In-Depth Survey Report

CONTROL TECHNOLOGY FOR DOWEL DRILLING IN CONCRETE

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Site Surveyed:

Laborer's Local 172
Safety, Education and Training Center
1100 Black Horse Pike
Folsom, NJ 08037

NAICS Code:

237310 Highway, Street, and Bridge Construction

Survey Dates:

August 7-8, 2012

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Abstract

Background

Workplace exposure to respirable crystalline silica can cause silicosis, a progressive lung disease marked by scarring and thickening of the lung tissue. Quartz is the most common form of crystalline silica. Crystalline silica is found in several construction materials, such as brick, block, mortar and concrete. Construction tasks that cut, break, abrade, or drill those materials have been associated with overexposure to dust containing respirable crystalline silica. Highway construction tasks that can result in respirable crystalline silica exposures include breaking pavement with jackhammers, concrete sawing, milling pavement, clean-up using compressed air, and dowel drilling. Dowel drilling machines are used to drill horizontal holes in concrete pavement so that dowels can be inserted to transfer loads across pavement joints. NIOSH scientists are conducting a study to assess the effectiveness of dust control systems sold by dowel drill manufacturers by measuring exposures to workers operating dowel drills with and without dust controls installed. This site visit was part of that study. The dust control assessed at this site consisted of a hood surrounding the drill steel at the drilling surface, flexible duct, an air cleaner, and an air mover.

Assessment

NIOSH staff performed industrial hygiene sampling at the Laborer's Local 172 Safety, Education and Training Center in Folsom, NJ on August 7 and 8, 2012. The personal sampling measured exposures to respirable dust and crystalline silica among two laborer-instructors who took turns operating a dowel drill to drill holes in a new concrete slab. The NIOSH personnel who visited the site also monitored the weather, collected data (e.g., air flow, design) about the dust collection system and observed the work process in order to understand the conditions that led to the measured exposures.

Results

The quartz content in the bulk samples ranged from 17 to 28 percent by weight, with an arithmetic mean quartz content of 22 percent. No respirable dust was detected on any of the personal samples. The minimum detectable concentration was 0.31mg/m^3 in a 32 minute sample collected when 27 holes were drilled. Quartz was only detected in one air sample; 0.09 mg/m^3 of quartz was found on an 8-minute sample collected during a drill maintenance task. The minimum detectable concentration for quartz in personal air samples collected while drilling was performed was 0.02 mg/m^3. The average number of holes drilled during each drilling sample was 23. Over the course of the two day study, air flow measured at the dust collector fell from 2.2 m^3/sec (76 cfm) to 1.8 m^3/sec (62 cfm).

Conclusions and Recommendations

The dust control performed well under the conditions of this test, controlling the laborers' silica exposures to levels below the NIOSH Recommended Exposure Limit

during drilling. The initial duct velocity with a clean filter was sufficient to prevent settling, but gradually fell below the recommended value to prevent dust from settling in the duct. In this site visit, the practice of raising the drill between each hole may have prevented the dust from settling in the duct. A slightly higher flow rate would prevent settling without regard to the position of the drill.

The laborers who operated the drill decided to empty the dust collection bucket and clean the filter based on their observations of the dust collection system's performance. The use of gauges to measure static pressure across the filter or at the hood would be a better way to monitor the system's performance.

Introduction

Background for Control Technology Studies

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, EPHB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concept techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

Background for this Study

Crystalline silica refers to a group of minerals composed of silicon and oxygen; a crystalline structure is one in which the atoms are arranged in a repeating three-dimensional pattern [Bureau of Mines 1992]. The three major forms of crystalline silica are quartz, cristobalite, and tridymite; quartz is the most common form [Bureau of Mines 1992]. Respirable crystalline silica refers to that portion of airborne crystalline silica dust that is capable of entering the gas-exchange regions of the lungs if inhaled; this includes particles with aerodynamic diameters less than approximately 10 micrometers (μm) [NIOSH 2002]. Silicosis, a fibrotic disease of the lungs, is an occupational respiratory disease caused by the inhalation and deposition of respirable crystalline silica dust [NIOSH 1986]. Silicosis is irreversible, often progressive (even after exposure has ceased), and potentially fatal. Because no effective treatment exists for silicosis, prevention through exposure control is essential. Silicosis is associated with a higher risk of tuberculosis and other lung disease [Parks et al. 1999]. Silica has been classified as a known human carcinogen by the International Agency for Research on Cancer [IARC 1997]. Occupational exposure to respirable crystalline silica has been associated with autoimmune diseases, such as rheumatoid arthritis, and kidney disease [Parks et al. 1999, Stratta et al. 2001].

Crystalline silica is a constituent of several materials commonly used in construction, including brick, block, and concrete. Many construction tasks have been associated with overexposure to dust containing crystalline silica [Chisholm 1999, Flanagan et al. 2003, Rappaport et al. 2003, Woskie et al. 2002]. Among these tasks are tuckpointing, concrete cutting, concrete grinding, abrasive blasting, and road milling [Nash and Williams 2000, Thorpe et al. 1999, Akbar-Kanzadeh and Brillhart 2002, Glindmeyer and Hammad 1988, Linch 2002, Rappaport et al. 2003]. Highway construction tasks that have been associated with silica exposures include jackhammer use, concrete sawing, milling asphalt and concrete pavement, clean-up using compressed air, and dowel drilling [Valiante et al. 2004]. Linch [2002] also identified dowel drills as sources of dust emissions on highway construction sites.

Dowel drilling machines (also known as gang drills or dowel drills) are used to drill horizontal holes in concrete pavement. Steel dowels transfer loads between adjacent concrete pavement slabs [Park et al. 2008]. They are typically used in "transverse joints in rigid airport and highway pavement to transfer shear from a heavily loaded slab to an adjacent less heavily loaded slab" [Bush and Mannava 2000]. Typical dowel drilling machines have one or more drills held parallel in a frame that aligns the drills and controls wandering [FHWA 2006]. The dowel drilling machine may be self-propelled or boom mounted, and may ride on the slab or on the grade [FHWA 2006]. After drilling to a typical depth of 23 cm (9 inches (in)) the anchoring material is placed, and the dowel is installed. The diameter of the hole is determined by the dowel diameter and whether cement-based grout or an epoxy compound is used to anchor the dowels [FHWA 2006]. Compressed air may be used to clean the hole prior to placing the anchoring material.

The study by Valiante et al. [2004] reported that dowel drilling respirable crystalline silica exposures ranged from 0.05 milligrams per cubic meter (mg/m^3) to 0.16 mg/m^3, 8-hour (hr) time weighted average (TWA). Linch [2002] also documented silica exposures during dowel drilling. The Linch [2002] study reported 8-hr TWA quartz exposures for operators and laborers using boom-mounted 3-gang dowel drilling machines. The operators' 8-hr TWA exposures ranged from less than the minimally detectable concentration[1] of 0.029 mg/m^3 to 0.11 mg/m^3, with a geometric mean respirable crystalline silica exposure of 0.037 mg/m^3 for 8 samples. The highest result was 2.2 times the NIOSH Recommended Exposure Limit (REL) for crystalline silica of 0.05 mg/m^3. The laborers' 8-hr TWA respirable crystalline silica exposures ranged from 0.12 -1.3 mg/m^3 (2.4 – 26 times the NIOSH REL), with a geometric mean of 0.24 mg/m^3 (4.8 times the NIOSH REL) for 8 samples. Linch [2002] concluded his study of dowel drilling exposures with this statement:

> "Means of controlling the respirable dust generated from concrete drilling during all operations needs to be developed, tested, and employed. Pneumatic drilling is the common method of drilling concrete pavement. Methods of using small amounts of water through the drill stem should be developed for these specific applications. High-velocity dust collection systems that effectively control respirable dust should be tested and made available."

There are only two American manufacturers of dowel drills, E-Z Drill, Inc. and Minnich Manufacturing. Both manufacturers offer optional dust control systems for their machines. The manufacturers both make local exhaust ventilation (LEV) dust control systems to capture the dust generated by the dowel drilling process. In addition, they both sell water kits to suppress the dust that results from drilling holes for dowels. One manufacturer's water kit supplies water through the drill steel, while the other manufacturer's water kit sprays water on the surface to be drilled. NIOSH research aims to evaluate the effectiveness of current dust controls for dowel drilling machines, work with manufacturers to improve dust controls if necessary, and promote the use of tools with dust controls.

Three approaches were planned to evaluate the effectiveness of current dust controls. The first measured respirable dust emissions from dowel drilling machines in a controlled setting, isolated from the effects of wind, weather, and other sources of particulate, assessing the effectiveness of the controls in reducing emissions. Emissions with and without the use of controls were compared. The second approach collected current data on respirable dust and crystalline silica exposures associated with dowel drilling without dust controls because the most recent dowel drilling exposure studies were published more than ten years ago [Linch 2002, Valiante et al. 2004]. The third approach assessed personal respirable dust and respirable crystalline silica exposures of workers operating dowel drilling machines with dust controls in place in a real-world setting to determine the ability of the dust controls to limit exposures.

This site report represents a modification of the third approach based upon lessons learned during the previous site visits conducted for this study. It was difficult to

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[1] The minimally detectable concentration is the analytical limit of detection divided by the sample volume [Hewett and Ganser 2007]. Linch [2002] reported an LOD for quartz on filters of 0.01 mg/sample and a sample volume of 350.2 L for an operator's sample.

control the work practices of employees using the drills on construction sites. It was also hard to control equipment maintenance and other issues not related to how well the dust-capture system worked. The purpose of this site visit was to use the low-pressure environment of a training center to control those factors and measure exposures with the dust control working as designed, using a drill and dust control from the factory with the manufacturer instructing the operator in its correct use.

Background for this Survey

In order to assess the effectiveness of the dust controls, it was necessary to evaluate exposures at a site where dust controls were used and maintained correctly during dowel drilling. This survey was performed on August 7 and 8, 2012 at the Laborers International Union of North America (LIUNA) Local 172 Safety, Education and Training Center in Folsom, NJ. Sampling was conducted to assess the extent of respirable dust and crystalline silica exposure while workers used a dowel drill equipped with dust controls to drill holes in concrete pavement.

The Federal Aviation Administration [FAA 2009] requires dowel drilling during runway construction, either using rotary-type core drills or rotary-type percussion drills. Contractors reportedly do not use core drills for this task because: 1) they leave a core that must be extracted from a blind hole (one that doesn't pass completely through the concrete); 2) the core may break in the hole, requiring the eventual use of a percussion drill to remove it; 3) core drills are slower, and; 4) core drills utilize water as a coolant, which mixes with concrete dust to create a slurry that must be collected, and water wets the hole, which interferes with the epoxy used to anchor the dowel rods. Dowel drills are also used in highway construction during full-depth repairs of concrete pavement and in lane additions.

Plant and Process Description

Introduction

The 20,000 square foot state-of-the-art LIUNA Local 172 Safety, Education and Training center in Folsom, New Jersey is the product of a labor-management partnership between the union and its signatory contractors. Local 172 represents workers in the heavy, highway and general construction industries (as well as several manufacturing plants), in the 9-county region of Southern New Jersey [New Jersey Laborers 2012].

Process Description

Dowel drilling was performed by two laborers who work as instructors at the training center. They took turns operating a single slab-riding dowel drill (model A1C, Minnich Manufacturing Company, Inc., Mansfield, OH). The drill was equipped with the manufacturer's dust collection system.

The drill used H-thread steels and bits to drill 3.5 cm (1⅜ in) diameter horizontal holes 36 cm (14 in) deep into the side of a new concrete slab. The slab was made of 4,000 psi air-entrained concrete, 30 ft long by 5 ft wide by 9 in high. The work cycle consisted of positioning the drill, drilling the hole, and moving the drill into position for the next hole. Maintenance practices included cleaning the filters (by rolling and tapping them on the ground) every time the plastic dust-collection bucket was emptied.

The laborers wore hardhats, safety glasses, ear plugs, work gloves, and work boots (Figure 1). They also wore filtering-facepiece, N-95 air-purifying respirators (model 8511, 3M Occupational Health and Environmental Safety, St. Paul, MN). Both instructors were trained, fit-tested, and medically qualified to use the respirators as part of the facility's respiratory protection program.

Figure 1 – Laborer Operating Dowel Drill

Occupational Exposure Limits and Health Effects

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators use mandatory and recommended Occupational Exposure Limits (OELs) when evaluating chemical, physical, and biological agents in the workplace. Generally, OELs suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Combined effects are often not considered in the OEL. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus can increase the overall exposure. Finally, OELs may change over the years as new information on the toxic effects of an agent become available.

Most OELs are expressed as a TWA exposure. A TWA exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have a recommended Short Term Exposure Limit (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. The U.S. Department of Labor OSHA Permissible Exposure Limits (PELs) [29 CFR[2] 1910.1000 2003a] are occupational exposure limits that are legally enforceable in covered workplaces under the Occupational Safety and Health Act. NIOSH recommendations are based on a critical review of the scientific and technical information available on the prevalence of health effects, the existence of safety and health risks, and the adequacy of methods to identify and control hazards [NIOSH 1992a]. They have been developed using a weight of evidence approach and formal peer review process. Other OELs that are commonly used and cited in the U.S. include the Threshold Limit Values (TLVs®) recommended by American Conference of Governmental Industrial Hygienists (ACGIH®), a professional organization [ACGIH® 2010a]. ACGIH® TLVs® are considered voluntary guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards." Workplace Environmental Exposure Levels™ (WEELs) are recommended OELs developed by the American Industrial Hygiene Association® (AIHA®), another professional organization. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA® 2007].

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers are required to comply with OSHA PELs. Some hazardous agents do not have PELs, however, and for others, the PELs do not reflect the most current health-based information. Thus, NIOSH investigators encourage employers to consider the other OELs in making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminating or minimizing identified workplace hazards. This includes, in preferential order, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation) (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection).

[2] Code of Federal Regulations. See CFR in references.

Crystalline Silica Exposure Limits

When dust controls are not used or maintained or proper practices are not followed, respirable crystalline silica exposures can exceed the NIOSH REL, the OSHA PEL, or the ACGIH® TLV®. NIOSH recommends an exposure limit for respirable crystalline silica of 0.05 mg/m^3 as a TWA determined during a full-shift sample for up to a 10-hr workday during a 40-hr workweek to reduce the risk of developing silicosis, lung cancer, and other adverse health effects [NIOSH 2002]. When source controls cannot keep exposures below the NIOSH REL, NIOSH also recommends minimizing the risk of illness that remains for workers exposed at the REL by substituting less hazardous materials for crystalline silica when feasible, by using appropriate respiratory protection, and by making medical examinations available to exposed workers [NIOSH 2002]. In cases of simultaneous exposure to more than one form of crystalline silica, the concentration of free silica in air can be expressed as micrograms of free silica per cubic meter of air sampled (µg/m^3) [NIOSH 1975].

$$\mu\text{g SiO}_2/\text{m}^3 = \frac{\mu\text{g Q} + \mu\text{g C} + \mu\text{g T} + \mu\text{gP}}{\text{V}}$$

Where Q is quartz, C is cristobalite, and T is tridymite, and P is "other polymorphs," and V is the volume of air in the sample.

The current OSHA PEL for respirable dust containing crystalline silica for the construction industry is measured by impinger sampling. In the construction industry, the PELs for cristobalite and quartz are the same. The PELs are expressed in millions of particles per cubic foot (mppcf) and calculated using the following formula [29 CFR 1926.55 2003b]:

$$Respirable\ PEL = \frac{250\ mppcf}{\%\ Silica + 5}$$

Since the PELs were adopted, the impinger sampling method has been rendered obsolete by gravimetric sampling [OSHA 1996]. OSHA currently instructs its compliance officers to apply a conversion factor of 0.1 mg/m^3 per mppcf when converting between gravimetric sampling and the particle count standard when characterizing construction operation exposures [OSHA 2008].

The ACGIH® TLV® for α-quartz and cristobalite (respirable fraction) is 0.025 mg/m^3 [ACGIH® 2010a].

Methodology

Sampling Strategy

This evaluation focused on task-based sampling, in order to quantify the exposure associated with the dowel drilling task. An air sample was collected while the instructor drilled a series of holes. When it was time to empty the dust collection bucket, drilling stopped and the sample was stopped. A separate air sample was collected while the bucket was emptied. That sample was stopped when the bucket was reinstalled, and it was time to position the drill for a new hole. Nine samples were collected during drilling (including one while the bit was changed). Seven samples were collected while the bucket was emptied (including one when the drill was turned and three when the filter was cleaned)

Sampling Procedures

Air Sampling

Personal breathing zone air samples for respirable particulate were collected at a flow rate of 9 liters/minute (L/min) using battery-operated sampling pumps (Libra Plus Personal Air Sampling Pump, model LP-12, A.P Buck, Inc., Orlando, FL) calibrated before and after each day's use. A sampling pump was clipped to each sampled employee's back belt (Figure 2). The pump was connected via Tygon® tubing fitting to a pre-weighed, 47-mm diameter, 5-micron (µm) pore-size polyvinyl chloride (PVC) filter supported by a backup pad in a three-piece conductive filter cassette sealed with a cellulose shrink band (in accordance with NIOSH Methods 0600 and 7500) [NIOSH 1998, NIOSH 2003]. The front cover of the cassette was removed and the cassette was attached to a Gussman-Kenny type respirable dust cyclone (model GK 4.162 RASCAL, BGI Inc., Waltham, MA). At a flow rate of 9 L/min, the GK 4.162 cyclone has a 50% cut point of (D_{50}) of 3.91 µm [HSL 2012]. D_{50} is the aerodynamic diameter of the particle at which penetration into the cyclone declines to 50% [Vincent 2007]. The cyclone was clipped to the strap of the sampled employee's back belt near their head and neck within the breathing zone (Figure 2). Bulk samples of dust were also collected in accordance with NIOSH Method 7500 [NIOSH 2003].

Figure 2 – Laborer Wearing Pump and Cyclone (Circled)

The filter samples were analyzed for respirable particulates according to NIOSH Method 0600 [NIOSH 1998]. The filters were allowed to equilibrate for a minimum of two hours before weighing. A static neutralizer was placed in front of the balance and each filter was passed over this device before weighing. The filters were weighed on an analytical balance (model AT201, Mettler-Toledo, LLC, Columbus, OH). The limit of detection (LOD) was 90 µg/sample. The limit of quantitation (LOQ) was 300 µg/sample.

Crystalline silica analysis of the respirable particulate samples was performed using X-ray diffraction according to NIOSH Method 7500 [NIOSH 2003] with modifications. Each filter was removed from the cassette and transferred to a 15 mL vial. The filter was dissolved by addition of 10 mL of tetrahydrofuran (THF) to each sample vial. The samples were mixed by vortex. The sample vial was placed in an ultrasonic bath for ten minutes. The sample suspension was transferred to a silver-membrane filter. First, a silver-membrane filter was placed in the vacuum filtration unit. Next, 2 mL of THF solvent was placed onto the filter. The sample suspension was vortexed and immediately added onto the silver membrane filter. The sample vial was rinsed with three separate portions of 2 mL THF. Each rinse was added to the sample on top of the silver membrane filter. Finally, vacuum was applied to deposit the sample suspension onto the filter. The silver-membrane filter was transferred to an aluminum sample plate and placed in the automated sample changer for analysis by X-ray diffraction. The LOD for quartz on a 47-mm PVC 5 µm filter was 6 µg/sample. The LOQ was 20 µg/sample.

In this sample set, the maximum air sample volume collected was 292 L. At the LOD for quartz of 6 µg/sample, the minimum detectable quartz concentration was 0.02 mg/m^3, less than half the NIOSH REL of 0.05 mg/m^3. The minimum quantifiable quartz concentration at the LOQ of 20 µg/sample was 0.068 mg/m^3.

Bulk samples were analyzed in accordance with NIOSH Method 7500. Approximately 2 g of sample was added to a mortar and ground to a fine powder with a pestle. The ground powder was wet sieved through a 10-µm sieve using 2-propanol and an ultrasonic bath. The alcohol was evaporated in a drying oven for two hours then the dried sample was stored in a desiccator. Approximately 2.0 mg of sieved-dried sample was weighed into a 50-mL beaker, and about 10 mL of 2-propanol was added. The beaker was coved with a watch glass and placed in an ultrasonic bath for about 3 minutes until agglomerated particles were broken up. The sample suspension was re-deposited onto a 25-mm diameter silver membrane filter as follows. First, a silver membrane filter was placed in the vacuum filtration unit. Next, 2 mL of 2-propanol was added followed by the sample suspension and beaker rinsing. Finally, vacuum was applied to re-deposit the suspension onto the filter. The silver membrane filter was transferred to an aluminum sample plate and placed in the automated sample changer for analysis by X-ray diffraction. The LOD for quartz was 0.3% by weight. The LOQ was 0.89%.

Measurement of Dust Control Flow Rate

Exhaust air flow rates were measured using a Sierra Instruments, Inc. (Monterey, CA) model 730-N5-1 fast response in-line mass flow meter (range 0-2.83 m^3/min (0-100 cfm)). A Sierra Instruments, Inc. Model 954 Flo-Box was used to read the signal from the meter.

The inlet into the dust collector was extended to measure air flow. A 5 cm (2 in) to 5 cm (2 in) flexible coupling (Model RC 50, American Valve, Greensboro, NC) was used to attach a 30 cm (12 in) long piece of Schedule 40 plastic pipe to the dust collector inlet. A threaded 5 cm (2 in) to 5 cm (2 in) adapter connected the pipe to the outlet of the mass flow meter. A second threaded 5 cm (2 in) to 5 cm (2 in) adapter was connected to the inlet of the mass flow meter. This adaptor was attached to a 27 cm (10½ in) long piece of plastic Schedule 40 pipe. The other end of that pipe was open to the atmosphere.

Weather Monitoring Methods

The NIOSH researchers used a data-logging weather station (Kestrel 4500, Nielsen-Kellerman, Boothwyn, PA) mounted on top of a tripod to assess weather conditions at the site. The weather meter was approximately 1.5 m (60 in) off the ground; about breathing zone height [NIOSH 2010]. The weather meter was programmed to record data every 10 minutes. Airport weather observations were gathered from the Internet as a back-up (http://www.wunderground.com/history). Average wind direction was calculated using published methods [EPA 2000].

Measuring Productivity

Productivity was measured by counting the number of holes drilled during each sampling period on both days.

Control Technology

The bit was surrounded by a close-capture hood at the work surface (Figure 3). The hood take-off was attached to 5 cm (2 in) diameter corrugated flexible hose (the interior surface is corrugated as well). The other end of the hose was attached to a dust collector at the back of the dowel drill unit. Suction was provided by a pneumatic transfer pump (an eductor) on top of the dust collector (Figure 4). Airborne dust was removed by the dust collector using a pleated filter cartridge with a Minimum Efficiency Reporting Value (MERV) of 13 (P/N P148646-016-340, Donaldson Company, Inc., Bloomington, MN). During the operation, dust was collected by the filter cartridge to build-up a dust cake on the filter surface. As the dust cake accumulates on the filter, the efficiency of the filtration becomes more effective, but resistance increases (ACGIH 2010b). This results in a reduced air flow rate. Therefore, the drill operator periodically cleaned the pleated filter cartridge by triggering a reverse pulse jet to dislodge the dust cake build-up on the filter surface. Attached to the bottom of the dust collector, a plastic bucket was used to collect the dislodged dust cake (as well as excess dust that collected on the filter during drilling). The plastic bucket was dumped when the laborer noticed visible dust around the surface of the drill. The laborer also removed and manually cleaned the filter at that time.

Figure 3 – Hood Surrounding Drill Steel at Concrete Surface

Figure 4 - Dust Collector (Inlet, Eductor, Bucket and Filter Housing Labeled)

Results

Table 1 presents the bulk sampling results. The air sampling results are reported in Table 2. One air sample, collected while 28 holes were drilled, was lost due to an error at the contract laboratory.

Silica Content in Bulk Samples

Four bulk samples were collected. The bulk samples were collected from settled dust near the drilled holes and from the dust collector bucket. The quartz content of the bulk samples is reported in Table 1. The quartz content in the bulk samples ranged from 17 to 28 percent by weight, with an arithmetic mean quartz content of 22 percent.

Air Sampling Results

Respirable dust results

No respirable dust was detected on any of the samples. Table 2 presents the results for each air sample as less than the minimum detectable concentration, which is the LOD divided by the sample volume. The LOD for respirable dust in this sample set was 90 µg/sample.

Respirable Quartz Sampling Results

Table 2 also presents the results of the respirable quartz air samples. Quartz was only detected in one air sample, when a laborer emptied the bucket, banged on the dust collector to dislodge dust, and used the reverse pulse feature. The rest of the results are reported as less than the minimum detectable concentration, which was less than the NIOSH REL for all of the drilling samples.

Weather Monitoring Results

During the sampled period on August 7, the average wind speed was 1.1 meters/sec (2.4 mph), the average temperature was 28 °C (83 °F), and the average relative humidity was 56%. The wind direction was 213°, which is from the South-Southwest.

Data from Atlantic City International Airport, Atlantic City, NJ were used when the data from August 8 were lost due to a hard drive failure. For data corresponding to the sampled period, the average wind speed was 2.3 meters/sec (5.1 mph), the average temperature was 25 °C (77 °F), and the average relative humidity was 89%.

Productivity Results

The number of holes drilled per sample ranged from 9 to 29 (including the 28 holes drilled for which the sample was lost), with an average of 23 holes drilled per sample and a total of 149 holes drilled. The 9-hole sample reflects a sample period during which a few holes were drilled and then the bit was changed.

Air Flow Results

The air flow was measured on both days of sampling. On the first day, the airflow was measured with a clean filter (2.2 m^3/min (76 cfm)), and after drilling (1.9 m^3/min (67 cfm)). On the second day, the air flow was measured before (1.7

m^3/min (60 cfm)) and after (1.8 m^3/min (62 cfm)) the filter was removed for cleaning. The results are presented in Table 3. The air flow column indicates the measured air flow. The velocity column reflects the calculated velocity based on the measured air flow and the cross-sectional area of a 5 cm (2 in) diameter duct.

Conclusions and Recommendations

Bulk samples of the concrete used in the slab contained an average of 22% quartz. No respirable dust was detected on any of the air samples. Quartz was only found on a sample collected during maintenance of the drill. Based on that 8-minute exposure at 0.09 mg/m^3, one could perform that task for 266 minutes in an 8-hour shift without exceeding the REL.

Most of the drilling sample periods ended when the operator determined it was time to empty the dust collection bucket. The average number of holes drilled per sample was 23. One might conclude as a rule of thumb that the bucket should be emptied after about two dozen holes are drilled, but that would vary based on the depth and diameter of the holes drilled.

Air flow dropped as the filter was loaded, and recovered somewhat when it was cleaned. The ACGIH® industrial ventilation manual recommends a transport velocity of 3500 to 4000 fpm for “average industrial dust” (e.g., granite or limestone dust, brick cuttings, silica flour) [ACGIH® 2010b]. The initial duct velocity with a clean filter was sufficient to prevent settling, but gradually fell below the recommended value. In this site visit, the practice of raising the drill between each hole may have dislodged dust that settled in the duct.

Instead of using the number of holes drilled or the observations of the laborer, installing a static pressure gauge across the filter would give the drill operator information on when the filter needed to be cleaned by briefly pulsing the system. This would preclude the need to remove the filter for cleaning and indicate when the filter should be replaced. The filter manufacturer could supply the recommended values. Alternatively, a static pressure gauge installed near the hood would indicate when the air flow rate was falling. The relationship between the air flow rate and hood static pressure would have to be determined experimentally. NIOSH would be willing to work with the drill manufacturer to help implement any of these recommendations.

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Table 1 – Quartz Content of Bulk Dust Samples

Date	Source	Quartz %
8/7/2012	Hole	17
8/7/2012	Bucket	28
8/8/2012	Hole	23
8/8/2012	Bucket	19

Table 2 – Air Sampling Results

Duration (min)	Volume (L)	Dust LOD (ug/sample)	Quartz LOD (ug/sample)	Respirable Dust (mg/m^3)	Quartz (mg/m^3)	Activity	Holes Drilled
18	164	90	6	<0.55	<0.04	drill holes	13
32	292	90	6	<0.31	<0.02	drill holes	27
28	256	90	6	<0.35	<0.02	drill holes*	27
17	155	90	6	<0.58	<0.04	drill holes†	9
17	155	90	6	<0.58	<0.04	drill holes	19
20	183	90	6	<0.49	<0.03	drill holes	26
32	284	90	6	<0.32	<0.02	drill holes	29
24	213	90	6	<0.42	<0.03	drill holes	28
3	27	90	6	<3.3	<0.2	empty bucket	
8	73	90	6	<1.2	0.09	empty bucket‡	
2	18	90	6	<4.9	<0.3	empty bucket	
6	55	90	6	<1.6	<0.1	empty bucket§	
3	27	90	6	<3.3	<0.2	empty bucket	
9	80	90	6	<1.1	<0.08	empty bucket¥	
9	80	90	6	<1.1	<0.08	empty bucket₫	

Notes:LOD means limit of detection. *The laborer raised the drill after drilling each hole beginning with the 24th hole during this sample. †The laborer stopped drilling after nine holes to change the bit. ‡The laborer dumped the bucket, cleaned the filter, banged on the side of the dust collector, and used the reverse pulse feature. §The sampled laborer removed the bucket, but the other laborer dumped it; they shared the task of cleaning the filter. ¥The drill was turned during this sampling period. ₫The laborer enclosed the filter in a plastic bag while he cleaned it.

Table 3 – Air Flow Results

Date	Condition	Air Flow m^3/min (cfm)	Velocity m/sec (fpm)
7-Aug	New filter	2.2 (76)	18 (3500)
7-Aug	After Drilling	1.9 (67)	16 (3100)
8-Aug	After Drilling	1.7 (60)	14 (2800)
8-Aug	After Cleaning	1.8 (62)	14 (2800)

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