

The Big Dig

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The most expensive highway project in the world is nearing completion in Boston, Massachusetts, USA. When completed in 2005, the project everyone calls the Big Dig will include a new tunnel under the harbor to the airport, a cable span bridge over the Charles River to the northern suburbs and the replacement of several miles of elevated highway through the center of Boston with an underground highway. The current estimate of cost is over \$14 billion. The Big Dig is the largest of several publicly funded infrastructure "mega-projects" that have been undertaken in the Boston region over the past twenty years to stimulate the economy by creating construction jobs in the short term and a positive business climate in the long term. The other projects include a sewer treatment plant, a convention center, a football stadium and a proposed baseball park.

Researchers at the University of Massachusetts Lowell have been conducting occupational health studies on The Big Dig for the past eight years under a mandate to improve health conditions for workers in the regional construction industry. What has been learned about occupational health in construction? What can we learn from this example about OHS and development? What impact will this development project have around the world?

Research

Researchers at the Construction Occupational Health Programme (COHP) at the University of Massachusetts Lowell (UML) call the Big Dig our Big Lab. Until a decade ago, very little research into the occupational health problems of construction had been conducted in the US. This was due in part to the transient nature of the workforce and the great variability in construction work and in part to the lack of resources, methods and capacity for effective health research in the construction work environment. In the late 1980's, the Building and Construction Trades Department (BCTD) of the AFL-CIO publicized the extent of health and safety problems in construction and lobbied the federal government for research money to be devoted to construction hazards. The BCTD established the Center to Protect Workers' Rights (CPWR) (ref 1) to coordinate research efforts around the country. This coincided with the beginning of the Big Dig and researchers in the Work Environment Department of UML were awarded grants to study the occupational health hazards of highway construction work. The COHP was established within the department to conduct this research.

The Big Dig has provided a unique opportunity for study and for addressing the transient and variable nature of construction work. The workforce has been fairly stable and the construction process is essentially the cycle of excavation, concrete construction and finish work repeated over and over. Observing these large construction stages and their constituent operations and tasks led to the

development of a taxonomy that has provided a framework for both better characterizing the work and better communicating research results to the industry (ref 2). The taxonomy nests stages, operations, tasks and activities in a hierarchy and provides an operational definition for each level of work.

Applying the taxonomic framework, the first six years of research were primarily focused on the development of practical and appropriate methods of exposure assessment for airborne agents such as silica and for musculoskeletal disorders. To be used on construction sites, exposure assessment methods needed to be mobile and flexible. Industrial hygienists working in the field developed a survey method called Time-Variant Exposure Assessment for collecting ambient data while doing personal air sampling on workers (ref 3). Ergonomists developed a work sampling method called PATH (Posture, Activities, Tools and Handling (ref 4). Researchers continue to use these methods to characterize exposures during many highway construction operations. Some results are generalizable to construction in other locations.

Musculoskeletal exposures in highway construction

Technological changes in the construction industry over the past decade have greatly increased the number of machines and reduced the number of manual workers. When the Big Dig was being planned, the projections were for up to 30,000 construction jobs. The actual peak employment over the 15-year life of the project is about 3,000. However, rates of musculoskeletal injuries among the workforce remain at approximately 40% of all workers' compensation claims. The causes, or risk factors, for these injuries are:

- Overhead work, such as ceiling installation
- Work below the knee and at floor level, such as tying reinforcing bar ("rebar")
- Use of heavy and vibrating power tools, such as jack hammers
- Moving large and heavy materials, such as 100-lb. bags of concrete mix (45 kg) and 4x8 ft. sheets of lumber (1.2m x 2.4m)
- Walking on uneven and slippery surfaces.



Figure 1. COHP research assistant uses force guage to weigh lift trunk used for pouring concrete.

Most construction jobs involve more than One risk factor. For example, wall tiling includes both overhead work and work below the knee. Holes may be drilled overhead using a heavy, vibrating tool. Large sheets of plywood may be moved over rutted and frozen ground. Elimination of one or more of these risk factors can potentially reduce injuries. The COHP is currently developing a user-friendly version PATH for use by practitioners in the field in assessing risk factors for musculoskeletal disorders and evaluating the effectiveness of interventions.

Silica exposure in concrete construction

Until the past decade, silica studies concentrated on rock and quarry work and little attention was paid to silica exposure from concrete. Although silica sand is a component used in making concrete, it was presumed that work was mostly done when the concrete was wet and therefore silica was not airborne. However, concrete is the main material in large construction projects and many more workers are involved in concrete construction than in rock quarry work. In addition, there is a great deal of work done on the concrete after it is cured and dry. COHP research has shown:

- There is great deal more concrete work in construction than the outsider would expect
- There is a lot of processing of dry concrete, including cutting, drilling grinding, etc
- Dry processing of concrete produces high levels of silica

- Workers doing concrete work, and working near dry concrete processing, are exposed to higher than predicted levels of silica.

These results have caught the attention of OSHA locally. Inspections have included silica assessment and some fines have been levied. Change, however, has been slow and impeded by both technological and cultural barriers. The current method of sampling for silica is insufficiently precise, but there has not yet developed a consensus for a new method. COHP researchers are working with NIOSH to improve the methods. Culturally, it is still accepted practice in the industry for workers to work in a cloud of dust. On a recent site tour with a site safety representative, we approached two workers sweeping in a tunnel. At a distance they were difficult to see through the cloud of concrete dust that surrounded them. The safety representative didn't notice the exposure until it was brought to his attention and then was at a loss as to what to do other than to ask the workers if they had had respirator training. This is a common occurrence on construction sites. Industry members need education regarding exposures and also need access to improved methods to reduce the hazards of construction.

From exposure assessment to intervention

Within the past two years, the emphasis has shifted to intervention research and the study of prevention methods (ref. 5). Exposure to silica in many concrete-related tasks is preventable through wet methods and local exhaust. However available technologies are often not easily adapted to the construction work environment and the industry is highly resistant to change. Although it is well documented that musculoskeletal disorders (MSDs) are the most common and costly injury in the industry, ergonomic principles are often ignored in construction planning. Given the current political climate in the US and the opposition of industry, it is unlikely that OSHA will soon create the standard needed to jump start industry efforts to reduce MSDs. Research into both technological changes and non-regulatory strategies for change are necessary.

We have had some successes. Six years ago, a carpenter developed a modular guardrail system to reduce the work in tearing apart and rebuilding guardrails every time materials needed to be moved into a shaft. We published John Hunt's idea as the first in a series of pamphlets called Bright Ideas (ref. 6). Now modular guardrails are the standard type on large projects in our region. Our greatest direct impact was contributing to the redesign of the main north/south tunnel. When we began our research in the first tunnel being constructed, we found workers drilling 26,000 holes for the placement of fixtures in the concrete ceiling. These workers were exposed to the dust and high force and awkward posture of overhead drilling with a heavy tool. It was an extremely high hazard job. We asked many questions, including why the tunnel was designed this way. Typical answers were that it had to be done this way and that no one had really thought about the problem in the design phase. Eventually we were able to identify the design team responsible for this tunnel design and the upcoming north/south tunnel. When we later met with the design team they told us that they had redesigned the new tunnel to eliminate the problem. They said that they had made the decision to redesign based on three factors: the cost, constructibility

and health effects of the original design. The new tunnel is under construction now and the high hazard operation has been eliminated.

Collaboration between researchers and the industry

Whenever feasible, we have taken an action research approach to our research and sought to collaborate with industry partners in the design and implementation of research activities and dissemination of results. These efforts have been very successful with the unions and less successful with the contractors. At the beginning of the construction project in the early 1990's, indicators of health and safety in the regional construction industry (fatality, injury and lost time rates) were higher than national averages. The size and visibility of the project stimulated efforts to improve injury rates. The project mandated that contractors create site-specific safety plans and employ fulltime on-site safety officers. These were very innovative requirements. The existence of the on-site safety officer was particularly good for researchers because it gave us a point of contact. Many, although not all, of the safety officers employed on the project welcomed our efforts and willingly collaborated with research activities. Cooperation has taken the form of facilitating contact with decision-makers, providing us with schedules and introducing us to workers who may be interested in being research subjects.

However, there are tremendous cultural barriers to collaboration between the construction industry and an academic research institution. The Big Dig includes over 25 separate construction contracts, and hundreds of subcontracts. The COHP is three fulltime researchers and four student research assistants. The construction industry, hierarchical and decentralized, is descended from the medieval guilds; the university, remote and insular, descended from the monasteries. These two surviving remnants of feudalism diverged 1,000 years ago and have not easily been rejoined. It took two years to negotiate a written memorandum of understanding with the state highway department to guide researchers' access to the project and to minimize the contractors' fears of liability. It took another year to distill this grand 40 page legal document into a five-page summary that could be understood by the researchers and frontline management who were responsible for implementing it on the construction sites. Since that time, the details of access to sites and workers have largely been worked out face to face in discussions by the individuals involved.

The memo of understanding's intent was to give equal access to all contractors on the project. But we found that there was no single approach to health and safety among the project's contractors and, therefore, no template for cooperation with the research has evolved. We have described our operative approach to collaboration with the contractors the "Low Hanging Fruit (LHF) Factor." The LHF are those contractors who are interested in participating in the research and pursuing ways to integrate occupational health into their organizations. They are low on the tree, ripe and ready for picking. Contractors interested in collaborating with the research have been large, highly capitalized enterprises, especially those who also do work in the Scandinavian countries where overall health and safety standards are higher. The Low Hanging Fruit are, unfortunately, very few, but we have found that resources are wasted and time lost trying to bang down doors and we are more efficient going where we are wanted.

Participation by workers and unions

Those who most value the research are the workers and the place we have been most welcome is the unions. The unions have, with few exceptions, collaborated in action research and supported more traditional researcher directed activities. We have had nearly universal cooperation from construction workers who have been asked to participate in the research. Health and safety professionals know that three things are true about workers:

- people love to talk about their work
- workers appreciate when others take a sincere interest in their working conditions
- most workers are very concerned about their health and the hazards of their jobs.

This last conclusion contradicts the prevalent myth of construction workers as risk-takers with little concern for their own safety. This myth motivates some of the behaviour-based safety approaches that blame workers for health and safety problems. We have found construction workers to be no different from other workers in their attitudes towards their personal safety and the dangers of their jobs. Many are very concerned about the potential impact of these hazards on their families and their futures. Respect for this concern is embedded in the research methods and activities of the COHP and has resulted in deep and mutually beneficial relationships. We have created two publications to increase the involvement of construction workers in the research. On the Beam, a newsletter published three times a year, is distributed to over 2,000 workers who have participated in research, including those wearing monitoring equipment, answering surveys, attending focus groups, etc. The goal of the newsletter is to return research results to the field as quickly as possible and in accessible forms. Bright Ideas is a series of pamphlets that publicize workers' innovations to reduce their risks of musculoskeletal injury. The purpose is twofold: to publicize a specific change in work and its value in making work healthier, and, by giving credit to the workers who design solutions, to counter the prevalent myth that workers are not interested in changing their working conditions.



Figure 2. Construction worker on Big Dig wears air sampling monitor to test for silica exposure.

Although there are no formal written agreements, the building trades unions have truly been partners in the research. They have provided resources such as space to conduct activities, volunteered time to assist in the research, mailings to workers and many other small and large contributions. They have answered the thousands of questions that we have asked and said yes to the vast majority of our requests. Most importantly, they have given us access to workers at union meetings and training centers and given the enthusiastic endorsement to our work that ensured that we would have the ear of the members as we introduced them to the goals and activities of the research. In so far as we have been able to integrate occupational health into the industry, it has been through the unions. They regularly use our publications to educate others on the research results. We are an accepted part of joint health and safety activities led by the unions and the state building trades council where we regularly present research designs and results for review and feedback and participate in conferences and on committees.

However, there are limitations on the power of the unions to impact change in the industry. Some factors are external to the construction sector and related to the relative power of labor and management under capitalism. Some are historical issues internal to construction and related to the conservative traditions of the craft unions. These include the value placed on individualism and competitiveness, the legacy of labour/management cooperation and the role of construction and industrial unions in the US in negotiating labor peace after World War II. However, research has illuminated certain structural aspects of the construction work organization that are directly connected to health and safety outcomes and may be responsive to intervention. Two factors, cross-trade communication and the critical role of stewards in a healthy work environment stand out.

Cross trade communication

In the US, there are 15 recognized building trades unions. Any number of these may work on the same construction site, but, with some key exceptions, they do not really work together. Each trade has its own internal hierarchy and chain of command. The COHP research has demonstrated that workers have a high ability to identify hazards but low ability to remedy them. One of the barriers to hazard reduction is the difficulty in workers communicating horizontally across trades. Under the dominant structure, each problem has to ascend a very fragile communication chain (worker to steward to foreman to safety officer to superintendent to project manager) and then solutions or permission to implement solutions have to descend through the same chain. Any break in the chain stops change. Where we have observed communication across trade, we have seen much more robust demands for change because multiple requests are made at the level of the foreman or the safety officer. Action research activities with site level safety and health committees have stimulated cross-trade communication and strengthened workers' capacity for change.

The critical role of stewards

Stewards, union appointed worker representatives on the work site, are usually designated to participate on work site health and safety activities and committees. Unlike the Swedish system of 90,000 trained health and safety representatives, stewards generally serve the dual functions of monitoring the employers' compliance with the collective bargaining agreement and observing health and safety conditions. Compared to the Swedish system, building trades' stewards in the US are woefully underprepared and undersupported for these duties. Most unions have no formal health and safety training requirements for stewards and those who are trained receive only a 10-hour course in OSHA regulations. Rarely do stewards receive any training in problem solving or strategic approaches to change. Of course, these deficiencies only apply to the union sector of construction. The 85% of construction workers who are not unionized have no health and safety representation at all. It is difficult to raise the standards of unions when they are already viewed as a great advance on those who have no standards.

Another challenge to the critical role of stewards in health and safety on site is the recent increase in highly centralized and top-down management safety systems. We have observed sites where the stewards are stripped of their traditional responsibilities for safety by management-directed safety programs. On one site, the safety program was run autocratically by a very competent but over extended individual safety officer. When the safety officer was abruptly removed from the site by upper management, the program collapsed. No safety meetings were held, personal protective equipment was unavailable and hazardous conditions increased. Well-trained stewards with recognized authority in safety and health are essential to a robust safety program that can withstand the hazardous conditions and rapid changes that occur on construction sites.

Role of the employers

If the unions are structurally limited in their abilities to integrate health and safety in the construction industry, the employers practice limits by regulation. The motto of construction contractors regarding health and safety might be, "Do no more than necessary." One example: COHP researchers were working closely with a contractor who had been very cooperative and interested in the research. He wanted to address noise hazards on his site and asked for our assistance. The first stage of any discussion of noise in construction is clarifying the difference between hearing protection and noise reduction. When we finally were able to clarify that noise reduction was the goal, we recommended that the contractor institute a company policy setting 85dB as the goal for noise reduction. Because the OSHA standard for construction is 90dB, the contractor thought that we were unreasonable in recommending a lower limit. Furthermore, he believed fervently, if incorrectly, that if he instituted a company policy below the OSHA limit, OSHA could cite him at the lower limit.

The above employer was Low Hanging Fruit: very interested in improving health and safety in his organization. The typical contractor is formulaic in his attention to health and safety. He complies with the minimum in area practices regarding safety, placing most emphasis on the high hazards of falls and electrocutions and does little about health unless cited by OSHA. On the Big Dig, researchers have been able to raise awareness of silica and musculoskeletal hazards, but we have not significantly reduced exposures for most of the workers exposed. In the September 1996 issue of the Swedish Association for Occupational and Environmental Health's Bulletin, Christer Hogstedt wrote, "Many work environment problems can be avoided without extensive costs if the knowledge and awareness exists. It would not have been especially expensive to avoid metal poisoning, silicosis, or asbestos cancer during the industrialization of Sweden if the awareness had existed." But here in Boston, in 2002, the knowledge exists, awareness is raised, but employers continue to resist the costs of respiratory protection and controls needed to protect workers from ancient illnesses.

The construction industry in the Boston area is safer now than it was when the Big Dig and the COHP began in the early 1990's. Reported injury rates are below the national average and there have been only two documented fatalities on the project. (This number does not include deaths on ancillary sites or deaths on-site by heart attack or other non-accident cause.) It is not possible to tell at this time if these improvements will be lasting, but several concerns and questions linger:

- Several years ago, the construction managers on the Big Dig instituted a "safety incentive program" that rewards low injury reports with very lucrative cash prizes. Injury rates went down at the same time. Are injuries not being reported? How can an incentive program reward safety practices and not low reporting? Should OSHA prohibit so called "safety bingo" before it spreads any further?
- No comprehensive medical management program was ever put in place on the project. This is not unusual in the US where workers carry the burden of exposure unless they can prove that their injuries are work-related. In addition to shifting costs to an individual's health insurance, there are no records to

document health and safety effects of the work on the project except those covered by OSHA regulations.

- Research efforts were limited by resources and the interests of the researchers involved. We did not address many health effects including noise, psychosocial and chemical exposures. We are a long way from comprehensively characterizing the occupational health effects of construction work.
- The technological barriers to reducing health hazards are minor compared to the political and economic ones. To give one clear example, we have known the dangers of silica for centuries and all the protections needed currently exist in the mining industry. Why are workers still dying? Why are employer profits more valued than employee health? Who will redress the imbalance and take the side of injured workers in the era of privatization and government deregulation?

The global impact of the Big Dig

These obstacles to changing the policies of contractors, and hence the work practices of highway construction, bring us back to the question of development. The Big Dig is not only a Big Lab for OHS research. It is also a massive research and development project in highway and engineering methods. Countless new technologies are being developed and refined. These include slurry wall construction, cofferdams, bridge work and tunnel jacking. Boston is a coastal city and much of the work being done is below the water table. The technologies being practiced in Boston will be exported to developing countries by the very contractors who are being capitalized through multi-million dollar contracts on the Big Dig. Bangkok, Bombay, Lagos and other megacities in the developing world will get the hand-me-downs from the Big Dig. These will include the heavy equipment, the cadre of management and the work practices bought and established in Boston. This will also include the hazards first generated here and exported with the technology. A policy question for us is, if we have been unable to integrate controls with the work, how can we follow the work with the controls? It will be up to researchers and labor unions in the places where the exported hazards go to follow the work. We at the COHP hope to continue to generate research in reducing the hazards that will benefit workers not just only in Boston but around the world.

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