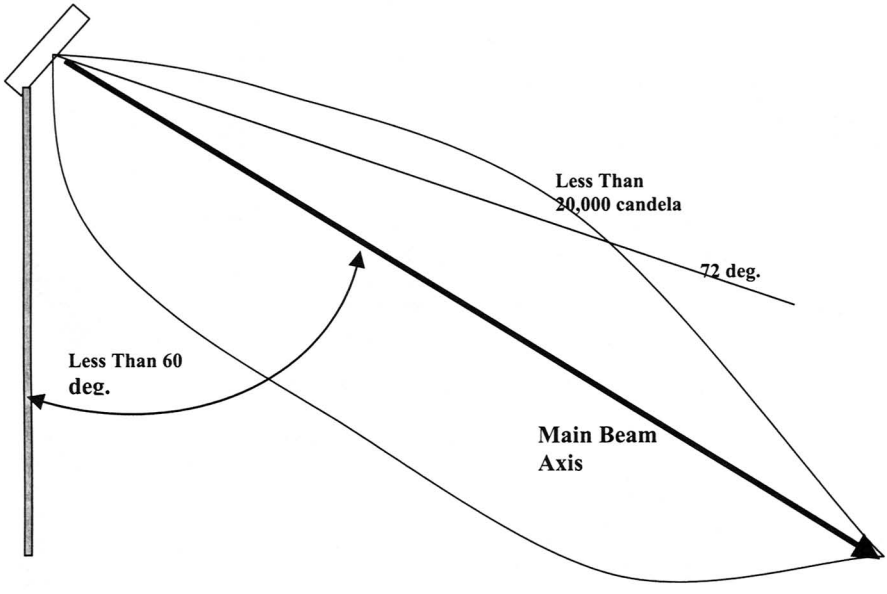

Figure 2 Lighting Beam Orientation for Glare Reduction

Supplemental Shading Hardware
The use of added shading devices on the luminaries could significantly reduce glare. These shielding devices are designed to cut off or block the light emitted beyond the desired range. Figure 3 presents an illustration of a typical glare control shielding hardware.

Mounting Height
Minimum mounting height is a function of the amount of light produced by the luminaries. More powerful lights should be mounted a greater distance above the work area.

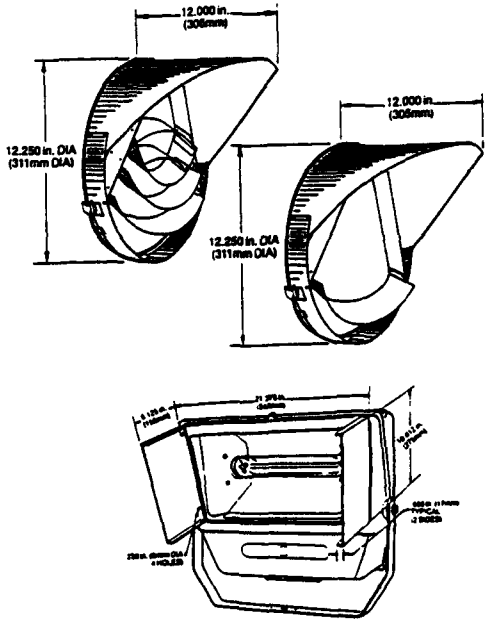

Figure 3 Typical Glare Control Shielding Hardware

Related Project Management Issues

Need for a Lighting Plan

A project lighting plan should be developed and approved prior to commencing night operations. This planning and review function is an important safe guard against mistakes that can impact on project quality and safety. Some State Highway Agencies require that a registered engineer prepare the plan and others do not. Regardless of who prepares the plan an engineer who has both construction experience and knowledge of lighting fundamentals should review it for approval. At a minimum the plan should address the following issues:

1. Lighting configurations on stationary and moving equipment
2. Lighting configuration of typical stationary work zone areas
3. Glare control measures
4. Inspection and maintenance of the lighting systems

Lighting for Inspection Activities

Normally the contractor provides the lighting systems for performing the night work activities. The focus is understandably on the immediate area of work. However for many reasons the inspection of the work by the State Highway Agency personnel may not conveniently occur at the location where the contractor is working. For example inspection of asphalt paving may take place some distance from the position of the paving machine and rollers working immediately behind the paver, far from the lighting provided by for the work activity. The point is that provisions must be made for the project quality control personnel to have adequate lighting resources independent of the contractors work activity.

Overlooked Activities

Care must be taken to avoid overlooking the small ancillary task that is often necessary but not part of the main work activity. The saw cutting of joints in concrete pavement is a good example. In a typical scenario the project supervisory focus is on the placement of the concrete pavement. All attention and lighting is focused on this main line activity until the day's work is complete and then everyone goes home. However, sometime after the placement has occurred a two-man pavement saw cutting crew must come and saw cut the required joints. These workers may be left without adequate lighting. All activities even the minor ones should be provided adequate supervision and lighting.

Summary

Construction managers responsible for nighttime construction should know basic lighting fundamentals. Appropriate construction area lighting is obtained by providing:

1. Minimum illumination levels
2. Minimum illuminated area
3. Glare Control

Illumination levels are readily verifiable using hand-held illumination meters. Guidelines for lighting highway construction areas have been developed by the Transportation Research Board and the essentials requirements have been included in this paper. Preparation and review of a project lighting plan that includes all work activity is recommended.

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MITIGATION OF COMMUNITY NOISE IMPACTS FROM NIGHTTIME CONSTRUCTION

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ABSTRACT

Construction activities have the potential to generate a significant amount of noise that can impact the surrounding community when construction occurs near where people live or work. In the past, construction noise was often considered to be a temporary nuisance that was unavoidable and that communities would have to live with in the interest of progress. However, with the increased concern about environmental issues and the proliferation of long-term "mega-projects" in recent years, the effects of construction noise can no longer be ignored. This is particularly true for construction that takes place during the more sensitive nighttime hours when background noise levels are lower and people are trying to relax at home; noise that people may tolerate during the day will often be considered unacceptable at night. Unfortunately, nighttime construction is becoming ever more prevalent, particularly for transportation projects where daytime disruption of highways, airports and railways must be avoided. In an effort to help project owners, engineers and contractors deal with this problem more effectively, this paper provides a review of practical approaches for mitigating community noise impacts from nighttime construction and presents illustrative examples from specific projects. Various mitigation methods are discussed, including noise control at the source (e.g. equipment noise limits, substitutions and operational restrictions), transmission path controls (e.g. equipment relocation and sound barriers) and noise control at the receiver (e.g. building sound insulation and temporary resident relocation). However, it is most important that potential construction noise problems be identified in the planning and design phases of the project so that appropriate mitigation measures can be specified proactively, prior to the start of construction. Good community relations and communication are also essential in mitigating nighttime noise problems, along with effective monitoring and complaint response mechanisms during construction.

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INTRODUCTION

Nighttime construction has become more prevalent in recent years due to the need to avoid disruption of daytime activities, particularly in the case of urban transportation projects. Some of the major noise nuisances associated with nighttime construction were identified in a recent synthesis report prepared for the Transportation Research Board [1]. Based on a survey of all 50 state transportation departments in the United States, the most frequent generators of the nuisances were reported to be back-up alarms, slamming tailgates and demolition equipment used in pavement breaking and bridge deck removal (e.g. hoe rams). These sources have tonal or impulsive characteristics that people find objectionable even when they contribute minimally to the overall noise environment. A review of nighttime complaint logs for a three-year period (1998-2000) during construction on the Boston Central Artery/Tunnel Project leads to a similar conclusion, as shown in Figure 1. This paper discusses methods that can be used to mitigate noise impact from such sources within the context of an overall noise control strategy, and presents examples of how specific projects have dealt with nighttime construction noise issues.

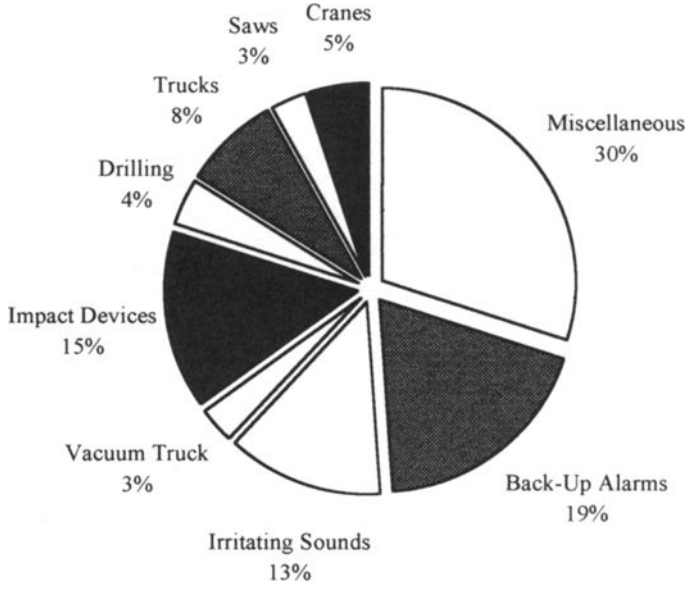

FIG. 1. Boston CA/T Project Noise Complaint Summary (1998-2000).

STRATEGY FOR NIGHTTIME CONSTRUCTION NOISE CONTROL

Approach

The noise control goal for nighttime construction projects is to minimize the noise impact in the community while maintaining construction progress. Achieving this balance requires the participation of all parties involved, including the project owner, the planners, the designers, the contractors, and the affected community. Overall direction and support must come from the owner, and be clearly communicated through the planners and designers to the contractors. Contractors need to understand that noise control is an integral part of the construction process, since the failure to adequately control nighttime construction noise can lead to significant public animosity and political action that can threaten the progress of the project. To avoid this type of situation, the community must also be informed about the project and the efforts that are being made to minimize noise disturbance. For a nighttime construction project to succeed, it is important that noise control be considered during the planning, design, and construction phases of the project as outlined below.

Planning

Potential community noise problems from nighttime construction should first be identified during the planning phase of a project. Noise problems can be anticipated whenever nighttime construction is planned near residences, hospitals, hotels and other noise-sensitive sites with nighttime occupancy. Measurements to document the existing nighttime noise conditions, along with preliminary estimates of construction noise, can provide an indication of the scope of the problem; such analysis is generally performed for major projects as part of the environmental impact assessment process. While it may not be possible to determine specific noise control measures during the planning stage of a project, it is important that the environmental documents identify the potential noise problems and commit to the approach that will be taken during the design phase to mitigate nighttime construction noise impact.

Design

Construction noise control specifications should be developed during the design stage of a project when the potential for noise impact has been identified. Effective specifications usually require that a detailed construction noise analysis be performed, using procedures such as those included in a guidance document prepared for the U. S. Department of Transportation [2]. In the latter document, noise predictions are based on construction scenarios that include the number and type of equipment, the noise emission levels of equipment (at a reference distance), the usage factor for the equipment (i.e. the fraction of time the equipment operates), the distance between the equipment and the community receivers and excess attenuation (noise reduction) from barriers and topography. Noise impact is then assessed based on applicable regulations and criteria, where the criteria are typically developed on a project-specific basis.

The results of the noise analysis serve as the basis for preparing the construction noise control specification. To achieve a proper balance between environmental protection and construction progress, the objective of the

specifications should be to minimize construction noise using all "reasonable" (i.e. cost vs. benefit) and "feasible" (i.e. physically achievable) means available. Items to be considered for inclusion in the contract documents are as follows:

- *Equipment noise emission limits.* These are absolute noise limits applied to generic classes of equipment at a reference distance (typically 15 m). The limits should be set no higher than necessary to be achievable for well-maintained equipment with effective mufflers. Lower limits that require source noise control may be appropriate for certain equipment when needed to minimize community impact, if reasonable and feasible. Provisions should also be included to require equipment noise certification prior to use on site.
- *Lot-line construction noise limits.* These are noise limits that apply at the lot-line of specific noise-sensitive properties. The limits are typically specified in terms of both noise exposure (usually over a 20-30 minute period) and maximum noise level. They should be selected based on applicable noise regulations as well as the pre-construction baseline noise level; limits that are 3-5 decibels above the baseline level are often used.
- *Operational and/or equipment restrictions.* It may be necessary to prohibit or restrict certain construction equipment and activities near residential areas during nighttime hours. This is particularly true for activities that generate tonal, impulsive or repetitive sounds, such as back-up alarms, hoe ram demolition and pile driving.
- *Noise abatement requirements.* In some cases, specifications may be provided for particular noise control treatments, based on the results of the design analysis and/or prior public commitments. An example would be the requirement for a temporary noise barrier to shield the community from noisy construction activities.
- *Noise monitoring plan requirement.* Some specifications require the contractor to submit a noise monitoring plan that outlines the measurement and reporting methods that will be used to demonstrate compliance with the project noise limits.
- *Noise control plan requirement.* For major long-term projects, specifications have required that the contractor submit noise control plans on a periodic basis (e.g. every six months). These plans should predict the construction noise at noise-sensitive receptor locations based on the contractor's proposed construction equipment and methods. If the analysis predicts that the specified noise limits will be exceeded, the plan should specify the mitigation measures that will be applied and demonstrate the expected noise reductions these measures will achieve. The objective of this proactive approach is to minimize the likelihood of community noise complaints by ensuring that any necessary mitigation measures are included in the construction plans.
- *Acoustical engineer requirement.* The contract documents generally specify qualifications for an experienced, acoustical engineer that the contractor must hire to prepare the noise control and noise monitoring plans and to oversee the equipment noise certification and noise monitoring requirements.

- *Complaint response procedure.* Last but not least, the construction noise control specification should include a procedure that the contractor must follow in responding to noise complaints.

Construction

During construction, the most significant noise control activities are mitigation monitoring and community relations. Mitigation monitoring includes the review of noise control plans, noise monitoring plans and noise measurement data. Ideally, these functions should be performed by a construction management organization on behalf of the owner. This is particularly important for the design-build type of project that has recently become popular, to avoid the situation where "the fox is guarding the hen house." This criticism has also been made in the case of standard design-bid-build projects where the contractor is responsible for the compliance measurements. In such cases, it is a good idea for an owner representative to perform quality control spot checks to verify the contractor's results. Finally, it is important for the project management to keep the community informed about the construction plans and efforts to minimize noise, to actively enforce the noise mitigation requirements, and to rapidly respond to noise complaints.

CONSTRUCTION NOISE MITIGATION METHODS

Construction noise control can be applied to the noise source, transmission path or receiver. A review of available noise mitigation methods in each of these categories is provided below, followed by case study examples from actual projects.

Noise Control at the Source

By limiting noise emissions everywhere, this approach provides the most effective means for controlling noise during construction, and should be applied whenever practical. Examples of this method are given below.

Emission limits. As discussed above, noise limits for equipment can be included in the construction specifications. The limits should be set no higher than needed to ensure the use of well-maintained equipment with effective mufflers. Lower limits, that may require specially quieted equipment or modified equipment, can also be specified when necessary and appropriate.

Equipment noise control. When quieter than normal equipment is required for certain applications, noise control treatments can often be applied. Examples of such treatments are described below for some major construction noise generators:

- *Impact pile driving.* Several techniques are available for retrofitting existing pile hammers to reduce noise. These include: (1) attaching an enclosure to the hammer to shield the impact area, (2) installing a muffler on the air exhaust port of the pile driver, (3) applying damping (energy-absorbing) materials to steel piles to reduce ringing noise, and (4) cushioning the impact between the pile and the hammer head. Such treatments can be expected to reduce the A-weighted sound levels from pile driving by about 10 decibels. There are also some quieter proprietary piling methods that have been developed overseas. These methods

employ various degrees of shielding, sound absorption and impact cushioning, and can provide noise reductions of 20 to 30 decibels. However, such methods have had little application in construction projects in the United States.

- *Concrete breaking.* Hand-held pneumatic breakers fitted with mufflers and damping collars that can provide A-weighted noise reductions on the order of 5 to 10 decibels are commercially available. However, there is some concern regarding the durability of these silencing treatments with rough handling and cold temperatures. There is also a newly-designed jackhammer that uses a smaller air compressor and an adiabatic process to produce forces comparable to a typical 80-lb jackhammer while generating noise levels about 10-decibels quieter than a conventional jackhammer. For excavator-mounted breakers, commercially made hammer brackets are available for limited applications. Due to the effects these treatments may have on equipment performance, they should be supplied by the equipment manufacturer; a retrofit approach is not recommended.

Substitution. Noisy equipment or processes can sometimes be replaced by quieter alternatives. However, because alteration of major processes is not always practical, particularly after construction has begun, substitution must usually be planned for during project design. Examples of this approach for impact pile driving and concrete breaking are provided below.

- *Impact pile driving.* Impact pile driving is one of the noisiest construction processes. Alternative methods that can be considered to reduce noise from such operations include: (1) substitution of hydraulic impact hammers for diesel impact hammers, (2) substitution of pre-cast concrete piles in place of steel piles, (3) use of auguring equipment to construct bored piles, (4) use of vibratory hammers for driving steel piles, (5) use of static load equipment to push rather than drive piles and (6) substitution of slurry wall foundations for driven pile foundations.

- *Concrete breaking.* The conventional method for removing concrete is to break it up using percussive breakers. Some noise reducing alternatives are: (1) substitution of hydraulic, electric or gasoline-powered tools for pneumatic equipment, (2) substitution of a whip-action impact hammer for a standard excavator-mounted hammer, (3) use of a thermal lance to burn holes in concrete, (4) use of diamond drills and saws, (5) use of hydraulic bursters or jacks, (6) use of excavator-mounted hydraulic crushers, (7) use of non-explosive chemical demolition agents and (8) use of high-pressure discharge of carbon dioxide gas.

Operational restrictions. Operational measures that can be considered to reduce construction noise impact include: (1) scheduling of noisy activity to coincide with periods of least noise sensitivity (e.g. prohibiting certain activities and equipment use near residential areas at night), (2) restricting equipment idling on site, (3) routing construction truck traffic away from residential streets, (4) prohibiting unnecessary rattling and banging, (5) requiring that certain equipment (e.g. vacuum excavator trucks) operate at the lowest possible power settings, (6) limiting the use of generators by encouraging the use of the local power grid and by specifying only grid connected or solar powered traffic control devices and message boards and (7) restricting the use of back-up alarms, annunciators and public address systems. Alternatives to standard