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Case Studies

Occupational Exposures in Seismic Retrofitting Operations

Dawn Tharr, Column Editor

Reported by John L. McKernan, Gregory M. Piacitelli, Kevin C. Roegner, Lisa Delaney, and James M. Boiano

The Hazard Section, Surveillance Branch of the National Institute for Occupational Safety and Health (NIOSH) conducted a study to assess exposures of construction workers to selected health hazards during seismic retrofitting of a historic mining engineering building at a university in California. The study was prompted by concerns regarding lead, noise, and other hazards typically associated with demolition and construction activities, and was conducted in cooperation with the university's Office of Environment, Health, and Safety, as well as a general construction contractor and several special trade subcontractors. The mining building was one of four multistory laboratory/classroom buildings being retrofitted on the university's campus at the time of this study. All of these retrofitting projects were funded by the Federal Emergency Management Agency (FEMA).

Background

Seismic retrofitting is the process of reengineering existing buildings to limit the extent of damage caused by earthquakes. This process involves reinforcing or replacing existing structural components to meet current building code requirements, and, depending on the age of the building, may necessitate lead and/or asbestos abatement prior to selective demolition and rebuild activities associated with the retrofitting process.

The study was conducted in an unoccupied, four-story, nonreinforced masonry building consisting of three aboveground levels and a subterranean level (i.e., sublevel) that was excavated specifically to accommodate pilings, beams, and "base isolation" units. Base isolation, as a structural design technique, involves decoupling of a structure from ground motion through the insertion of an energy-deflecting layer (i.e., base isolation units) between the structure and the foundation.(1) Prior to initiating retrofitting activities, lead-based paint and asbestos were abated from selected areas within the building. This study focused primarily on health hazards associated with selective demolition and rebuild activities. During the evaluation, approximately 65 workers from several special trade subcontractors worked a full shift at the site.

Methods

In April 2000, a preliminary observational walkthrough of the building was conducted to identify health hazards and associated occupations for subsequent quantitative exposure assessment. Bulk samples of selected building materials (i.e., concrete, brick mortar, and plaster) were collected and analyzed to confirm the presence of crystalline silica (quartz).

Based on information gathered from the walkthrough, special trade subcontractor in 11 occupational groups having potential exposure to crystalline silica, lead, diesel exhaust, and noise were selected for quantitative assessment during a three-day follow-up survey conducted in June 2000. Worker exposures were quantitatively evaluated by collecting integrated personal and/or area air samples and noise dosimetry measurements in accordance with the sampling strategy presented in Table I. In a few cases, area air samples were collected in the general vicinity of the worker, when the worker indicated that he would not wear the sampling equipment. Most of the samples were collected over a full shift (i.e., 7 to 8 hours); samples with durations less than 7 hours were collected for the duration of a particular task.

Lead

The personal breathing zone (PBZ) air samples for lead were collected using NIOSH Method 7082.(2) The sampling and analysis method was modified by the use of preweighed 37-millimeter (mm) polyvinyl chloride (PVC) 5-micrometer (μm) pore-size membrane filters at a flow rate of 3 liters per minute (Lpm). The PVC filters were used for gravimetric analysis; the sample results are not reported herein because they were unremarkable. The analytical method was modified for nitric acid/microwave digestion of the PVC filters. If lead was not detected by this method, the sample was subsequently analyzed by the more sensitive NIOSH Method 7300.(2) Limits of detection (LOD) and quantitation (LOQ) for samples analyzed by NIOSH Methods 7300 and 7082 ranged from 0.0002 to 0.005 and from 0.0006 to 0.020 milligrams per sample (mg/sample), respectively.

Crystalline Silica

The PBZ samples for respirable crystalline silica were collected in accordance with NIOSH Method 7500, using 5.0 μm pore-size PVC filters and a 10-mm nylon cyclone to remove the nonrespirable fraction (> 4 μm mass-median aerodynamic diameter [MMAD]) at a flow rate of 1.7 Lpm.(2) Filters were analyzed for quartz using x-ray diffraction according to this same method. The LOD

TABLE I
Sampling strategy

Occupation	Number of samples			
	Lead	Respirable crystalline silica^A	Diesel exhaust^B	Noise
Brick mason	—	—	—	1 (P)
Building carpenter	—	—	1 (A)	2 (P)
Pneumatic chipper operator	4 (P)	7 (P)	—	3 (P)
Equipment operator	—	2 (P)	4 (P)	3 (P)
Construction laborer	—	—	1 (A), 4 (P)	1 (A)
Construction supervisor	—	1 (P)	2 (P)	—
Core drill operator	—	1 (P)	—	1 (A)
Lead abatement worker	2 (P)	3 (P)	—	3 (P)
Rebar installer	—	1 (P)	—	3 (P)
Roofer	—	—	—	2 (P)
Welder	2 (P)	—	—	—

^A Measured as quartz; other forms of silica were not detected in bulk samples.
^B Measured as elemental carbon.
A = Area sample; P = Personal sample.

and LOQ for the analysis were 0.01 and 0.03 mg/sample, respectively.

Diesel Exhaust

The PBZ and general area air samples for diesel exhaust were collected and analyzed in accordance with NIOSH Method 5040.[2] The air samples were collected on 37-mm quartz-fiber filters, utilizing a high-flow respirable-thoracic cyclone (BGI Inc., Waltham, MA) with an MMAD cut size of 6 μm, at a flow rate of 3 Lpm. The air samples were analyzed for elemental carbon (EC), a surrogate for diesel exhaust particulate exposure. Three air samples (one per day) were collected on the roof of the building, away from any diesel emission point sources, to assess background concentrations. The LOD and LOQ for the analysis were 0.008 and 0.026 mg/sample, respectively.

Noise

Occupations and tasks with noise levels $\geq$85 A-weighted decibels (dBA), measured during the first day of the follow-up evaluation using a sound level meter (Quest Electronics, Model 215, Oconomowoc, WI), were selected for personal and area dosimetry. Noise dosimetry was conducted using noise dosimeters (Quest Electronics, Model Q-300, Oconomowoc, WI), which were worn by the workers, with the microphone positioned on the shirt lapel/collar, directly below the ear. When personal dosimetry was not possible (2 of the total 19 samples), the dosimeter was placed in the immediate vicinity of the worker. The dosimeters were programmed to measure noise levels in two separately calibrated channels, one using a 3-dB exchange rate and an 80-dB threshold for comparison to the NIOSH Recommended Exposure Limit (REL), and the other using a 5-dB exchange rate and a 90-dB threshold for comparison to the OSHA Permissible Exposure Limit (PEL).[3–5] In this study, these two channels are subsequently referred to as the REL channel and the PEL channel, respectively. At the end of each work shift, stored data were downloaded to a personal computer for evaluation.

Results

Air sampling results for lead, crystalline silica, and diesel exhaust by occupation, observed task(s), sample type, number of samples collected, and sampling duration are presented in Table II. Personal and area noise levels, measured in the REL and PEL channels, are presented in Table III by occupation, observed task(s), sample type, number of samples collected, and sampling duration. Maximum noise levels for each of these samples are also reported in Table III. All air sampling and noise results were compared to applicable NIOSH RELs, OSHA PELs, and American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Values (TLVs®).[3–9]

Lead

Lead concentrations for the eight PBZ samples ranged from trace (i.e., greater or equal to the LOD but less than or equal to the LOQ) to 0.05 milligrams per cubic meter of air (mg/m^3), as shown in Table II. The highest concentration, 0.05 mg/m^3, equivalent to the PEL, REL, and TLV, was from a chipper operator during removal of lead-contaminated concrete and plaster from the sublevel ceiling. Lead exposures of the welder during welding of structural steel ranged up to 0.024 mg/m^3 over a sampling period of approximately two hours.

Crystalline Silica

Silica concentrations for the 15 PBZ samples ranged from nondetectable (ND) to 0.27 mg/m^3 (Table II). Occupations with exposures exceeding the REL and TLV of 0.05 mg/m^3 included chipper operators; lead abatement workers; and the rebar installer during dry-drilling of holes in steel, concrete, and bricks. However, sample results did not approach 20 percent of applicable PELs, calculated as 10 mg/m^3/(%Silica [%quartz for that sample] + 2). Nondetectable or trace levels were measured for the core drill operator during wet drilling of steel, brick, and concrete, and for the construction equipment operators.

Diesel Exhaust

Diesel exhaust (as EC) concentrations ranged from ND to 0.08 mg/m^3

TABLE II
Personal and area air sampling results for lead, respirable crystalline silica, and diesel exhaust

Occupation	General tasks (and locations)	Sample type	N	Sample duration (min)	Airborne concentration (mg/m): Lead	Respirable crystalline silica	Diesel exhaust
Building carpenter	Constructing concrete forms (sublevel)	Area	1	431	—	—	ND
Pneumatic chipper operator	Chipping lead-contaminated concrete and plaster (sublevel)	Personal	4 5	318–413 319–411	Trace–0.05	—	—
	Chipping concrete and brick (1st floor)		2	278–428	—	ND	—
Equipment operator	Excavating soil with backhoe (sublevel)		1 1	255 417	— —	— Trace	0.04 —
	Transporting soil with front-end loader (sublevel)		1 2	392 424–443			
	Breaking up soil with equipment-mounted jackhammer (sublevel)		1	419			
Construction laborer	Operating survey and measuring equipment (sublevel)	Area	4	407–431	—	—	ND–0.08
	Removing debris from construction areas with front-end loader (outdoors)	Personal	1	460	—	—	ND
Construction supervisor	Supervising workers and material handling (all floors)		1 2	349 343–459	— —	Trace —	— ND
Core drill operator	Drilling brick, concrete, and steel (sublevel)		1	194	—	ND	—
Lead abatement worker	Removing lead-contaminated plaster (1st and 2nd floors)		2 3	267–305 244–307	Trace —	— Trace–0.13	— —
Rebar installer	Drilling rebar holes in brick, concrete, and steel (1st and 2nd floors)		1	460	—	0.06	—
Welder	Welding new steel girders to existing structural steel (1st floor)		2	65–127	Trace	—	—
		Evaluation criteria:		NIOSH REL: ACGIH® TLV®: OSHA PEL:	0.05 0.05 0.05	0.05[A] (C) 0.05 (H) F	LFC 0.02[B] (H) NE

[A]REL established to prevent silicosis.
[B]Notice of Intended Changes, respirable fraction TLV® for diesel exhaust as elemental carbon.
Because samples were not collected according to ACGIH® respirable sampling criterion, results are not directly comparable to the TLV®.
N = Number of samples; NE = Not established; ND = Not detected or less than the LOD; Trace = Analytical result was between the LOD and LOQ; LFC = Lowest feasible concentration—considered to be ≤ ambient background levels; C = Potential occupational carcinogen; H = Suspected human carcinogen; F = 10 mg/m^3/(% SiO_2 [as quartz] + 2).

TABLE III
Personal and area noise dosimetry results

Occupation	General tasks (and locations)	Handheld tools?	Sample type	N	Sample duration (min)	Noise levels (dBA)		
						REL channel[A]	PEL channel[B]	Maximum[C]
Brick mason	Drilling and chipping brick, concrete, and plaster (1st floor)	Yes	Personal	1	435	90.9	83.9	111
Building carpenter	Constructing wood door frames and concrete forms (sublevel and 1st floor)	Yes	Personal	2	421–440	86.6–97.7	76.8–85.9	138
Pneumatic chipper operator	Chipping lead-contaminated concrete and plaster (sublevel)	Yes	Personal	3	374–417	105–112	100–108	127
Construction laborer	Stripping concrete forms (sublevel)	Yes	Area	1	468	80.8	65.0	113
Core drill operator	Drilling brick, concrete, and steel (sublevel)	Yes	Area	1	430	90.1	87.5	105
Lead abatement worker	Removing lead-contaminated plaster and metal ductwork (1st and 2nd floors)	Yes	Personal	3	106–314	82.5–103	69.7–93.6	123
Equipment operator	Breaking up, excavating, and transporting soil using diesel-powered excavation equipment (sublevel)	No	Personal	3	347–416	92.8–98.7	85.4–97.2	116
Roofer	Cutting and installing steel roof decking and sawing concrete (roof)	Yes	Personal	2	431–432	89.7–99.6	82.0–90.7	121
Rebar installer	Drilling rebar holes in brick, concrete, and steel (1st and 2nd floors)	Yes	Personal	3	445–466	91.9–98.2	86.0–92.8	122
Evaluation criteria:					NIOSH REL:	85.0	—	140
					OSHA PEL:	—	90.0	140

[A]Dosimeters programmed using an 85-dB criterion, 80-dB threshold, and 3-dB exchange rate.
[B]Dosimeters programmed using a 90-dB criterion, 90-dB threshold, and 5-dB exchange rate.
[C]Maximum slow-response level measured during sampling period.
N = Number of samples collected.

(Table II). The four PBZ samples from operators of various pieces of diesel-powered equipment ranged from trace to 0.04 mg/m^3. Four area samples, collected to assess exposures of construction laborers who were working in the immediate vicinity of diesel-powered equipment, ranged from ND to 0.08 mg/m^3. Samples collected from the building carpenter, construction laborer, and supervisors were ND. Because NIOSH and ACGIH consider diesel exhaust a potential human carcinogen,[6,9,10] it is prudent to maintain exposures at or below the lowest feasible concentration (LFC). For purposes of this study, the LFC (i.e., NIOSH REL) was equivalent to ambient background concentrations, which were all nondetectable, i.e., less than 0.008 mg/m^3. The sampling results indicated that equipment operators were exposed to diesel exhaust levels of up to five times the NIOSH REL, and that the construction laborers' exposures ranged up to 10 times the REL (worst-case scenario, given that none of the workers remained in the sublevel for the entire shift).

Noise

Personal and area TWA and maximum noise levels, for both the PEL and REL channels, are presented in Table III, by occupation and observed task(s). Noise exposures in the PEL channel ranged from 65 to 108 dBA, with eight personal samples at or above the PEL. Occupations with exposures at or above the PEL included the pneumatic chipper operators, rebar installer, construction equipment operators, roofers, and lead abatement workers. In the REL channel, noise levels ranged from 80.8 to 112 dBA, with 16 of the personal samples and one area sample at or above the REL. Occupations with exposures at or above the REL included building carpenters, brick masons, core drill operators, and those that exceeded the PEL. Maximum slow-response noise levels ranged from 105 to 138 dBA; none of the samples exceeded the REL and PEL of 140 dBA.

Discussion

Lead

Exposure of the pneumatic chipper operators to lead levels ranging up to the REL and PEL was somewhat unexpected since lead-based paint was abated from the work surfaces prior to the start of the retrofitting project. Apparently, removal of lead-based paint from these surfaces was not 100 percent effective; it is also possible, however, that the chemical stripping technique reportedly used in the lead abatement phase (which preceded this study) caused residual lead to leak into the work surfaces. As a result, airborne particulate, generated during chipping of plaster and other surfaces previously coated with lead-based paint, presented a potential health hazard for the chipper operators. The chipper operators, however, appeared to be adequately protected since they were observed using respirators (with a protection factor of at least 10) and protective clothing (i.e., hooded coveralls and gloves).

Crystalline Silica

The chipper operators, lead abatement workers, and rebar installers were exposed to respirable crystalline silica in excess of the PEL, REL, and TLV. These criteria were established primarily to prevent silicosis.[11,12] However, recent evidence indicates that crystalline silica is a potential human carcinogen.[13–15] The abatement worker and those workers who were chipping or otherwise removing concrete, brick, and/or plaster appeared to be adequately protected since respirators (with a protection factor of at least 10) and protective clothing were worn by these workers.

Diesel Exhaust

Sampling results for diesel exhaust (as EC) indicated that the highest exposures were among construction equipment operators and laborers working in the sublevel. This area was completely enclosed with the exception of three openings in the exterior concrete foundation, which were cut out to facilitate access by compact diesel-powered earth-moving equipment such as backhoes and bobcats. Although these openings allowed some air circulation to occur, natural ventilation was minimal for adequate dilution of diesel exhaust emissions. Diesel exhaust is composed of very small particles (< 1 μm), most of which remain airborne for long periods—especially when ventilation is lacking—thereby increasing the likelihood of worker exposure. None of the sampled workers were observed wearing respirators.

Noise

Of the nine occupations evaluated, the chipper operators had the highest noise exposures, with levels in the PEL channel ranging from 100 to 108 dBA. All three concrete chippers were observed wearing appropriate hearing protection devices (HPDs). Overall, 6 of 8 employees exposed above the PEL, and 8 of 17 exposed above the REL wore HPDs during the evaluation. The monitored workers reported that they were not enrolled in a hearing conservation program; those wearing HPDs did so voluntarily.

Those workers who used handheld power tools (saws, drills, impact tools, etc.) had exposures similar to those of the diesel-powered equipment operators; however, the former workers were exposed to a wider range with higher maximum exposures than the latter. Maximum noise levels for all sampled workers ranged from 111 to 138 dB, with the highest value being measured for the building carpenter. These values, by comparison, were below the PEL and REL of 140 dB for maximum noise levels.

Recommendations

Based on the results of this evaluation, NIOSH provided the university, the general construction contractor, and its subcontractors with the following recommendations, which were intended to improve health and safety at the work site:

1. Workers involved in concrete chipping, rebar installation, and lead abatement activities should use wet methods and/or tools

equipped with local exhaust ventilation to minimize exposure to airborne particulate containing lead and/or crystalline silica. In situations where engineering controls are not practical, use of appropriate half-mask respirators equipped with HEPA filters, as well as protective equipment and clothing (PPE/C), should be continued or otherwise implemented.

2. Consideration should be given to situations in which unexpected exposures may occur, such as collateral exposures from nearby work activities involving lead-contaminated (i.e., previously abated) building surfaces. Before any demolition work or other similar activities are initiated, it is recommended that an initial assessment be performed to identify the potential for lead-exposure/hazardous lead concentrations. In addition, proper hygiene practices (i.e., hand washing, showering, and on-site storage of work apparel) should be followed, and proper PPE/C should continue to be worn by all lead-exposed workers (regardless of their lead exposure) and removed prior to leaving the site, in order to prevent accidental lead ingestion and take-home exposures.
3. Diesel exhaust exposures should be kept at or below the LFC (i.e., background concentrations) by one of the following methods: using excavation equipment powered by alternate fuel sources (i.e., LP gas), implementing forced-air ventilation (i.e., fans), limiting worker exposure times, or (less preferably) requiring workers to wear appropriate respirators.
4. An effective hearing conservation program needs to be developed and implemented in accordance with the requirements of the OSHA noise standard, including, but not limited to, audiometric testing, employee notification, noise measurement, use of hearing protection devices (HPDs), employee training, and record-keeping. Engineering controls, such as the replacement of older tools and equipment with newer, quieter models, should be considered. Workers should be involved in the selection process to ensure widespread acceptance. Use of quieter tools would eventually reduce the number of workers required to wear HPDs.

Conclusion

Because of heightened concerns about the condition of existing infrastructures, there has been a recent increase in seismic retrofitting activities in areas susceptible to earthquakes, such as regions in the western United States. Seismic retrofitting basically involves construction activities and work tasks similar to other construction renovation work. This type of work typically involves workers of various trades performing tasks, often simultaneously and in close proximity to each other. These conditions result in hazardous exposures as indicated by the limited sampling results from this study. It is important that workers, site managers, and industrial hygienists recognize the potential for these exposures to occur and, in turn, take adequate measures to minimize exposures among all workers.

REFERENCES

1. Kelly, J.M.: Base Isolation: Origins and Development. National Information Service for Earthquake Engineering, University of California, Berkeley (1998). [http://www.eerc.berkeley.edu/lessons/kelly.html] Date accessed: May 2001.
2. National Institute for Occupational Safety and Health: NIOSH Manual of Analytical Methods (NMAM), 4th ed. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, DHHS (NIOSH) Pub. No. 94-113. NIOSH, Cincinnati, OH (1994).
3. National Institute for Occupational Safety and Health: Criteria for a Recommended Standard—Occupational Noise Exposure (Revised Criteria, 1998). U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, DHHS (NIOSH) Pub. No. 98-126. NIOSH, Cincinnati, OH (1998).
4. Code of Federal Regulations: 29 CFR 1926.52. U.S. Government Printing Office, Office of the Federal Register, Washington, DC (1998).
5. Code of Federal Regulations: 29 CFR 1910.95. U.S. Government Printing Office, Office of the Federal Register, Washington, DC (1997).
6. National Institute for Occupational Safety and Health: NIOSH Pocket Guide to Chemical Hazards (NPG). U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, DHHS (NIOSH) Pub. No. 97-140. NIOSH, Cincinnati, OH (1994).
7. Code of Federal Regulations: 29 CFR 1926.55. U.S. Government Printing Office, Office of the Federal Register, Washington, DC (1998).
8. Code of Federal Regulations: 29 CFR 1910.1000. U.S. Government Printing Office, Office of the Federal Register, Washington, DC (1997).
9. American Conference of Governmental Industrial Hygienists: 2001 TLVs® and BEIs®: Threshold Limit Values for Chemical and Physical Agents and Biological Exposure Indices. ACGIH®, Cincinnati, OH (2001).
10. National Institute for Occupational Safety and Health: Current Intelligence Bulletin 50—Carcinogenic Effects of Exposure to Diesel Exhaust. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, DHHS (NIOSH) Pub. No. 88-116. NIOSH, Cincinnati, OH (1988).
11. National Institute for Occupational Safety and Health: NIOSH Alert—Request for Assistance in Preventing Silicosis and Deaths from Sandblasting. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, DHHS (NIOSH) Pub. No. 92-102. NIOSH, Cincinnati, OH (1992).
12. National Institute for Occupational Safety and Health: Criteria for a Recommended Standard—Occupational

Exposure to Crystalline Silica. U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control and Prevention, DHEW (NIOSH) Pub. No. 75-120. NIOSH, Cincinnati, OH (1975).
13. U.S. Department of Health and Human Services: Sixth Annual Report on Carcinogens—Summary, 1991, pp. 357–364. DHHS, Public Health Service, National Institute of Environmental Health Sciences, Research Triangle Park, NC (1991).
14. International Agency for Research on Cancer: IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans—Silica and Some Silicates. Vol. 42, pp. 49, 51, 73–111. World Health Organization, IARC, Lyon, France (1987).
15. National Institute for Occupational Safety and Health: NIOSH Testimony to the U.S. Department of Labor—Statement of the National Institute for Occupational Safety and Health. Presented at the Public Hearing on OSHA PELs/Crystalline Silica, July 1988. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH Policy Statements. NIOSH, Cincinnati, OH (1988).

EDITORIAL NOTE: John L. McKernan, Gregory M. Piacitelli, and James M. Boiano are with the Surveillance Branch of NIOSH. At the time this study was conducted, Kevin C. Roegner and Lisa Delaney were with the Hazard Evaluation and Technical Assistance Branch of NIOSH. The authors gratefully acknowledge the workers and managers that participated in the study, with special thanks to Gary Bayne and Katy Medinas. For further information on topics of interest in construction, NIOSH reports and other publications may be obtained by accessing the NIOSH website at http://www.cdc.gov/niosh/pubs.html, or by calling 1-800-35-NIOSH.