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Occupational health and safety in construction

Construction work is inherently dangerous, combining a constantly changing work environment with work at height, continuous movements of people, materials and vehicles, the use of power-driven machinery, plant and equipment and exposures to wide range of hazardous substances.

Occupational health and safety (OH&S) risks experienced by construction workers are many and varied and construction is often singled out by legislators and policy-makers as an industry deserving special treatment in terms of the prevention of work-related deaths, injuries or illnesses.

The types of incidents and mechanisms of injury impacting construction workers are similar the world over, whether these related to low frequency-high impact or high frequency-low impact injury outcomes. Falling from height, being struck by falling or mobile objects, being trapped or crushed by collapsing structures or coming into contact with electricity are the most common incident types associated with fatal or serious injury. While the occurrence of slips, trips and falls (on the same level) and musculoskeletal problems linked to manual handling are frequently cited in non-fatal injury reports.

Traditionally, a great deal of focus has been placed on the understanding and addressing the causes of 'immediate effect' safety incidents. Historically, occupational health risks have received less attention than safety risks. This is despite the fact that deaths arising from work-related illness are estimated to far outweigh injury-related deaths. For example, on average over 250 Australian workers die from an injury sustained at work each year, yet it is estimated that over 2,000 workers die from a work-related illness each year (Safe Work Australia, 2012). This is consistent with UK estimates that construction workers are at least 100 times more likely to die from a disease caused or made worse by their work as they are from a work-related injury (IOSH, 2015).

Key occupational health risks applicable to construction work include:

- asbestos,
- dusts including silica and lead,
- hazardous chemicals,
- sunlight, and ultraviolet radiation exposure,
- diesel engine exhaust emissions,
- loud noise,
- the use of vibrating tools,
- excessive manual handling of loads , and
- stress and fatigue (IOSH , 2015).

International studies show that rates of occupational illness are high among construction workers. For example, Stocks et al. (2011) analysed instances of medically reported work-related ill health among construction workers in the United Kingdom and found elevated rates of contact dermatitis, all types of skin neoplasma, non-malignant pleural mesothelioma, lung cancer, pneumoconiosis and musculoskeletal disorders.

Sherratt (2015) observes that legislation in the UK (and also in Australia) bundles occupational health and safety together, which she sees as being unhelpful because, unlike safety, which occurs at the site, at a fixed point in time, health occurs over extended periods and is not specific to a single

worksite. OH&S legislation requires the protection of workers from occupational health risk exposures. Yet, as Sherratt observes, employers sometimes confuse this responsibility with the implementation of health promotion programs targeting 'lifestyle' risk factors, such as alcohol consumption, smoking cessation, diet and physical activity. Although programs focused on improving workers' health-related behaviours may produce benefits, their implementation does not remove the legal duty of employers to reduce exposure to occupational health risk factors so far as is reasonably practicable.

This risk reduction should focus on providing the highest level of protection that it is reasonable to implement in a particular situation, and be guided by the hierarchy of control. The hierarchy of control is applied to OH&S risks and arranges control measures in descending order of effectiveness. The top three levels are preferred as they address aspects of the physical workplace, while the bottom two levels rely on workers' behaviour for their effectiveness and are generally considered to be less reliable. Figure 1 shows an example hierarchy of control for managing the risk of diesel exhaust emissions in the construction industry.

Figure 1: Example risk control hierarchy for diesel exhaust emissions (Lingard et al. 2018).

When applied to occupational health, a failure to apply the hierarchy of control properly in decision-making is likely to perpetuate the selection and implementation of behavioural controls for occupational health risks, such as worker training and a reliance on the use of personal protective equipment. These are often limited in their effectiveness, particularly in the construction context because:

- they protect workers engaged in a particular activity but may not protect those working in the surrounding environment, or
- they are inconsistently applied by workers who may be engaged to work at a site for a limited period of time (Sherratt, 2015).

However, barriers to the selection of more effective forms of control for occupational health risks in the construction context have been identified, including labour market forces and productivity pressures, and a normalisation of risk, pain, injury and illness among the industry's workforce (Stergiou-Kita et al., 2015).

Research also highlights the importance of considering OH&S before construction work commences, for the selection and implementation of more effective technological controls for OH&S risks (see case example 1 below).

Case example 1: Timing of decision-making and effective risk control selection and implementation

An international benchmarking study of design decision-making and its impact on construction workers' OH&S tested the proposition that early consideration of risk control measures in project decision-making would produce better outcomes, in terms of the selection of technological, rather than behavioural forms of control. The study:

- measured the effectiveness of risk controls in case study construction projects
- identified whether risk control measures were identified and developed before the commencement of construction, and
- examined whether risk control decisions made early in the project lifecycle, i.e. before the commencement of construction, were more likely to produce effective (upper level) controls for identified risks.

Data were collected from a total of 23 construction projects, 10 of which were in Australia/New Zealand and 13 were in the United States of America. The research design involved replication and cross validation across two diverse and different samples (i.e., the US and Australia/New Zealand project samples). The relationship between the timing of project decisions and the effectiveness of risk controls was evaluated in the Australian and the American data independently.

In-depth interviews were conducted with stakeholders involved in the planning, design and construction features of work particular to each project. Interviews explored the timing and sequence of key decisions and the quality of risk control solutions that were ultimately implemented during the construction stage of the project. The findings were based on 288 interviews (185 conducted in Australia and 103 conducted in the USA).

A statistically significant, positive relationship was found between the selection of risk control measures in the early stages of a construction project (before construction work commenced) and the quality of risk controls implemented in the construction stage of the project. Thus, when risks were identified and control decisions taken before the commencement of construction, it was more likely that risks would be controlled at source, through the implementation of technological control measures.

When decisions about risk control were left until the construction stage, it was more likely that measures implemented to control OH&S risks would be lower levels of control that rely for their effectiveness on workers' behaviour, for example administrative controls or personal protective equipment (Lingard et al. 2015).

Project-based work

OH&S impacts arising from the processes, equipment and materials of construction have been well documented elsewhere (see, for example, Lingard and Rowlinson, 2005). However, hazards can also arise as a result of the organisation and management of construction projects and, in some cases, the absence of effective management and integration of OH&S into project decision-making.

Unlike many other industrial sectors, construction is characterised by complicated and unstable supply relationships. Construction projects are commissioned by clients and delivered through temporary coalitions of organisations, working interdependently to achieve project outcomes. Project timelines are often tight and financial penalties are applied for late delivery. Contractor selection decisions made by construction clients are often based upon a number of criteria (including OH&S), but price is usually a heavily weighted factor. The construction industry's reliance on competitive tendering means that project delivery teams constantly change as different constellations of actors are formed and then disbanded. This instability limits opportunities for learning from experience (Briscoe and Dainty, 2005). Further, Gadde and Dubois (2010) observe that relationships tend to be contractual and 'arms-length' and the development of trust, a shared culture and a mutual orientation to issues, such as OH&S is hard to achieve within the duration of a single project.

Construction projects are organisationally fragmented, both vertically and horizontally (Fellows and Liu, 2012). Horizontal fragmentation describes a reliance on many actors (individuals, organisations, business units) to carry out different functions at the same stage of a construction project. For example the engagement of specialist subcontractors has been identified as a characteristic of construction projects that creates coordination challenges for OH&S. Vertical fragmentation describes a situation in which different stages of a construction project involve contributions from different functional actors. For example, the quality and nature of interaction between a commissioning client, members of the design team and contractors engaged to provide construction services can impact OH&S.

Vertical and horizontal fragmentation can make it difficult to develop cultural alignment and a common purpose with regard to OH&S in construction project organisations. Indeed, Lingard et al. (2015) report that constructors, design professionals (architects and engineers) and OH&S specialists varied significantly in their understanding of and willingness to accept OH&S risk. It is perhaps not surprising that the complex supply arrangements typical of construction project delivery are reported to have a detrimental impact on OH&S (Swuste et al. 2012). For example, Priemus and Ale (2011) describe how, the design and construction of a mixed use development of commercial, residential and recreational facilities in the Netherlands was divided into three parts, each requiring a separate building permit. Responsibility for delivery was split between two developers, two building agencies (without a senior structural engineer), three architects' firms (with no consistent overall and final responsibility), one main contractor and around 50 sub-contractors. Time pressures in the project were intense, the coherence of decision-making and effectiveness of communication were compromised and project monitoring control systems failed, resulting in a significant structural safety incident (Priemus and Ale, 2011).

Alignment and integration of OH&S into project decision-making is also influenced by clients' selection of a project delivery approach, which shapes the contractual relationships, roles and

responsibilities of the parties. In some cases design and construction services are bundled into a single contract, with one organisation engaged to deliver both of these services. In other situations design work is undertaken by a specialist consultant before a construction contractor is selected. Eriksson and Westerberg (2011) argue that choices made by clients at all stages in the buying process will affect the extent to which the project governance structure will operate on the basis of competition or collaboration. An emphasis on cooperation, rather than competition, in project procurement has been linked to improved OH&S (Lingard and Rowlinson, 2005; El Asmar et al., 2016). Traditional competitive approaches emphasise design specification by the client, competitive tendering, high emphasis on price in contractor selection and output-based pay. In contrast, cooperative procurement emphasises shared (i.e. client and contractor) responsibility for design, selection of a contractors through direct negotiation, and emphasis on 'soft' parameters (not just price) to inform contractor selection decisions and the use of performance incentives (Eriksson and Westerberg, 2011).

Calls for greater client involvement in project OH&S

In recent years there has been an increased focus on the role of construction clients in driving OH&S in the projects they procure. In her review of deaths in the UK construction industry, Rita Donaghy argued that "public procurement is important because of its size and its potential for insisting on driving up standards including health and safety" (Donaghy, 2009, p.12). The *Australian Work Health and Safety Strategy 2012–2022* also recognises the potential role of public sector clients in driving OH&S performance improvements. The Strategy specifically calls for commercial relationships to be used to improve OH&S, and for Australian governments to use their investment and purchasing power to improve OH&S (Safe Work Australia, 2012).

As the initiators of projects and purchasers of the construction industry's product, clients are in an influential position to drive the cultural change needed to improve OH&S in the construction industry. Clients make key decisions concerning project budgets, timelines, objectives and performance criteria. Clients also select the project delivery method and contracting strategy, and choose design and construction team members. All these decisions can potentially impact OH&S in a construction project (Gibb et al. 2014). Further, when clients have considerable construction volume, they are in a stronger position to initiate major improvements in the construction supply chain than when they engage in single one-off projects (Vrijhoef & Koskela, 2000).

In the USA, Huang and Hinze empirically evaluated the impact of a range of client-led OH&S initiatives on construction project safety performance. Their work revealed that high levels of OH&S performance were significantly linked to the involvement of the client in pre-project planning, financially supporting constructors' safety programs, and participating in project OH&S activities (Huang & Hinze 2006a, 2006b). Clients' OH&S leadership behaviour is important for developing strong and positive safety climates in construction projects (Zhang et al. 2018). Examples of construction industry clients taking a more proactive stance to improve OH&S in construction projects are becoming more prominent, particularly in delivering large engineering construction projects (Eban, 2016).

However, the mechanisms through which clients influence project OH&S are not well understood and few attempts have been made to evaluate client OH&S activities in construction projects. A notable exception is the analysis undertaken by Spangenberg et al. (2002) who conducted an analysis of the impact of a client-led OH&S program implemented during the construction of the Øresund rail link between Denmark and Sweden. They found that a 25 per cent reduction in the number of injuries resulting from safety incidents was produced through a multifaceted program which included a large-scale information campaign, a twice yearly monetary award, and specific

themed campaigns aimed at improving OH&S-related behaviour. However, Spangenberg et al. (2002) also note that the campaign's impact was limited because it focused too heavily on trying to change attitudes towards OH&S (through providing information) rather than changing OH&S practices and contractors were only involved in the project for relatively short periods of time, limiting their exposure to the campaign.

The important OH&S role to be played by government clients has also been recognised in Australia, where a Model Client framework was developed (on behalf of the Office of the Federal Safety Commissioner) to help government agencies drive safety in projects through procurement and project management practices. The framework recommended that public sector construction clients undertake some key management actions and entrench these actions into their safety culture (Lingard et al., 2009, Votano and Sunindijo, 2014).

In recent years, public sector clients in the Australian construction industry have sought to commercially incentivise OH&S performance by:

- establishing OH&S as a project 'key result area,'
- establishing minimum levels of performance for OH&S,
- using lead and lag metrics to measure contractors' OH&S performance in project delivery, and
- establishing complex mechanisms to financially reward exceptional OH&S performance and/or penalise substandard OH&S performance.

These measures have been embedded in the commercial frameworks used to deliver a number of large infrastructure construction projects in Australia (Lingard et al. 2016).

Designing for OH&S

The recognition that decisions made during the design stage of construction projects can significantly impact construction workers' OH&S has led to the implementation of statutory OH&S responsibilities for persons who design buildings or structures in many industrialised countries, including Australia (Toole 2001; Behm 2005; Driscoll et al. 2008). However, design work in construction is a complex and iterative process, involving multiple parties, iterative decision-making and many exchanges of information (Lingard et al. 2012). Further, product complexity and high levels of specialisation has segregated design and construction processes that were historically directed from inception to completion by a 'Master Builder' (Yates and Battersby, 2003).

Commentators have identified significant implementation issues with safety in design in the construction industry. For example, Atkinson and Westall (2010) note that many widely-cited safety in design solutions, such as designing anchorage points for fall arrest devices in structures and providing guard-rails do not eliminate an inherently dangerous activity, i.e., working at height. They suggest that these measures produce a modest reduction in OH&S risk experienced by workers but fall short of eliminating hazards or optimising the reduction of risk. Researchers also comment that design professionals in the construction industry (architects and engineers) possess limited knowledge of construction processes (Yates and Battersby 2003). Even in the UK, where the Construction Design and Management Regulations have been in place for some 18 years, Brace et al. (2009) report that *"many designers still think that safety is 'nothing to do with me,' although there are a small cohort who want to engage and are having difficulty doing this because they do not fully understand what good practice looks like"* (p. 12).

The decoupling of design and construction work (implicated in traditional forms of procurement) has been identified as a barrier to the effective management of OH&S in design work. For example, a recent review of OH&S in the UK construction industry identifies separation and poor

communication between the design and construction functions as a causal factor in construction fatalities (Donaghy, 2009).

Atkinson and Westall (2010) also note that, even in more integrated projects utilising a design and construction delivery approach, the design of the product to be constructed is often outsourced to a specialist team of professional designers and positive OH&S outcomes are not guaranteed.

Lingard et al. (2014) examined the quality of OH&S risk control outcomes associated with decisions made during the design stage of construction projects and found evidence that more effective technological forms of risk control (e.g. elimination, substitution and engineering controls) were more likely to be implemented when people with construction process knowledge were involved in decision-making. When construction process knowledge was not available to decision-makers, there was a heavier reliance on behavioural forms of risk control (e.g. administrative measures and the use of personal protective equipment). This is attributed to the detailed knowledge of construction methods, materials and technologies which often resides with specialist subcontractors who may not be engaged when design decisions are made (see, for example, Franz et al., 2013). Given the importance of informing design decision-making with in-depth knowledge of construction processes, Lingard et al. (2018) evaluated the use of infographics to convey this information and report that design professionals who utilised the infographics were better able to understand less “visible” OH&S issues inherent in their designs.

Process as well as product design

The following case study also highlights the importance of considering design of construction processes and the opportunities afforded by technologies that can eliminate (or significantly reduce) hazards associated with conventional, manual construction work processes.

Case example 2: Process design for cropping concrete piles

Breaking down the tops of concrete piles to expose steel reinforcement bars has traditionally been carried out using hand-held pneumatic breakers (see Figure 2).

Figure 2: Using a hand-held pneumatic breaker to break down concrete pile heads

This method of pile-breaking involves several serious occupational health hazards , including exposure to hand arm vibration (HAV), dust, noise and the risk of work-related musculoskeletal disorder (Gibb et al. 2007).

A recent study in the Australian construction industry revealed that systems of work designed to reduce the exposure to these hazards while breaking down piles were not effective. In particular, an integrative passive risk control method was intended to be adopted. This method involved the installation of a layer of non-bonding material (foam) at the cut-off point during construction of the concrete piles. This material is installed before the concrete is poured.

If performed effectively, the incorporation of the non-bonding material would significantly reduce the duration of the mechanical breaking activity. One participant reported that failure to install the material correctly increased the duration of the task from one to approximately four to five hours per pile.

The study revealed that the pile construction work and pile breaking work were undertaken by two different subcontracted work crews. In many instances, the pile construction crew did not install the non-bonding material correctly, resulting in a substantial increase in health risk exposure for the workers who would subsequently break the pile heads.

This indicates how a lack of attention to the coordination of work crews and poor work process design produced an unnecessary and unanticipated exposure to occupational health risks. In this case the risk control measure that was specified was rendered ineffective due to poor on-site management processes.

However, if considered at the design stage of a project, technological risk controls are available. Several commercially available hydraulic pile-breaking technologies are available (EFFC, 2015). In addition, ‘integrated’ active systems have been developed. These systems incorporate an active pile breaking system within the pile. This system is activated when the concrete is cured. An example of an integrated active pile-breaking method is the ‘Recepieux’ system, which: uses a system of breakers installed at the desired cut off position before pouring concrete (Figure 3A); introduces an expanding agent into the pile (at least 72 hours after pouring) through carefully positioned ducts which deliver the chemicals to the breakers (Figure 3B), enabling the pile top to be cut off within the ground, the breakers working like a jack (Figure 3C), and finally enabling the pile top to be mechanically lifted off without the need for jackhammering (Figure 3D).

Figure 3: The Recepieux pile breaking method (images reproduced with permission)

The adoption of ‘integrated’ active systems of pile breaking require intervention at the early design and planning stages of construction work (Gibb et al. 2007). A failure to adequately consider the health risks associated with mechanical pile-breaking using a pneumatic breaker at the design stage is likely to be a barrier to the adoption of these methods. Furthermore, a failure to fully appreciate the potential production efficiency gains associated with these methods is also likely to act as a barrier to their specification.

Managing subcontractors’ OH&S

Another feature of construction work that has the potential to impact OH&S is the heavy reliance on subcontracted labour. Subcontracting involves “the subletting of the execution of a section(s) of a project to a contractor(s) who in most cases is a specialist in that section(s) of work” (Manu et al. 2013, p.1018). Most site-based construction work is performed by subcontractors (Dubois and Gadde, 2000; Hartemann and Caerteling, 2010).

Subcontracting is can create challenges for the management of OH&S (Arditi and Chotibhongs, 2005). For example, in Australia, Loosemore and Andonakis (2007) argue that subcontractors “lack the resources, culture and skills” to manage OH&S risks effectively (p.580). In a study of the residential building sector of the construction industry, Wadick (2010) found that the dangers of subcontracting were made worse by poor communication between different trade-based subcontractors and ineffective consultation between management and workers in relation to OH&S. Further, subcontractors often work on a ‘payment-by-results’ basis which, when combined with competitive tendering processes and the emphasis on price in selecting subcontractors, can encourage subcontractors to ‘cut corners’ with regard to OH&S compliance (Mayhew et al. 1997).

McDermott and Hayes (2018) examined the role of civil construction contractors engaged in an infrastructure construction project in which work was performed in close proximity to buried infrastructure (i.e., high pressure gas lines). The use of multiple levels of subcontracting, selection of subcontractors based on price and payment by square meterage of work completed led subcontracted workers to routinely break OH&-related rules. Detailed procedures to identify the location of buried infrastructure (e.g., using dial-before-you-dig and non-destructive pot-holing methods) were in place. However, these could not be followed if subcontractors were to meet tight production targets and remain profitable when working on this project (McDermott and Hayes, 2018).

While many studies have identified subcontracting practices as having the potential to negatively impact OH&S, relatively few studies have examined the ways that principal contractors manage the OH&S of subcontractors. Manu et al. (2013) investigated the way that UK-based principal contractors manage subcontractor OH&S. Some of the subcontractor management practices used by the UK-based principal contractors were driven by regulatory requirements, including: undertaking competence assessment for subcontractors; ensuring the preparation of risk assessments by subcontractors; conducting safety training and induction for subcontractor workers and consultation with the subcontractor workers/representatives on site safety matters. However, Manu et al. (2013) also found other measures are used to reduce the safety risks inherent in subcontracting, including:

- (i) restricting layers/tiers of subcontracting,
- (ii) engaging a regular chain of subcontractors,
- (iii) introducing a reward system for subcontractors, and
- (iv) the establishment of specific site-supervisory arrangements.

The critical role of supervisors

Site-based supervisors plan, organise and facilitate daily work activities in construction projects and have a strong influence on the way work is performed, including in relation to workplace safety (Hardison et al. 2014). Supervisors operate primarily at the principal contractor-subcontractor interface and their role is critical in shaping work practices and safety. For example, in a study of the London Olympic construction program, Finneran et al. (2012) identified supervisors' capabilities and competencies as a critical factor driving project safety performance. In Denmark, Jeschke et al. (2017) found that training construction supervisors in communication behaviours changed the way they interacted with workers and produced higher levels of safety-related cooperation and performance among subcontractor workers.

The influence that supervisors have on site-based safety practices is also believed to be significantly greater than that of senior managers due mainly to the frequency of supervisors' interactions with workers (Therkelsen and Fiebich, 2004). While workers rarely interact with senior managers, they receive daily instructions and performance feedback from their supervisors (Zohar, 2000). Fugas et al. (2011) also describe how supervisor-worker interactions produce social norms that determine the safety-related behaviours that are 'expected' of workgroup members.

Although subcontractors are engaged to perform physical construction work, in most cases the principal contractor provides a foreman to oversee subcontractors' operations at a worksite (Sherratt, 2016). This foreman supervisory role is additional to the role of the supervisors who are directly employed by individual subcontractors to manage the work of their own workgroups. Previous research suggests the interaction between these two levels of supervision has the potential to shape safety practices in the workplace. For example, in a study conducted in the Australian construction industry, Lingard et al. (2010) report the safety climate of a subcontracted workgroup was most strongly influenced by the emphasis placed on safety by the subcontractor supervisor. However, subcontractor supervisors' safety-related practices were also significantly shaped by the extent to which they perceive the principal contractor's foreman to be concerned about safety (Lingard et al. 2010). The engagement of a foreman whose role is to oversee and coordinate the work of subcontractors has also been identified as a strategy adopted by principal contractors to reduce the negative impact of subcontracting on safety performance in the UK construction industry (Manu et al. 2013).

Case example: Managing OH&S as the principal contractor-subcontractor interface (Lingard et al. 2017).

Researchers spent over 100 hours observing interactions between general foremen, subcontractor supervisors, workers and OH&S professionals at four large commercial construction sites in Melbourne, Australia. Safety climate surveys among these workgroups and social network data was collected to analyse the communication patterns between supervisors and workers. Survey data was collected from 39 workgroups across four worksites between May 2017 and October 2017. A total of 154 workers and 39 supervisors participated in the data collection. The density of communication within subcontracted workgroups was significantly and positively associated with the group's safety climate. Density of communication captures the extent and frequency of WHS-related communication that occurs between the supervisor and all other members of each workgroup (i.e, worker-to-supervisor and supervisor-to-worker communication), as well as the frequency of WHS-related communication that occurs between the workers who make up each workgroup and all other worker members of the group (i.e., coworker-to-coworker communication). The bivariate correlation results, as well as the regression results (models 1 and 2), reveal that the valued density of the workgroup communication networks is positively linked to the workgroup safety climate. Thus, the greater the extent and frequency of OH&S-related communication between all members of a workgroup social network (including the supervisor), the more positive the safety climate will be.

Site-based observation of interactions also revealed that general foremen and subcontracted supervisors play a critical role in shaping OH&S behaviour within work groups and that the development of respectful and working relationships between foremen and subcontractor supervisors is critical to ensuring that OH&S procedures are correctly followed. In particular higher levels of subcontractor cooperation, compliance and participation in relation to OH&S are achieved when foremen:

- are respectful of subcontractors' technical and often highly specialised knowledge,
- are willing to listen and engage in active problem-solving in relation to OH&S with subcontractor supervisors, and
- effectively communicate the reasons behind the principal contractor's OH&S policies and requirements.

Engaging the workforce

The management of OH&S is based on underlying theories about people, organisations and behaviour (Nielsen, 2000). In many instances, workers are seen as having limited competence and a high propensity for error. If this is assume, then it follows that workers' behaviours need to be constrained through the establishment of detailed rules and formal procedures developed by technical specialists, professionals and managers (Hale et al., 2003). However, this paternalistic approach is increasingly challenged as it devalues workers' knowledge and the important insights gained from situated work practices. A gap between work as imagined (and documented in formal procedures) and the practical reality of the workplace can undermine the usefulness and acceptance of safety rules by those expected to follow them (Knudson, 2009; Lofquist et al. 2017).

For example, Vidal-Gomel (2017) describes how French concrete delivery workers rely on experience and judgement in adapting rules to suit the needs of the different construction site environments they visit, balancing delivery demands and situational constraints against rule compliance.

Construction workers offer a valuable source of OH&S knowledge that, if accessed and utilised can be used to improve processes and performance. However, in a study of the UK construction industry, Sherratt et al. (2013) reveals that, despite statements of collective responsibility for OH&S, the way in which H&S is spoken and written about on construction sites reflects an emphasis on 'top down' enforcement rather than engagement with the workforce. In Australia, Ayers et al. (2013) similarly describe how, despite a statutory requirement to consult workers about OH&S matters, most construction organisations do not involve workers in making strategic decisions about the way that health and safety are managed in the workplace. For example, it is rare for workers to be asked to participate in the design of systems of work or the selection of equipment.

This is a missed opportunity because workers possess a wealth of knowledge about OH&S hazards associated with the work tasks they perform and about ways to work safely. Much of this knowledge is tacit, i.e., it is difficult to transfer to another person by means of writing it down or verbalising it (Polanyi 1958). This type of knowledge can be described as "know how," rather than "know what." In many cases the people who possess tacit knowledge are not aware of the knowledge and do not know how valuable it could be to others. Construction workers may not appreciate the extent and value of their knowledge and are unlikely to possess the skills to easily communicate this knowledge to others.

Recent developments in OH&S have recognised the benefits associated with engaging workers in OH&S improvement processes. Integral to a worker engagement approach is the understanding that providing workers with input into decisions that affect them will produce better OH&S outcomes. For example, participatory (worker-led) training approaches have produced demonstrably better results in terms of knowledge acquisition and injury prevention than traditional OH&S training approaches (Burke et al. 2006).

Case example: Using participatory video to improve work processes

Participatory video (PV) is a "group-based activity that develops participants' abilities by involving them in using video equipment creatively to record themselves and the world around them and to produce their own videos" (Shaw and Robertson, 1997, p1). It is used across a range of contexts and has been particularly successful in projects that seek to support otherwise disempowered groups in generating new forms of understanding and of representing themselves. It is also seen as an interventional method because it can produce change (Mitchell et al 2012: 1-2).

A team of construction workers whose work involved installing insulating materials in the residential construction sector were engaged in a PV intervention.

During the process of making videos about their work, the insulation installation workers shared their frustrations concerning the impracticality of following the company standard operating procedure (SOP) for accessing ceiling spaces to install insulation. Many ceiling manholes that the workers need to enter are at a height of between 2.4 and 2.7 metres from the floor. The SOP required workers to *place a straight ladder at an angle of 75 degrees*, extending 900mm beyond the "step off" point. In the video, the workers showed how this is practically impossible to achieve due to conduits, cables, beams and other obstructions. The small size of the manholes did not allow adequate entry for the ladder, the worker and the pack of insulation to be installed. Having viewed the footage, the company OH&S manager observed how information contained in the SOP may be "theoretically correct" but the video materials highlighted the gap between documented work methods and situated work practices. The manager halted the filming and engaged workers in a project to find an industrial-rated solution for accessing ceiling manholes safely at the required height.

While making a similar film about the use of mobile tower scaffolds, the workers identified a point in the scaffold erection process at which workers were working adjacent to an unprotected edge. The workers redesigned the erection sequence for the scaffold, using a system of temporary platforms and horizontal members, to eliminate the hazard. The new erection sequence was video-recorded and has become the standard procedure for erecting scaffolds of this type within the company.

The insulation installation workers were interviewed about their experience of the PV intervention. They described the benefits associated with visual methods to understand, review, critique and revise work processes. Importantly, the PV process prompted the identification of OH&S issues inherent in the company's work processes as workers and managers were able to identify hazards and engage in creative problem-solving through the production and review of the video materials and identify ways to eliminate these hazards through the production and review of the video materials. The insulation installation workers also spoke positively about having a genuine input, through the PV process, into the redesign and improvement of the company's work procedures (Lingard et al. 2015).

Figure 4: Scaffold erection sequence before (A) and after (B) the modification

Conclusions

The construction industry is a hazardous industry in which to work. Many hazards relate to the physical work processes, equipment and materials used in construction work. However, there is an increasing focus on hazards arising from the way that construction projects are designed and delivered, and construction work is organised and managed. Client organisations are increasingly recognising a need to become more active and to use their purchasing power to shape improvements in OH&S performance. The consideration of construction OH&S in the pre-construction and design stages of projects can also improve the quality of risk controls implemented during the construction stage. At the local worksite, effective frontline supervision is critically important to ensuring that the physical work undertaken by subcontractors is well managed and OH&S requirements are met. Participatory forms of management are also helpful to identify work process improvements, drawing on workers' practical knowledge and worksite experience.

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