42 Construction Workers

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NATURE AND CHARACTERISTICS OF CONSTRUCTION WORK

Construction workers build highways, stadiums, industrial plants, office buildings, and homes. They also repair or renovate roads, bridges, and other structures and demolish or clean up former building sites. In the United States, construction work also includes cleanup of hazardous waste sites. The work is hard physical labor, often under difficult conditions, including hot, cold, and wet weather (Fig. 42-1).

ORGANIZATION OF THE WORK

Several factors exacerbate safety and health problems in construction, related to how the industry operates or how the work is performed.

Construction rarely provides steady employment; construction workers are always working themselves out of their jobs. Although some projects may last several years, many last only a few months. And many assignments on a project, such as roofing or painting, last only a few days each, with several trades working on a site simultaneously. Therefore, a construction worker may have five or more employers in a year.

Just as the work assignments change throughout a construction project, so do the topography of the worksite and the cast of employers. Each trade on a site may work for a different contractor.

The universe of contractors is marked by high turnover. The U.S. Census counted 634,000 construction establishments in 1995, excluding the self-employed. (Some companies may have been counted more than once, depending on the number of business offices they have.) Most of the establishments were "mom-and-pop" operations; 82% had one to nine employees. An estimated 35% of all firms belonged to a construction organization, such as the National Erectors Association or the Associated General Contractors.

These features create public health problems. With so many job changes and small and short-lived firms, it is difficult to monitor an individual's work history. It is even more difficult to monitor injuries or exposures to hazards (see the following section). In the United States, the recording of injuries (ex-

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FIG. 42-1. Construction workers building a large sewage treatment plant. Women remain a small minority of the construction workforce in most countries. (Photograph by Marvin Lewiton.)

cept those that can be handled with first aid alone) in a log—as required by the Occupational Safety and Health Administration (OSHA)—has proved virtually unenforceable. (And the requirement does not apply to the 40% of construction workers who are self-employed or work for firms having fewer than 11 employees.) A 1987 study commissioned by the National Academy of Sciences noted the difficulties in obtaining injury and illness data for construction. Among other things, the study cited poorly defined responsibility for reporting injuries and illnesses (1).

The constantly changing worksite has another marked effect on safety and health. In contrast to an industrial setting, where the tasks are often repetitive and controlled by the location of machinery, the construction site allows and requires extensive movement by the worker from moment to moment. This means that the worker is much more responsible for self-protection.

In addition to risks of injuries and exposures to hazardous substances, construction workers face long-term risk from the stress of episodic employment. Stress may be caused by the fear of not having a paycheck. And because construction jobs can be few and far between, construction workers may have to travel long distances daily to work or may need to move their families often.

A lack of comprehensive employer organizations to work with hampers some public health efforts. Labor-management organizations have served as the vehicles for successful safety and health programs in the Netherlands, Sweden, and Ontario, Canada. (Some 24% of blue-collar construction workers in the United States—including 40% of those in public-sector construction—belong to unions or are covered by union contracts.) For all these reasons, it is difficult to implement preventive safety and health programs, including training, in the construction industry.

Although the causes of work-related injuries are well defined, the risks of chronic work-related musculoskeletal disorders are poorly defined, as are the relations between exposures and chronic diseases.

EPIDEMIOLOGIC OVERVIEW

The construction industry in the United States employs about 6% of the labor force—about 8.3 million workers (or 7.9 million full-time equivalents). In 1997, however, this industry had 18% of the fatal injuries and more than 10% of the lost-workday cases resulting from injuries. The death rate is 13.9 per 100,000 full-time construction workers, or more than 1,000 deaths per year; on average, four or more workers are killed by injuries sustained on the job each workday.

The rate of lost-time injuries, which increased slightly from 1975 to 1990, declined by 40% from 1990 to 1996, the most recent year of injury reporting by the Bureau of Labor Statistics. During that time, injury rates for other industries declined as well, although to a lesser degree in some cases.

No apparent changes in construction industry practices can account for such a dramatic decline.

Other factors in injury rates continue to hold. Generally, the largest firms have the lowest injury rates. For workers, experience is a factor, with the rate of injuries decreasing substantially as length of service increases (2). Familiarity with a job site also is a consideration. For laborers, who have some of the highest injury rates, 12% of lost-time injuries occur during the first day on a job site; this pattern appears to hold for most of the trades (occupations).

The workforce, drawn largely from immigrants and other low-income groups, faces predictable occupational ailments. These include the white finger of the jackhammer operator, silicosis of the tunnel builder, low back pain of the bricklayer, dermatitis of the cement mason, carpal tunnel syndrome of the ironworker or electrician, solvent-induced kidney ailments of the painter and roofer, lead poisoning of the bridge rehabilitation worker, asbestosis of the building demolition worker, and heat stress of the hazardous waste cleanup worker (from wearing "moon suits").

For a mix of reasons—work-related and not, many still poorly understood—the average age at death for construction workers in the United States is substantially lower than for other groups such as teachers or physicians (Fig. 42-2). Standardized mortality ratios (SMRs) for selected occupations in California show that many construction-related occupations have SMRs that are much greater than the average for all professions (100), and many times higher than for low-risk occupations.

Protection of the construction workforce in some industrial countries appears to be more effective than in the United States. International comparisons are difficult to make, but the death rates for construction workers in the United States, Australia, and Japan are high for industrial countries, at about 14 or 15 deaths per 100,000 full-time-equivalent workers. By contrast, the death

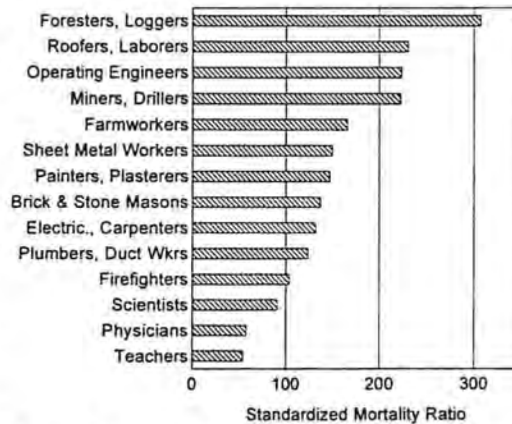

FIG. 42-2. Standardized mortality ratio for selected occupations. (Data from California Department of Health Services. California Occupational Mortality, 1979–1981. Table 7A. Sacramento, March 1987.)

rates for Sweden and the Netherlands, countries that have long-standing safety and health programs, are at about half that level (3). And, since 1970, the rate of deaths from worksite injuries in Sweden has been reduced by 75%.

The magnitude and severity of occupational health and safety hazards in construction work are greater in developing countries (Box 42-1).

Nonparticipants

In Sweden, the construction unions and employers established a comprehensive program focusing on safety and health, Bygghälsan, which monitored more than 225,000 construction workers for about 25 years. The rate of cardiovascular disease—the leading cause of death for workers and the general population—was lower among the construction workers. Cancer incidence was at 90% to 95% of the rate for the overall population, with some exceptions (Table 42-1). Bygghälsan attributes the differences partly to selection mechanisms but also to preventive programs it implemented on hypertension, smoking, diet, and exercise.

One striking finding involved a cohort of

Box 42-1. Construction Work in Developing Countries: The Experience in East Africa

Occupational health and safety hazards facing construction workers in developing countries are even greater than those facing their counterparts in industrialized countries. The experience in the East African countries of Kenya, Tanzania, and Uganda is illustrative.

In these developing countries, the hazards that are inherent in construction work are compounded by hot and humid conditions, inadequate training of workers, and shortages or inadequacies of construction tools, scaffolding, and helmets and other basic personal protective equipment. There is a great variety of inconsistency in equipment and processes. Among major construction hazards cited in Kenya, for example, are excavation work, inadequate scaffolds (Fig. 42-3) and electric equipment, and lack or inadequacy of lifting equipment. In these and other countries, hand tools and diesel engines at construction sites generate much noise; dusts and fumes are also major problems, especially in confined spaces.

In East African countries, well over half of construction workers are casual workers who are employed on a daily basis and do not belong to unions, as many other construction workers do. In these countries, construction workers are often paid on a piece-rate basis, which encourages rapid work and often unsafe work practices. Clean water and nutritious food are often not available to construction workers in the countries of East Africa. The same is true for basic health and safety services.

Data for work-related injuries and illnesses of construction workers in East Africa are even more incomplete than comparable data for these workers in industrialized countries. Nevertheless, available data provide some useful descriptions of the situation. Reporting is highly variable; for example, in Zanzibar, Tanzania, 44 construction incidents were reported between 1983 and 1989, with the number varying from 0 to 19 annually. In Kenya in 1989, according to workers' compensation data, there were 1,117 reported injuries among the approximately 60,000 building and engineering construction workers. Of these injuries, 43 were fatal and 52 caused permanent total incapacity.

The rate of reported fatal injuries for construction workers (72 per 100,000 workers per year) was three times the estimated rate in the United States and 12 times the rate in Denmark. Of the 618 injuries that could be classified, 40% were caused by stepping on or being struck by objects and 31% were caused by transportation vehicles.

Ministries of labor in the East African countries, with assistance from the International Labor Organization, the Finnish Institute of Occupational Health, and other organizations and groups, are attempting to improve safety and health in the construction industry by improving training of workers, establishing better means of surveillance and evaluation of hazards, and instituting better measures for prevention, often using low-cost, readily available materials and methods.

(Adapted from the East African Newsletter on Occupational Health and Safety, December 31, 1990.)

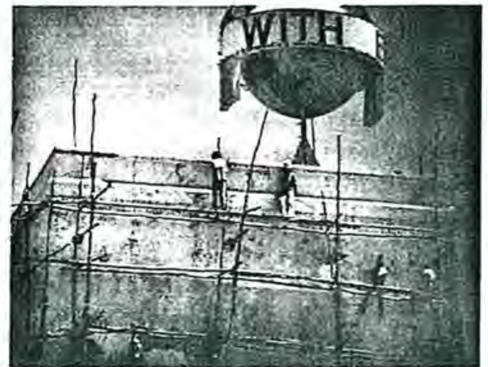

FIG. 42-3. Construction laborers work, without personal protective equipment, on dangerous bamboo scaffolding in Kenya. (Photograph by Barry S. Levy.)

TABLE 42-1. *Selected excess mortality and incidence for cancer and other disorders, Swedish construction workers*[a,b]

Trade	Cause of death (n)	SMR	Incident cancers (n)	SIR
Bricklayer	—	—	Peritoneum (2)	12.5
Carpenter	—	—	Nose (11)	2.2
Driver (truck/heavy equipment)[c]	—	—	Lip (6)	3.6
			Multiple myeloma (7)	2.7
Electrician	Bladder cancer (13)	2.3	[Bladder (39)]	1.3
Insulator	Pneumoconiosis (2)	40	Peritoneum (2)	200
Laborer	Accidental falls (67)	1.5	Lip (41)	1.8
			Stomach (152)	1.2
Maintenance worker[c]	Other accidents (7)[d]	8.4	Colon (11)	2.5
	Drowning (5)	4.7		
Plumber	Pneumoconiosis (4)	4.4	Pleura (15)	6.3
			Lung (105)	1.3
Sheet metal worker	Accidental falls (11)	2.4	Lung (26)	1.6
Tunnel worker	Prostate cancer (20)	1.9	[Prostate (33)]	1.1
	Other accidents (10)[d]	6.1		
	Violent death (69)	1.5		

SMR, standardized mortality ratio; SIR, standardized incidence ratio.
[a] Ratios are based on comparison with the white male Swedish population. The cohort of more than 225,000 workers was established in 1971 to 1979. Mortality was followed through 1988. Cancer incidence was followed through 1987.
[b] All values are statistically significant unless in brackets.
[c] Compared with the other construction trades, drivers and maintenance workers have a risk of death from heart disease of 1.37 and 1.40, respectively.
[d] Other accidents were predominantly work-related injuries.
Data from Göran Engholm, Bygghälsan, 1992.

48,754 male union painters and certified plumbers and insulators. The group was divided almost equally into workers who participated in voluntary medical examinations and those who did not, either because they chose not to or because they were no longer employed in construction. By 1988, nonparticipants showed mortality rates 72% higher than those of participants. By 1987, similar results were obtained for cancer incidence.

The differences between nonparticipants and participants were especially noteworthy for diseases associated with poor health behaviors. A disparity in mortality rates from cancer of the larynx probably could be assigned to differences between the two groups in alcohol and tobacco consumption; SMRs for nonparticipants and participants were 3.12 and 1.11, respectively. Excess mortality from alcoholism, cirrhosis of the liver, and cardiovascular disease could also be tied to behavioral differences.

A second distinguishing factor is analogous to the healthy worker effect, whereby the employed population tends to be healthier overall than the total population. (This is particularly true in occupations with heavy manual labor, including most construction work.) For example, a higher mortality rate from diabetes among nonparticipants may reflect the inability of workers who initially were part of the cohort to remain employed, because of illness.

These findings point up the risk of basing epidemiologic conclusions on the results of a voluntary screening program. Although voluntary screenings can suggest whether a problem exists, results based on those who participate in a voluntary program would show a large selection bias. In this case, the findings would paint much too rosy a picture of the health status of construction workers generally.

Female Workers

Female workers are only beginning to join the skilled trades in substantial numbers in

most countries; in the United States, they accounted for 2.5% of blue collar workers in 1996 (4). Injury rates for women in construction have been lower than those for men, at least partly because women have been restricted from the most dangerous and highest-paying jobs (5,6). Women's safety and health risks in construction are tied to gender discrimination (7,8). Discrimination can take the form of a lack of site orientation or cooperation by coworkers, sexual harassment, or outright threats to safety (e.g., a brick dropped from overhead). One obvious result is increased stress. In addition, female construction workers face problems tied to anatomy. Some job equipment (e.g., hand tools) or personal protective equipment (e.g., respirators) may not properly fit women, who tend to be smaller than many men. A lack of private sanitary facilities may lead women to avoid urinating during a workshift, with consequent discomfort and health problems (see Chapter 36).

TABLE 42-2. *Distribution of lost-time injuries (fatal and nonfatal) among roofers and laborers*

Cause of injury	Roofers	Laborers
Falls from elevations	23%	11%
Overexertion	23%	22%
Struck by an object	14%	25%
Contact with temperature extremes	9%	2%
Struck against	7%	10%
Falls from same level	6%	7%
Bodily reaction[a]	5%	3%
Caught in/under/between (including cave-ins)	3%	8%
Rubbed/abraded	3%	7%
Contact with radiation, caustics, etc.	2%	3%
Other[b]	5%	2%

[a] Includes, for instance, slipping and twisting body to catch oneself or twisting an ankle while climbing a ladder.
[b] Includes transport and nonclassifiable injuries.
Labor injury data from Bureau of Labor Statistics. Injuries to construction laborers. Bulletin 2252. Washington, DC, March 1986:8. Roofer injury data from Martin E. Personick, Bureau of Labor Statistics, based on workers' compensation data, selected states.

INJURIES AND ILLNESSES ASSOCIATED WITH CONSTRUCTION WORK

Traumatic Injuries

Construction workers are at great risk of injury partly because of where they work, from scaffolding and roofs hundreds of feet up to trenches. Specific hazards and overall risk vary by trade (Table 42-2). Based on what is known in the United States, ironworkers have the highest risk of work-related deaths, more than twice the rate of the next-highest group, laborers; in other countries, roofing may be the most dangerous trade because of the danger of falls and exposures to hot tar (9,10).

The rankings of causes of fatal and nonfatal injuries appear to differ, however. For instance, falls from heights tend to be so serious that they are responsible for most of the traumatic work-related deaths. For nonfatal injuries, most studies list overexertion, followed by "struck by" injuries (see Chapters 8 and 24) (11). (In regions where a large proportion of the construction labor force consists of immigrants, workers' inability to understand the national language may increase the risk of injury.)

Musculoskeletal Disorders

Some musculoskeletal disorders result from traumatic injuries, but many others develop incrementally. These stem from repetitive tasks, awkward body positions, and materials handling on the job. The bricklayer lifts an estimated 3 to 4 tons daily, with 1,000 trunk-twist flexions. The ironworker tying intersections of the perpendicular rods used to reinforce concrete may bend over for more than half the workday, repeatedly twisting the wrist under pressure. In building construction, much of the finishing work involves areas above shoulder height or below knee level. Wallboard sizes typically used in the United States (4 ft × 12 ft × 5/8 inch) weigh more than 100 pounds apiece and are often packaged in pairs. (Arbouw, the Dutch institute on safety and health in construction, rec-

ommends that wallboard weigh less than 20 kg [45 lb]).

Although musculoskeletal disorders are not fatal, they are significant. Disorders of the back and upper extremities account for roughly one-third of all workers' compensation claims (see Chapters 11 and 26) (12). Very little detailed analysis has been performed on the problems of each trade. A Bygghälsan questionnaire from 1989 to 1992 was completed by more than 83,000 construction workers, including more than 19,000 carpenters. Responses to questions about the proportion of time spent in certain work postures and about the locations of the most prevalent musculoskeletal complaints suggest a correlation between the two.

The most detailed scientific report on musculoskeletal disorders was done by Holmström, who produced a series of studies, one of them on a randomized, cross-sectional sample of 1,773 construction workers in Malmö, Sweden (13). Holmström found low back pain to be correlated with increasing age, construction trade, personal habits, and psychosocial factors. Only 8% of the workers studied reported no musculoskeletal problems in the preceding year; low back pain was reported by 72%, knee problems by 52%, and neck-shoulder pain by 37%.

The prevalence of most musculoskeletal symptoms increased with age. Low back pain correlated with frequent handling of handheld equipment, handling of bricks and roofing materials, and awkward postures such as stooping or kneeling for more than 1 hour per day. The prevalence and type of disorder varied by trade; roofers, carpet and tile layers, and scaffolding erectors had the highest prevalence of low back pain.

Reported low back pain was 2.7 times more prevalent for smokers than for nonsmokers. Psychosocial factors also contributed significantly to "explain" low back pain, when other factors were kept constant. Workers who reported no low back problems were generally in better physical condition, were more involved in recreational activities, smoked less, and had a more positive outlook. They reported fewer psychosomatic symptoms and were more active participants in worksite decision making. The average length of employment in construction for this group was 15 years. Workers reporting severe low back problems had significantly reduced back muscle endurance. Both groups of workers were found to have the same maximum abdominal and back muscle strength.

Illnesses

Some work-related illnesses appear to be correlated with specific construction trades (Table 42-3). In addition, some illnesses may develop as a result of the location of work. For instance, in the United States, construction workers who work outdoors where Lyme disease is found have an increased risk of developing the disease, compared with the general population (14). Listeriosis, histoplasmosis, malaria, yellow fever, and rashes from poisonous plants are other ailments tied to location. For several reasons, including long latencies, it has generally been difficult to relate chronic diseases to an individual worker's employment history.

Pulmonary Diseases, including Lung Cancers, and Bystander Exposures. Construction sites are generally dusty; powdered bags of cement are emptied for mixing, wood is sawed, heavy machinery lumbers across uneven terrain, and pneumatic tools are used on drywall, concrete, and rock that contains quartz. Fumes are also produced by such activities as welding, roofing, and paving. So, in several ways, construction workers' lungs are exposed to toxic hazards.

Asbestos and silica are the two best-documented hazards. The National Institute for Occupational Safety and Health (NIOSH) (15) found that the highest proportionate mortality ratios (PMRs) for white male construction workers younger than 65 years of age were for asbestosis (393) and silicosis (327). These findings, derived from underlying cause-of-death codes on death certificates for 1984–1986, compared with a PMR for falls of 177 (see Chapter 25).

TABLE 42-3. *Common toxic hazards on the construction site*

Substance	Key source of exposure	Substance	Key source of exposure
Dusts		**Solvents**	
Asbestos[a]	Demolition, maintenance, insulation	Benzene[a]	Hazardous waste cleanup, petrochemical plant sites
Cement	Foundations, sidewalks, floors	Methylene chloride	Paint strippers
Synthetic vitreous fibers, other insulation	Insulation on pipes, air conditioning	Toluene	Varnishes, paints, adhesives, cleaners
Silica	Sandblasting, tunneling	Trichloroethylene	Varnishes, paints, adhesives, cleaners
Wood dust[a]	Remodeling, demolition, sawing	**Other chemicals** Epoxy resins	Impermeable paints, wood floor primers
Metals (dusts and fumes)			
Cadmium[a]	Welding, cutting pipe	Polyurethanes (isocyanates)	Seam sealers, insulation, electrical wire coats
Hexavalent chromium[a]	Welding, cutting pipe		
Copper	Welding, cutting pipe	Coal tar pitch[a]	Roofing, road work
Lead	Demolition, work on lead-paint surfaces		
Magnesium	Welding, cutting pipe		
Zinc	Welding, cutting pipe		

[a] Human carcinogen. Asbestos is a disease risk only when asbestos is disintegrating (friable).

Adapted from Workplace Hazard and Tobacco Education Project. Construction workers' guide to toxics on the job, Berkeley: California Public Health Foundation, 1993.

Studies have documented a pattern of lung cancer among insulation (asbestos) workers, as well as the risk for other neoplasms and the likelihood that others besides workers producing or handling asbestos are also at risk (16). The research showed an almost seven times greater risk of death from bronchogenic carcinoma and mesothelioma, compared with the general U.S. population. The higher the exposure, the greater the risk for developing asbestos-related disease; nonetheless, any worker near asbestos work is at risk of developing disease through "bystander exposure." Although the spray application of asbestos insulation has been banned in the United States since 1973 and most uses of asbestos are controlled, construction workers involved in demolition continue to be exposed to asbestos-containing materials that were installed years ago. There is no scientific basis for application of differing regulations for different asbestos fiber types (17–19).

Similarly, although OSHA has set permissible exposure limits for respirable silica, new cases of silicosis are still reported in the United States; however, the disease is underdiagnosed and therefore underreported. Those at risk include tunnel workers, sandblasters, workers in trades working with concrete and mortar (laborers, masons, concrete finishers, tile setters, and plasterers), and bystanders (20). Depending partly on the percentage of silica in the materials used, a wide range of tasks can prove hazardous, including drilling holes, grinding concrete surfaces,

power-cleaning concrete forms, and cutting through concrete block, walls, or pipe. The risks have been documented for decades and are not limited to new construction. For instance, powered grinders may be used to remove mortar for restoration.

A health examination survey of construction workers formerly employed at U.S. Department of Energy facilities found evidence of positive results on lymphocyte proliferation tests, a clinical indication of beryllium exposure. Although work that may lead to beryllium exposure is not widespread in construction, such exposure should be considered particularly during maintenance, demolition, and cleanup of nuclear facilities, other types of power generating plants, and aerospace facilities, where beryllium may have been used.

Other Cancers. Exposures to carcinogens are possible in all types of construction. Some sources are well known, such as polycyclic aromatic hydrocarbons in roofing tar. Welding can produce carcinogenic fumes, such as fumes of cadmium, nickel, or hexavalent chromium.

More than 60 million tons of asphalt (bitumens) are produced worldwide annually. Although studies have not yet established that asphalt exposure leads to human cancers, general agreement exists, on the basis of experimental studies, that asphalt may pose such a risk (21). When working with asphalt, skin exposures should be avoided; work in poorly ventilated areas should be done only with engineering controls and use of personal protective equipment.

Some carcinogenic exposures are of relatively recent origin. The use of plastics has been multiplying, and the health effects of their use remain unknown. Specialty paints may include metals and dangerous solvents. Among resins, epichlorhydrin in epoxies and isocyanates in polyurethanes pose potential but sometimes poorly documented risks. Benzene and vinyl chloride are among the substances commonly found at Superfund cleanup sites.

Central Nervous System Disorders. Lead poisoning continues to be a particular concern for construction workers. Although lead has been restricted to trace amounts in residential paints since 1978 in the United States, it is still allowed for industrial uses, including signs, road paints, and steel structures. The California Occupational Lead Registry found that construction workers accounted for 18% of the workers who had peak blood lead levels of 80 μg/dL (22). (This is well above the 50 μg/dL level requiring medical removal.) Exposures to lead occur during rehabilitation or demolition of lead-painted structures, including housing built before 1950. Lead exposures can occur during scraping, cutting with torches, sandblasting, and welding. (See also Chapters 3, 15, 29, 31, 33, and 35.) Welders may be exposed to fumes containing lead, but also manganese, nickel, and decomposition products of epoxy, polyurethane, and polyvinyl chloride coatings. In California, a welder's Parkinson's disease has been tied to work-related manganese exposures for workers' compensation (see Chapter 29.)

Threats to the nervous system commonly found by hazardous waste cleanup workers include toluene, trichloroethylene, tetrachloroethylene, arsenic, benzene, lead, and mercury.

Skin Disorders. Bricklayers, cement masons, and others who handle wet cement are prone to allergenic and irritant dermatitis on the hands and other exposed areas. The symptoms can be severe enough to necessitate leaving the trade. The irritant dermatitis is believed to be caused by the abrasive nature and high pH of wet cement (see Chapter 27).

Hearing Loss. Noise levels on construction sites represent a long recognized and inadequately addressed problem. Among other things, limited hearing endangers workers who cannot hear an approaching vehicle or warnings of immediate danger. Reports from Sweden, Germany, the United States, and British Columbia, Canada, show extensive hearing loss, apparently work related, among construction workers. In the

United States, a 1997–1998 study of construction sites in Washington State found that 40% of workers were commonly exposed to noise levels greater than 85 dB (23). A jackhammer can exceed 105 dB; a bulldozer, 95 dB. Bygghälsan found in 1974 that bilateral normal hearing among construction workers decreased gradually with age, so that only about 8% of those examined at 50 years of age had hearing in the normal range. At the same time, about 12% of construction workers at that age had bilateral severe high-tone hearing loss. (See also Chapter 18.)

Temperature Extremes. Some of the most difficult hazards faced by construction workers are those presented by extremes of temperature, particularly in summer and winter. Consequences of overexposure to heat are similar to those documented for other working groups (see Chapter 19). Although the same is true for the consequences of cold temperatures, there is the additional hazard of increased risk of traumatic injury that can result from contact with frozen surfaces or reduced ability to handle tools and equipment properly.

Family-Contact Disease. Asbestos fibers reportedly have been transported in asbestos products carried home to show family members and inadvertently on clothing, in hair, and on shoes. A similar risk exists for lead poisoning among construction workers' families, particularly children, who are more vulnerable to lead.

APPROACHES TO PREVENTION

Adaptation of Measurement Technology

Industrial hygiene exposure measurements in construction have some special aspects. To measure exposures in manufacturing, integrated samples are collected to determine 8-hour time-weighted averages. Such an approach may not give an accurate picture about health effects in construction, however. Brief, high-level exposures are common and may have different and significant health effects compared with longer-term, low-level exposures. Air sampling based on tasks may be more relevant. There is a need for researchers to take on the special issues in construction and develop new methods, such as real-time monitoring, that may help address this problem. One goal would be to develop exposure profiles of individual tasks and possibly of trades.

Use of exposure profiles is limited, however, in that individual construction workers or workers in a given trade do not perform the same tasks each day. The lack of consistent exposures and varying ambient conditions (e.g., wind, rain, temperature) limit the effectiveness of air-sampling measurements for routine monitoring.

Construction workers can also be subject to bystander exposures. Because construction workers all move about a site, each worker's position in relation to exposure sources changes often. At some moments, a worker may be directly exposed while using a hazardous substance, but at other times the worker may be exposed to another substance as a bystander 10 feet downwind. It is therefore difficult to anticipate all the substances and degrees of exposure an individual may encounter on a given day or in a career.

In addition, air sampling does not measure skin absorption or ingestion of toxic substances, which contribute an unknown, but not necessarily insignificant, amount of exposure, particularly on worksites where sanitary facilities for hand washing are nonexistent.

New Technologies

Technological improvements have reduced the risks of musculoskeletal and other health problems. Many of the changes are straightforward. For instance, a two-handed screwdriver with a longer handle, now used in Sweden, increases torque and reduces stress on the wrists.

To make lifting easier for the bricklayer, bricks in Germany now are designed with

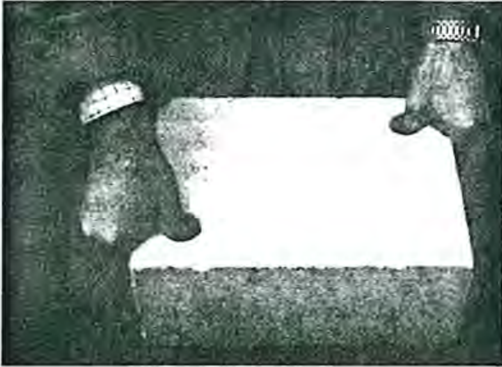

FIG. 42-4. A variety of handholds can be designed to assist in lifting bricks of different sizes and shapes. (Photograph by Bau-Berufsgenossenschaft, Frankfurt.)

holes or handles (Fig. 42-4). Regulations require that bricks weighing more than 25 kg (55 lb) be lifted only by machine. In the Netherlands, brick manufacturers, unions, and management developed a system in which bricks are packaged in sets that are easily moved about the worksite on dollies and lifted by levers to a height that is convenient for the worker.

Tower crane cabins are being redesigned in Germany and Sweden. One change extends the window to the cabin floor. This enables operators to see below without having to lean forward constantly. As a result, they report less chronic neck pain.

To reduce the risk of silicosis by about 90%, researchers in Germany have turned to wet blasting using water to dampen sand as it is being sprayed and thereby minimize dust. Nevertheless, throughout Europe, silica is being banned, except where its use is essential.

In Denmark, Finland, Sweden, and Germany, researchers found that adding small amounts of ferrous sulfate to cement changes water-soluble hexavalent chromium to trivalent chromium. This modification was applied beginning in the mid-1980s and appears to explain the substantial decline in allergic dermatitis in the Nordic countries since that time. The change costs about $1 per ton.

Some efforts to improve worker health combine technologies and training. By 1986–1990, such efforts by Bygghälsan had reduced noise-related hearing loss by half among workers 30 to 50 years old, the ages for which hearing loss could have been affected by Bygghälsan's interventions.

Personal Protective Equipment

Engineering or work-practice changes are preferable to relying on personal protective equipment. Workers may not know when they need to use protective equipment. If they do know, they may lack proper equipment or the needed training. And use of some controls may create problems. For instance, although construction workers often perform as teams, respirators may prevent coworkers from communicating with each other. Full-body protective clothing can also contribute to heat stress.

Having protective gear without knowing its limitations can do more harm than good, by giving the worker or employer the illusion that the worker is protected. For instance, no gloves can protect for longer than 2 hours against methylene chloride, which is present in many paint strippers. And some solvent mixtures can seep through the best gloves in minutes, even though the components may each have breakthrough times of 4 hours or longer.

A lack of eating and sanitary facilities may also present problems. Often, workers cannot wash up before meals and must eat in the work zone. A lack of showering and changing facilities may result in transport of contaminants from the workplace to a worker's home.

Regulation

Since 1989 in the United States, OSHA has implemented standards that could improve safety and health in construction. Among these are: Process Safety Management of Highly Hazardous Chemicals (29 CFR 1926.64), 1992; Hazardous Waste Operations

and Emergency Response (29 CFR 1926.65), 1993; Lead Exposure in Construction (29 CFR 1926.62), 1993; and a proposed revised Subpart R Steel Erection standard.

Recent studies have confirmed, however, what critics have long believed to be a major deficit in OSHA's enforcement of its construction regulations. OSHA tends to repeatedly inspect the largest worksites maintained by the largest companies, where unsafe conditions are least likely to exist (24). To direct its limited resources to more hazardous sites, OSHA has developed a "focused inspection" program. If a worksite has an effective safety and health program that includes worker training and participation, OSHA inspectors are authorized to focus on the hazards known to cause 80% or more of deaths from injuries: falls, and "struck by," "caught in-between," and electrical hazards. If a focused inspection finds no violations of OSHA standards, inspectors normally move on to other worksites. Some OSHA standards do not apply to construction, however. Such as a mandatory safety and health program (29 CFR 1900.1) and a proposed ergonomics standard.

Ergonomics is beginning to be addressed by other agencies. Since 1996, the U.S. Army Corps of Engineers has had an ergonomics standard for its construction contractors. A Swedish ergonomics standard in place since 1998 applies to construction and requires training for workers; the standard, for instance, notes that 90-cm-wide gypsum wallboard is 25% lighter than traditional, larger board and should be used whenever feasible (25).

Sometimes regulation has unintended negative effects. Regulation and the threat of lawsuits regarding use of asbestos in industrial countries have led to its exportation to developing countries, where it is not controlled. In Africa, Asia, and Latin America, asbestos is used mainly not for insulation but in asbestos cement, to build homes and produce drinking-water pipe. Workers installing asbestos in developing countries generally are not warned of potential health hazards to themselves or their families. Instead, the industry promotes asbestos as a safe material. Even if asbestos use is immediately banned in such countries as Zimbabwe, China, the Philippines, Thailand, and Brazil, the hazards from asbestos already in place will continue for decades. Furthermore, potential substitutes for asbestos must be monitored for possible similar health risks, and, if necessary, regulated.

Site Safety and Health Planning and Management

There is widespread agreement that planning is key to improved safety and health at the worksite. It is most effective to require initially a written plan by a project owner who monitors its use; such a plan should include accountability, coordination among subcontractors, and active worker participation. In the United States, written site safety plans have long been required and enforced by the Army Corps of Engineers, which reports an injury rate one fourth of that for the entire industry. Such plans are increasingly being used, at least by the largest multinational firms; as of 1998, contractor fees from the U.S. Department of Energy are based partly on execution of site safety plan requirements.

Education and Training

Safety training and worker and manager education have long been provided by some companies and some unions. The training programs cover such topics as rigging, trenching, stretching exercises, and substance-abuse recovery.

In the United States, many training programs include instruction about dangerous substances, which is mandated under OSHA's Hazard Communication Standard. The Building and Construction Trades Department, representing the 15 construction unions in the AFL-CIO, has produced training on safety and health in more than 10 one-hour modules, on topics ranging from confined spaces to ergonomics.

In Germany, the Gefahrstoff-Informationssystem der Berufsgenossenschaften der

Bauwirtschaft (GISBAU) program works with manufacturers to learn the content of all substances used on construction sites. The information is provided in a form to suit the differing needs of health staff, managers, and workers through training programs, in print, and on CD-ROM. The software, known as WINGIS, can be used on construction sites. It tells how to substitute for some risky substances and how to safely handle others.

ROLE OF THE CLINICIAN

The major safety and health need in construction remains the broad implementation of what may be considered best practices, particularly by smaller employers. Few of the risks and successful interventions that have been documented through increased research on construction safety and health are new discoveries. An obscure presentation in 1942 by M.F. Trice, an industrial hygienist for the State of North Carolina, listed most of the major risks known today and proposed solutions that are still accepted (26). For whatever reasons, occupational safety and health professionals shied away from the construction industry and its occupations.

The occupational health professions can have a major impact in the construction industry. To be effective, however, health professionals must first understand the organizational and sociologic aspects of construction work, so that effective health care delivery systems can be developed. Second, health professionals must understand the risks that workers face on the job. And third, health professionals must develop protocols and programs appropriate to the needs of construction workers and their families.

Delivery Systems

There are numerous opportunities to provide improved health programs for construction workers through health and welfare plans, workers' compensation carriers, employers, and unions. Structured care systems are needed that are based on close cooperation among clinicians and experts in physical therapy, occupational hygiene, and safety engineering.

Few employers provide their own medical staff. Therefore, existing community or academic occupational health clinics generally have a large volume of building trades activities, seeing individual workers who have been referred or self-referred and investigating special problems in the worker population. This pattern, however, does not reflect industrywide health care use. Because of the episodic nature of construction employment and the high cost of health care, most construction workers do not have continuous medical care or a long-term relationship with a medical provider who knows them—except, perhaps, where there is universal health care or national health insurance.

A partial exception in the United States has been in the unionized sector, which since the late 1940s has provided health insurance through health and welfare funds that are jointly trusteed (with employers). There are about 750 such funds of varying size in the United States, most of them local. To address episodic employment, the health and welfare funds have established hour banks in which workers can accumulate hours worked to qualify for coverage. Workers can thereby maintain group coverage through as much as 3 to 6 months of unemployment by drawing on their bank reserves. But this system has its limitations. With erratic employment, some workers still are not able to build up reserve hours. And, even with good coverage, medical care utilization has been poor.

Despite this spotty record, construction may be unique in the strong incentives it offers employers and workers to support preventive health care. Although workers' compensation costs in the industry in the United States have leveled off and are being reduced, in some cases, through state-approved collective bargaining, construction premiums remain excessive. For instance,

the workers' compensation premium for ironworkers in 1998 averaged $37.64 per $100 of payroll, and the rate for general carpenters was $18.08 (27); the rates vary enormously, depending on trade, jurisdiction, and type of work done. The high costs mean that most safety and health programs can have positive economic impacts.

Preventive Services. Targeted preventive services are needed in health insurance plans that cover construction workers and their families. These should include identification of each patient's occupation, and then discussion with the patient regarding precautions to take around the hazardous substances most likely to be encountered in that trade.

Development of Protocols. Few occupational medicine protocols have been developed and validated for use for construction groups, even for preventive medicine generally. Issues include whether there is a role for chest radiographs in periodic preventive medical examinations and whether liver function tests have a useful role in predicting fitness for work in hazardous waste cleanup.

Targeted Medical Monitoring. Because of the difficulties of reliably establishing work histories and exposures, medical monitoring is especially important, particularly in hazardous waste cleanup and lead abatement. Only a few types of exposures require medical monitoring in the United States, whereas German law specifies medical monitoring for many potentially toxic substances in the work setting. In Germany, checkups are required before work begins and at specified intervals. For some known carcinogens, checkups are required at regular intervals even after exposure ends. The preemployment checkup provides a baseline for future examinations. Information from the checkups that can be used to improve workplace conditions is given to employers. Employers are responsible for continuing the medical monitoring according to a schedule begun with the previous employer. However, if a worker is unemployed for longer than the scheduled interval for checkups, the examination schedule usually begins over again with a baseline examination at the time of next employment.

Screening for Disease. Although there is a long history of screening programs for asbestos-related diseases, relatively little is known about the prevalence or incidence of most musculoskeletal disorders, hearing loss, dermatitis, silicosis, or other chronic diseases. As the first and second waves of asbestos disease end, it will also be useful to study whether the overall incidence is in decline. (In industrial countries, the first wave of asbestos disease early in the 20th century was related to asbestos mining, milling, and manufacturing; the second wave accompanied end-product use.) A third wave of asbestos disease is beginning to appear as buildings and materials containing asbestos introduced during the second wave deteriorate or are demolished.

Determination of Disability and Support for Rehabilitation

Medical Panels. Better medical support to determine disability under workers' compensation and help workers return to work early are needed. Closed medical panels for disability determination can help make the system more responsive to the needs of disabled workers. The occupational physician can also help identify light-duty tasks that match a worker's level of disability. (See Chapter 12.)

Standards Setting. Occupational health physicians can help with the setting and implementation of health-related standards. In the United States, most OSHA standards are inadequate in terms of medical monitoring requirements for construction workers. Medical monitoring requirements in the OSHA Hazardous Waste Operations Standard, for instance, are vague. The OSHA Lead Exposure in Construction Standard has clear medical requirements for monitoring and actions, but it is impractical. For instance, a worker with a high blood lead level is supposed to be provided another job removed from the lead exposure and at the same pay. But if a project has been com-

pleted, the contractor no longer is required to provide a job. The worker then may have difficulty finding another job until the blood lead level decreases.

Future Research Needs

Issues such as the measurement of and consequences of toxic exposures are poorly understood, partly because of inadequate past research on work-related safety and health in construction. For health professionals interested in research, construction is largely unexplored terrain. Areas that have not been addressed are exposure characterization, epidemiology, health services, interventions, and policy.

Exposure Characterization. Differences among construction sites hamper efforts to predict exposures. In response to this challenge, researchers have been trying to develop an exposure assessment model for construction work (Fig. 42-5). The intent is to efficiently collect descriptive and quantitative data that can predict exposures before jobs begin and present the information in a form that workers can easily use on site.

FIG. 42-5. Worker, spraying fibrous glass insulation on a building under construction, illustrates the difficulties of assessing and controlling construction-site hazards. (Photograph by Ken Light.)

Given the limits of existing technology, the best approach may be to develop estimates of the range of exposures for given tasks (e.g., rod tying, drywall sanding, welding), taking into account such factors as the substances used, duration of use, and ventilation. For welding, for instance, an estimate would consider the welding method, the welding rod used, and the materials welded, including any coatings. These estimates should include exposures via ingestion and skin absorption. Exposures worth special attention include noise, dusts, solvents, vibration, manual lifting, and work postures.

Epidemiology. Epidemiologic surveillance systems cover few workers in the United States, and estimates based on different data sets show major inconsistencies. Work-related illnesses are grossly underreported, for a mixture of reasons. There is a shortage of reliable data on the mortality and morbidity patterns of the various trades. Virtually no research has been done on patterns of disability for the trades. Descriptive studies are needed. So are longitudinal cohort studies of construction workers to determine the magnitude of many of these problems.

Health Services. No research has been done on the delivery of occupational or general medical services for construction workers in the United States, and little is known about construction workers' patterns of health care use. If one accepts that continuity of care is a key determinant of the effectiveness of medical care, the episodic nature of construction appears to be a major barrier.

Interventions. Studies are needed regarding four types of intervention. First, various approaches to the delivery of preventive services should be tested. Second, information is needed on a host of preventive measures, including training, certification of workers and contractors, and use of technologies, work practices, and personal protective

equipment that may reduce exposures. Third, no studies have been performed on the best systems for monitoring the health of construction workers, such as exposure monitoring, medical monitoring, or the tracking of workers in this transient industry. Fourth, studies should be performed to reduce the sequelae of disability and to return injured workers to gainful employment.

Policy. Little consideration has been given to the economics of improved safety and health in construction. There have been no valid studies to examine the effects of disability on workers and their families. In addition, there have been no systematic attempts to characterize the construction industry's composition in a defined geographic area. Much more needs to be done to understand better what types of interventions work in an industry in which employers are mostly very small contracting companies, employment is transient, and worksites are temporary and constantly changing—and with different employers working together without adequate coordination.

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This publication characterizes the industry through the use of 128 charts in five categories—industry summary, labor force characteristics, employment and income, education and training, and safety and health—based on a wide range of government and private-sector sources. The format is easy to use and the text explains how data were derived for each chart. (It is available for downloading at http://www.cpwr.com.)

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