OCCUPATIONAL SAFETY AND HEALTH ISSUES ASSOCIATED WITH GREEN BUILDING

1 Introduction

This e-fact aims to raise awareness of the occupational safety and health (OSH) risks associated with the planning and construction of green buildings, their maintenance, renovation (retrofitting) and demolition, as well as the collection of related construction or demolition waste on site (excluding the subsequent waste treatment and recycling). Some of these OSH risks are new compared with traditional construction sites and are associated with new green materials, technologies or design. Other risks are well-known to the construction sector (for example working at height), but they arise in new situations or combinations associated with green buildings that demand specific consideration.

1.1 What are 'green buildings'?

A green building is a structure that is environmentally responsible and resource-efficient throughout its life-cycle, from siting to design, construction, operation, maintenance, renovation, and demolition. A common feature of green buildings is that they drastically reduce emissions, material use and water use. Green buildings have the potential to reduce energy use by 80% or more by integrating efficient systems (heating, cooling, lighting, water); use alternative energy sources (for example passive solar, wind energy, bioenergy); retain energy (efficient insulation and windows, thermal mass); and use recycled, reused, or low-energy building materials. In Canada and in the United States of America (USA), certified green buildings represents 1.5% and 3% of the total respectively. [1, 2].

The International Labour Organization (ILO) has developed seven principles for sustainable construction and renovation, taking into account the entire life cycle of a building [3]:

- reduce resource consumption,
- reuse resources,
- use recyclable resources (recycle),
- protect nature, eliminate toxics,
- eliminate hazardous chemicals,
- apply life-cycle costing (economics),
- focus on quality.

Some of these principles, such as the elimination of hazardous chemicals, may be beneficial to OSH. However, practices in green construction aimed at improving safety and health are often primarily aimed at a building's final occupants. The design and construction of buildings using current sustainability practices do not always benefit construction workers' safety and health [4]. Additionally, ecological and efficiency principles are applied in determining the use of resources for the construction of green buildings. This entails using different technological skills and management requirements and therefore might require developing workers' skills and facilitating training beyond those needed for traditional buildings to allow workers to perform their jobs safely [3]. Examples of these are working with extensive scaffolding, applying vegetation on the roof and the manual separation of recyclable materials.

1.2 Certification and assessment schemes

Various assessment and certification schemes that measure the sustainability of buildings have been in operation for a number of years in many countries. Eleven countries are members of the World Green Building Council, and dozens more are in the process of forming national councils or adopting certification standards. The established green building standards include [5, 6]:

- BREEAM in the United Kingdom[1]
- DGNB Label in Germany[2]
- LEED in Canada[3], United States of America (USA)[4] and India
- CASBEE in Japan[5]
- Green Star in Australia[6] and New Zealand
- Passivhaus in Australia, Germany and the United Kingdom

One of the best examples in Europe is the BREEAM rating system established in the United Kingdom by the Building Research Establishment (BRE), which has been used for the assessment and certification of more than 100,000 buildings since 1990 [7]. The US Green Building Council developed the LEED system, which is a green building certification system that sets voluntary standards for environmental performance. LEED accreditation seems to be leading to changes in the way designers, contractors and owners approach building design, construction and operation. This change and the motivation to attain LEED certifications can be related to several factors, such as the desire of buildings' owners to enhance their public image as being environmentally friendly, the use of the certification as a marketing tool for contractors, reduced operation and maintenance costs, and the improved health of building occupants [4].

There are currently more than 40,000 LEED-accredited professionals involved in green building design, construction, operation, or maintenance in the USA; 1,500 LEED-accredited professionals in India; 1,197 BREEAM-licensed assessors in the United Kingdom; and 900 Green Star professionals in Australia [8]. These numbers will most likely rise as the green building concept takes over a larger share of the construction market.

LEED awards points based on a building's performance in the following areas: sustainable sites; water efficiency; energy and atmosphere; materials and resources; indoor environmental quality; location and linkages; awareness and education; innovation in design; and regional priority. Only one of the above areas has a connection to construction workers' health and safety, and that is indoor environmental quality (also called indoor air quality). Today's certification programmes for green buildings do not consider workers' health and safety in assessing whether or not a building is green [3], and they may even have a negative impact on OSH [9, 10].

2 OSH risks associated with green buildings

Information on OSH risks specifically related to green construction is scarce. A survey among nine construction firms in the USA, involving 86 construction projects, revealed that the green (LEED-certified) projects had slightly higher numbers of incidents than non-green projects [11] but that green and non-green projects had similar numbers of incidents that caused a loss of working time. There was no relationship between the number of LEED credit-points that a specific project received and safety performance within that project. However, several factors could hinder the identification of clear differences in safety and health performance between green and non-green projects. These include project type, type of facility being built, project complexity, project height, project location and project funding [11].

2.1 Traditional construction risks and green buildings

Known risks found on traditional construction sites such as working at height, slips, trips and falls are also an issue at green building sites [9], where they are in certain cases even more severe. A LEED certified green building in the USA appears to have more complex design elements that may be more hazardous to construct than traditional designs [10]. This was illustrated in a construction project in Las Vegas where six workers died, although the project was LEED 'gold' certified for green buildings [10]. Causes of death cited mainly included 'conventional' accidents such as falls, persons being hit

[1] For more information visit British Green Building Council, at http://www.breeam.org
[2] For more information visit German Green Building Council, at http://www.dgnb.de
[3] For more information visit Canadian Green Building Council, at http://www.cagbc.org
[4] For more information visit US Green Building Council, at http://www.usgbc.org
[5] For more information visit Japan Sustainable Building Consortium, at http://www.ibec.or.jp/CASBEE
[6] For more information visit Green Building Council Australia, at http://www.gbc.au;

by trucks, and persons being hit by large objects. Time pressure was identified as a major cause of these accidents [12].

Because green buildings are often tightly sealed and more thoroughly insulated in order to save energy, ventilation may be reduced during internal finishing work. This may increase exposure to volatile organic compounds from, for example, paints or adhesives, and to dust, including crystalline silica [9, 10].

The re-insulation of existing buildings may bring about exposure to conventional insulation materials [13], such as man-made mineral fibres (glass wool, rock wool). Cutting or sawing these materials releases fibres. Exposure to these fibres may lead to dermatitis, eye irritation and airway disease such as bronchitis or asthma. Alternatively, polyurethane foam is often used. These contain isocyanates, which can cause (allergic) asthma, irritation of the respiratory track and mucous membranes of the eyes and gastrointestinal track, and contact dermatitis [5]. In many cases, one-pack systems that contain limited free isocyanate are used. However, two-pack systems are still used for insulation of floors, walls and roofs[7]. These are mixed on site and, consequently, exposure to isocyanates is considerably higher than when using one-pack products, because the concentrated isocyanate-hardener is added manually. Thus, isocyanate vapours become airborne, while control measures such as local exhaust ventilation are usually lacking at construction sites [5, 14]. The National Institute for Occupational Safety and Health (NIOSH) found that construction workers who sprayed polyurethane foam insulation on a roof were exposed to isocyanate concentrations exceeding the occupational exposure limits [5].

Retrofitting older buildings in order to install energy efficient heating or hot water systems mainly involves known hazards related to conventional jobs such as pipe fitters, sheet metal workers, HVAC (heating, ventilation, air conditioning) technicians, electricians etc. [8]. These include high physical workload due to the manual handling of heavy equipment, exposure to silica dust and asbestos, and noise and vibration due to drilling [13]. However, the activities may be carried out more frequently in retrofitting, and/or retrofitting workers may specialise in these tasks, thus increasing exposure to these hazards.

2.2 New OSH risks associated with new green technologies, products or design

2.2.1 New and green building materials

General trends in material use in green building include the use of renewable materials, recycled materials, water-based products and – though still limited – nanomaterials.

Renewable materials used in green building include bamboo, straw, sheep wool, flax and cork. Insulation is a common application of these materials. In addition, the use of wood – which was common in former times – is often reintroduced or increased. Exposure to wood dust may be regarded as an ‘old’ OSH risk; skin, eye and airway irritation as well as bronchitis, asthma and nasal cancer are among its recognised health effects. However, the relative risk may vary between wood types, and it has been noted that some hardwood types from sustainable sources, western red cedar in particular, may be relatively strong sensitisers [14]. Moreover, hardwood dust is considered a carcinogen, and a binding occupational exposure limit of 5 mg/m^3 has been set in the European Union (EU) Carcinogens Directive [15].

Generally, materials from renewable organic sources might bring elevated risks of exposure to protein-based allergens, and micro-organisms such as bacteria, moulds and fungi or endotoxins. The use of sheep wool in insulating blankets does not result in exposure to dust, and the material has been cleaned and disinfected in order to remove micro-organisms. However, some people are allergic to sheep wool and exposure of the skin to it may provoke an allergic response.

[7] Two-pack systems: products that have to be mixed on site, immediately before use (usually, a ‘curing agent’, such as an isocyanate, has to be added, which starts the curing reaction). One-pack system: products that do not have to be mixed on site.

Shells are sometimes used for insulation of the room voids under buildings. They consist of 98% chalk [16]. The shells are 'sprayed' by means of a hose, which may mean a high physical load for workers, because of the heavy weight of the hose, which has to be dragged manually. This activity may generate exposure to noise and dust as well (see Figure 1). Chalk dust does not contain crystalline silica, which is relatively toxic and may cause silicosis or lung cancer [17]. However, chalk dust, like any other type of dust, may cause chronic obstructive pulmonary disease (COPD) [18].

Figure 1: Application of shells as insulation

Source: http://www.icdubo.nl.

One example of the use of **recycled materials** is recycled paper flakes for insulation. These may be applied in panels, but most often loose flakes are used. These are manually scattered or sprayed into room voids. Generally, the flakes are impregnated with 8% boric acid (sodium tetraborate), which serves as a fire retardant and an antimicrobial agent [14]. Boric acid has been classified as a reprotoxicant in the EU [19]. This means that this substance is toxic to the reproductive system. Therefore, inhalation of the paper dust generated should be prevented. Similarly, flax wool insulation, which is used in panels or blankets, may be impregnated with boric acid as well.

Fly ash, recycled asphalt from roads or debris from buildings is often used as filler in concrete or asphalt. Fly ash contains heavy metals such as cadmium, mercury, nickel and chromium. In addition, fly ash and recycled asphalt may contain polycyclic aromatic hydrocarbons (PAHs), some of which are carcinogenic [5, 9, 20].

In the Netherlands, attempts have been made to obtain agreement between producers of construction materials and building contractors on a responsible application of recycled materials in construction products [20]. The potential health risks for construction workers resulting from the use of recycled materials were assessed by means of a 'quick scan tool'. This tool combined data on the health hazards of the contaminants present in the recycled materials (i.e. the hazard pictograms and hazard statements [8] assigned to these contaminants) with their estimated (average) content present in the recycled materials. Subsequently, this was combined with the estimated exposure of workers to dust from the recycled material during specific activities, which was regarded as the major route of exposure. One case involved the use of fly ash from coal energy plants in asphalt for road construction or in concrete. Although the main exposure situations were found during production of concrete or asphalt and mixtures when fly ash is added, i.e. off the construction site, when at the construction site, workers were exposed to the contaminants present in the dust generated by activities such as drilling, sawing or milling [20].

[8] Hazard pictograms and hazard statements (H statements) from the CLP (classification, labelling and packaging) Regulation (CE) 1272/2008 – replacing previous hazard symbols and risk phrases (R phrases) from Directive 67/548/EEC

Fly ash in concrete

Usually, concentrations of fly ash in concrete are around 5%. The calculations of a ‘worst-case exposure’ of 10 mg/m^3 of concrete dust during, for example, drilling of concrete, showed that, even in this case, exposures to heavy metals present in the concrete dust would be far below (< 3%) the occupational exposure limits [20]. However, as some of the metals present are genotoxic carcinogens – chromium-VI, nickel and beryllium – exposure should be minimised as much as possible.

Water-based products are often promoted as green alternatives for solvent-based paints, adhesives, waterproofing agents and concrete form oils[9]. The use of these products largely reduces exposure to volatile organic compounds. In the conventional, solvent-based products, mixtures of aliphatic – and sometimes aromatic – hydrocarbons are used, most of which may be neurotoxic as well as irritating to the airways and the skin [21, 22]. However, water-based products contain biocides to prevent the growth of micro-organisms. Generally, these biocides are not volatile and thus do not readily result in exposure through inhalation. However, some of these may give rise to allergic skin disease [3, 22, 23]. On the other hand, research in the Netherlands has not indicated an increase in skin disease after the introduction of a legal requirement to use water-based paints in place of solvent-based paints for interior painting work [22]. Research has shown that allergies to biocides frequently originate from exposure to soaps or cosmetics, and may be mistaken for allergies caused by exposure to water-based paints or adhesives [22].

In a green building there may be a trade-off between reducing long-term emissions in order to protect the future building occupants and reducing the short-term emissions that may harm construction workers [22]. ‘Green’ products such as ‘natural’ linseed oil-based paints give rise to exposure to volatile terpenes, which may be relatively strong irritants, or even sensitisers [22].

Nanomaterials, finally, are increasingly being used in construction. Some examples of ‘green claims’ about their use are the application of nano-enabled coatings that reduce the need for maintenance, and the use of nanoscale fillers in concrete. The latter provide ultra-high strength to the concrete, which enables the construction of thinner, lighter walls or bridges [24]. At one construction site, workers were exposed to nanoparticles during the preparation and mixing of such materials, although drilling finished concrete did not result in exposure to ‘free’ nanoparticles [25].

2.2.2 New and green technologies

The ‘green’ technologies in construction are mainly related to energy or water-supply equipment, waste reduction and more efficient material use, and emission reduction.

Separated water circuits (‘dual plumbing’), low-flow showerheads and low-flush toilets reduce clean water consumption, and do not seem to introduce new OSH risks. The same applies to rainwater collection systems that collect water run-off from the roof [4]. The installation of renewable energy supply systems such as solar panels and small wind turbines combines risks arising from working at height, manual handling, electrical risks and possibly other risks such as exposure to dust or to high temperatures. More information on OSH risks and solar and wind energy can be found in the dedicated e-facts and Hazard Identification checklists [3, 26].

Off-site production of building elements such as precast concrete walls leads to less ‘production’ and more ‘assembly’ work at construction sites. This may result in a more efficient use of resources, and more opportunities to prevent emissions to the environment. Similarly, the exposure to hazardous substances such as fresh concrete mortar and concrete release agents, as well as to noise and physical workload related to concrete casting (positioning moulds and casting equipment, handling vibration devices), may be reduced on site. However, assembling precast concrete walls may also involve a high physical workload. Additionally, it may require the use of hazardous sealants or adhesives, including sealants that contain isocyanates, or two-pack epoxy adhesives, which are strong sensitisers [27]. If optimally designed, prefabricated elements may reduce the need for operations such as drilling, thus reducing exposure to crystalline silica, noise and vibrations. For example, slots for ducts may be constructed at the factory instead of on site [28]. Off-site painting of

[9] Concrete form oils are used in concrete-casting.

doors, stairs and window frames – under more 'controlled' conditions than on site – is on the increase as well, and reduces exposure to volatile organic compounds at the construction site.

New **demolition technologies and waste separation** for reuse and recycling usually mean that recyclable waste materials such as plastics, wood, glass and metal are manually separated and accumulated in containers on site [7, 29]. In some cases, material assemblies must be dismantled piece by piece before separation. Construction workers at 'green' sites in the USA reported that they handled materials 'two to three more times' than on conventional construction sites [4]. This results in a higher physical workload as well as higher risks of strains, slips, falls, sprains, punctures and getting struck by objects [4, 5, 30].

A pilot study, on a green university construction project in the USA, showed that the construction materials recycling programme increased the risks to which workers were exposed. An example of an incident was a worker's foot being punctured by a nail while the worker was separating wooden pallets for recycling [11]. Although such incidents might occur at conventional construction sites as well, the waste separation on site seemed to increase the risk. Representatives of construction firms who were interviewed noted that the additional material handling on site 'could' be a cause of concern for worker safety [11]. Another negative aspect mentioned is that multiple recycling dumpsters create congestion because they hinder the smooth movement of trucks that deliver construction materials [4]. One might suppose that this can give rise to increased emissions of diesel motor exhaust at the construction site because vehicles with a running motor are present for a longer period. In addition, it has been noted that forklifts, manoeuvring in tight spaces, sometimes increase the risk of accidents in these circumstances [5]. On the other hand, workers at a US green construction site, where active separate waste collection and recycling were carried out, reported that the site was 'cleaner'. According to the workers, this also reduced the risks of trips, slips and falls [4].

The increased use of insulation materials in green building may lead to increased exposure to, for example, man-made mineral fibres in demolition activities [14]. These fibres act as strong irritants to the airways, the eyes and the skin. It may be assumed that waste separation on site also increases exposure to these substances, as well as exposure to silica dust and contaminated packaging with residues of, for example, paints and adhesives.

In order to facilitate material separation and recycling of building demolition waste, organisations that promote green building recommend avoiding the use of adhesives, sealants or, for example, fixing bitumen roofing by melting in order to avoid different types of materials being irreversibly bound together [16]. Instead, a careful design or the use of rubber bands may prevent the use of sealants on seals between walls. Similarly, gravel or tiles may be used to fix bitumen roofing, instead of melting or adhesives. However, this may result in a shift from chemical exposure (adhesives, bitumen smoke) to a high physical workload, caused by handling heavy tiles or gravel.

One example, illustrating a potential for synergy between environmental and OSH considerations, involved the use of permeable paving stones. While these were designed to allow water to penetrate through, thus eliminating the need for a site storm water system [4], one might expect that permeable paving stones have a lighter weight than conventional paving and thus might reduce physical workload.

2.2.3 New and green design

Green design elements that have been reported to cause OSH risks include skylights and atriums, which are meant to provide natural lighting [4, 5]. The construction of these involves an increased use of scaffolding. Scaffolding is one of the major risk factors for falls in the construction sector [5, 30, 31]. At a pilot site in the USA a large atrium was constructed above the centre of a high (four-storey) building. Furthermore, skylights are usually not designed to withstand heavy loads and do not have guardrails that may protect workers from falls. Finally, atriums may be designed with large glass panes that can be heavy and difficult to carry [5].

'Lighter construction' is another trend in green building, because it saves (natural) resources by reducing the quantity of them needed for production of the construction material itself. For example, thinner bricks, which have a reduced weight, are used for masonry work [16]. The use of these bricks may reduce the physical workload for bricklayers.

The use of double-glazing or other types of highly insulating glass is more common in green buildings. These are usually heavier than conventional glass. Conventional windows of 4 mm thickness weigh roughly 10 kg/m^2, whereas a double-glazed window of the same size has about twice that weight.

On the OSH aspects of green roofing, i.e. roofs that are partially covered with plants, no information has been found in the literature. However, high physical workload related to the manual transport of sand or soil might be an issue. Additionally, skin contact with plants may, in specific cases, give rise to irritative or allergic skin reactions and, in the case of maintenance, inhalation of moulds or endotoxins attached to dead leaves might occur. Finally, work at height – and related risks of falls – may increase, because maintenance is needed approximately two to three times a year [32].

2.3 Work organisation

Construction firms vary in many different ways, including safety culture and performance, and this is not related to specific building projects being ‘green’ or ‘non-green’. In a survey of 86 green and non-green construction projects it appeared that there was a statistically significant difference between the safety performance of the *contractors* who participated, and those who did not [11].

Clear differences in terms of subcontracting, work organisation and workforce between contractors carrying out green projects and those working on non-green projects are not obvious and have not been described in the literature.

It is becoming more and more common for construction work to be subcontracted. Most often this work is of a sporadic nature, which implies that workers are needed only temporarily. Specialised companies and their employees are hired to perform the work better, faster and usually more cheaply. So when employers hire contractors, these contractors in turn could hire subcontractors and a chain of companies emerges. The executed work often takes place mostly where the lead contractor is working. This has implications for the safety and health of the workers involved [33]. Problems regarding the safety and health performance of contractors may be aggravated by the lack of a skilled and experienced workforce. This is particularly relevant in the context of the increasing number of green building projects, which unskilled workers may see as job opportunities. Construction companies may also be attracted by such opportunities but, under time pressure to perform, may not take the time to train their workers on the specific risks associated with green construction techniques. In addition, many subcontractors are micro or small enterprises, which tend to have lower OSH expertise and OSH awareness and fewer resources available for OSH, and to be less frequently inspected [34]. This leads to a less secure working environment. Furthermore, in the case of migrant workers, this could lead to illegal employment, where workers have limited access to trade unions and other forms of collective representation and to organisations that can promote better health and safety and more adequate risk management systems [34]. This applies also to green building construction sites, even to a higher extent, as the contractors and sub-contractors have to operate with materials and technologies, or in situations, that differ from conventional construction activities. Therefore, it is essential to address thoroughly the traditional hazards and identify possible new hazards associated with green design elements while assessing the risks to workers’ safety and health [3], and either eliminate the hazards or minimise the risks.

3 Prevention

EU and Member States’ legislation require employers to carry out risk assessments and to establish prevention strategies according to the ‘hierarchy of controls’ [35]. Measures to control risks to workers’ safety and health should be taken as close to the source of the risk as possible. This applies equally to green building projects. In addition, the main stakeholders, contractors and subcontractors, including their workers, should be involved in order to ensure proper coordination of occupational safety and health at construction sites. Generally, ‘designing out’ the hazards at the design stage will be the most effective prevention strategy [10]. To that end, designers, architects and manufacturers of construction materials are crucial partners. Many of them may need information and support in order to enable them to select materials and techniques that reduce occupational hazards and risks, thus being beneficial to both the environment and to workers. Therefore, it has been suggested that a ‘hot list’ of design suggestions be constructed to help these architects embrace the concept of ‘prevention through design’ [36].

The Hazard Identification checklist https://osha.europa.eu/en/publications/e-facts/e-fact-71-hazard-identification-checklist-occupational-safety-and-health-issues-associated-with-green-building/view that accompanies this e-fact contains practical information with regard to prevention.

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Further reading

Sustainable construction materials library: www.rematerialise.org.

Prevention through Design on NIOSH website: http://www.designforconstructionsafety.org/.

From EU-OSHA:

- Report *Green jobs and occupational safety and health: Foresight of new and emerging risks associated with new technologies by 2020*, 2013. Available at: https://osha.europa.eu/en/publications/reports/summary-green-jobs-and-occupational-safety-and-health-foresight-on-new-and-emerging-risks-associated-with-new-technologies-by-2020
- Hazard identification checklist for OSH associated with green building, available at: https://osha.europa.eu/en/publications/e-facts/e-fact-71-hazard-identification-checklist-occupational-safety-and-health-issues-associated-with-green-building/view
- E-facts on OSH and small scale solar energy applications, available at: https://osha.europa.eu/en/publications/e-facts/e-fact-68-osh-and-small-scale-solar-energy-applications/view
- Hazard identification checklist and small scale solar energy applications, available at: https://osha.europa.eu/en/publications/e-facts/e-fact-69-hazard-identification-checklist-osh-risks-associated-with-small-scale-solar-energy-applications/view
- E-facts on OSH in the wind energy sector (in preparation).
- Hazard identification checklists for OSH in the wind energy sector (in preparation).
- State of the art review report on OSH in the wind energy sector (in preparation)