK.

Silator, *from page 2*

the walls act as very thin plates exhibiting bending resonances at low frequencies. The many bending resonancies of the thin plastic walls allow a relatively efficient coupling between the acoustic field and the vibration response of the walls. Sound absorption is achieved by the dissipation of the vibration energy in the thin plates. As far as the required installation volume is concerned, this acoustic absorber offers little advantage over the Helmholtz resonator.

Another device of this group, which functions by interacting with the acoustic pressure, is the SILATOR or vacuum bubble resonator suggested by Bschorr. In this device, lens-shaped capsule walls enclose an evacuated space. The capsule volume may be made as small as desired since, because of the vacuum inside, there is no air stiffness. This device also embodies a resonator, which is formed by the mass and stiffness of the walls.

The object of the study reported in this paper is to establish the principles of this resonator technology and to yield technical information needed for designing these resonator elements for various applications.

To obtain a copy of the complete report, please contact Richard Sohn at:

PCV Technologies
P.O. Box 84
Niceville, Florida 32588-0084.

Update, *from page 3*

- "Public Response to Noise Barriers" has been evaluating methods for determining public responses to highway traffic noise and noise barriers. The study includes (1) designing an appropriate questionnaire, (2) conducting a survey, (3) analyzing the results, and (4) developing conclusions and recommendations (New Jersey DOT).
- "Normalizing Traffic Noise Measurements for the Effects of Meteorology" has been developing a procedure for making adjustments to highway traffic noise measurements for wind direction and wind speeds up to 12 mph (19.3 kph) (California DOT).

PLANS FOR NEXT YEAR

- "Improving Highway Traffic Noise Prediction Procedures" will improve highway traffic noise prediction procedures by reevaluating the reference energy mean emission levels and incorporating recent advances in traffic noise acoustics and computer technology. Phase 2 will involve the development of new computer software for traffic noise prediction (FHWA).

Questions and comments concerning this column should be directed to Bob Armstrong at 202 366-2073 or Steve Ronning at 202 366-2078.

The Product Approval Process

by Soren Pedersen

Part II - Preparing the Submission

The presentation of the noise barrier design submission for acceptance by a transportation agency is the most critical stage in getting a noise barrier product approved and must never be treated lightly. It can also be the most frustrating for both the manufacturer and the approving agency. The key is in knowing what the requirements and specifications are for acceptance by the agency. And, just as important, in what format the agency is accustomed to reviewing such submissions.

Since highway and transportation agencies are dealing with public funds, they are obligated to ensure that every product used on a roadway meets durability, safety and functionality requirements, as well as being cost effective. How this is accomplished varies significantly among agencies. Many have adopted to some degree the approval strategy and principles outlined in the National Cooperative Highway Research Program, Synthesis of Highway Practice, Report 90: New Product Evaluation Procedures.

Although this report details the procedures for the evaluation of new or unusual products, designs and concepts, it is equally relevant for common products such as noise barriers from a new or existing manufacturer. Even though this report was written over ten years ago, the information contained in it has withstood the test of time and will do so for years to come.

It is critical that the submission package presented is complete. Every aspect of the agency requirements must be thoroughly addressed. Otherwise, the response time for an incomplete submission may be just as long as for one which has gone through the entire evaluation process. And at the end of it, the only response could be a very brief note stating that the submission in its present form was incomplete and to please try again.

To avoid this type of rejection, first contact the approving agency to learn what the specific requirements for acceptance are. If the requirements reference local agency specifications, find out how to obtain the latest copy of these. This is true for both first time applicants and repeats. If parts of the requirements are unclear, do not hesitate to ask for more details or a clarification before proceeding. If specific requirements are not available or have not been developed by the agency, then the basic acceptance principles of durability, safety, functionality and cost effectiveness must be thoroughly addressed and proven.

The current trend in writing specifications is leaning toward performance-oriented requirements rather than detailing such things as specific ingredients in a compound or a minimum weight. This has allowed the manufacturer to be more creative in both the materials used and in the overall design of the product. Generally, this has resulted in a more durable and better designed product with a much more competitive price. This type of specification is particularly suited for dealing with new materials and concepts.

Material Description: Every submission must have a detailed description of all materials used in the noise barrier structure, including the standards to which the components were manufactured. This would encompass everything from the panels, posts and footings down to the type of fastenings, coatings and other accessory items. In some cases, the agency specifications may stipulate restrictions on the materials which can be used. Make sure that the restricted materials are avoided in the design, if possible. If not, then the onus is on the manufacturer to prove that it would be of benefit to the agency to allow the use of the restricted material.

If common construction materials such as concrete, steel or wood are used, the specific requirements for these are probably included in the agency's noise barrier specifications. However, the recent proliferation of new materials generated by the current trend to use plastics and recycled materials has most likely not been specifically addressed in the agency's

specifications. Many specifications will have only general references to these, which generates another instance where the acceptance fundamentals (durability, safety, functionality, cost effectiveness) along with performance criteria must be used.

Test Results: Test reports are crucial to any acceptance process. How tests are conducted and by whom could mean the difference between acceptance and rejection of the submission. All testing should be performed by an accredited, independent testing laboratory acceptable to the approving agency. On rare occasions, agencies have permitted testing to be performed by the manufacturer, but only in the presence of an agency representative knowledgeable in the specific test procedure.

Testing should be conducted on full production run samples, whenever possible. In some cases, it may be advantageous to have the approving agency select the samples for testing. Agencies become cautious when the tests were conducted on samples made specifically for testing purposes.

In selecting a suitable test lab, make sure that the test personnel are familiar with the test procedures specific to the material and the final product, and insist that they contact the approving agency to verify these procedures before commencing. The submission should include complete copies of all required test results. Names of the laboratories, technicians and telephone numbers should also be provided if the agency wishes to discuss certain aspects of the test results.

Drawings and Associated Notes: Before starting the drawings, check with the agency to see what size is preferred, what details are required and in what format. But in most cases the drawings should at least include the following items:

- Details of individual components
- Location and sizes of reinforcing steel in concrete
- Schematic drawing of assembled system
- Footing design details for installation in earth and rock
- Structure-mounted details
- Termination and transition details
- Typical grading details
- Panel stepping details
- Special posts for changes in alignment
- Access door and firehose port details
- Type and location of manufacturer's I.D. on major components

The accompanying notes should include:

- Reference wind pressure
- Codes to which the barrier was designed
- Installation procedures
- Noise Reduction Coefficient (NRC)
- Sound Transmission Class (STC)
- Handling and storage requirements
- Physical properties of all materials used
- Type of special coatings, stains, etc.

Finally, they should be dated, stamped and signed by a registered professional engineer.

Engineering Calculations: In most areas, the manufacturer is responsible for the structural integrity of the noise barrier system. Therefore, copies of comprehensive design calculations must be provided which prove that the panels, posts and footings are capable of withstanding various wind loads and soil conditions in accordance with the Codes stipulated by the approving agency.

Quality Control Plan: The quality control plan outlines the manufacturer's procedures to ensure production of a consistently acceptable product. This document has become more of an issue in recent years and should be included in all submissions even though this may not be a compulsory requirement.

Maintenance: Details should be provided to indicate what protection has been used to address the graffiti problem and how to restore the components to their original appearance. Also, in cases of minor damage, a description of the repair technique should be included. For severe damage situations where the components must be removed and replaced, the manufacturer should provide a guaranteed delivery time for replacement parts.

Remember that highway and transportation agencies are always on the lookout for new and improved materials and systems. In the next issue, I will begin to discuss what makes an effective noise barrier specification.

Soren Pedersen is a Design Development Analyst for the Ministry of Transportation of Ontario, head office located in Toronto, Ontario, Canada. He may be contacted by phone at 416-235-3509, or by fax at 416-235-5314.

1991 Papers, *from page 6*

to helicopter operations will be well below measured existing ambient noise levels. Increases of the ambient community noise levels (on an L_{dn} basis) due to helicopter operations will be insignificant. Helicopter operations will sometimes be audible in the vicinity of the hospital, but will occur much less frequently than the existing comparable freight train noise events (a maximum of 400 helicopter annual operations as compared to more than 18,000 freight trains per year).

Finally, a sound reflection analysis was undertaken in response to claims of increased train noise near the hospital allegedly due to the introduction of the new hospital wing (thus providing a potential sound reflective surface). This analysis showed that reflections off the hospital wall are 9 to 13 decibels below the direct path. The level of these reflections add less than 1 decibel to the original signal which is an insignificant change. Other variables that may have contributed to the perception of increased noise include l) increased train or bus activity, or 2) increased train noise due to use of different or improperly maintained equipment (such as wheel flats). ■

The Wall Journal™
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Stafford, VA 22555-1286

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