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THE INFLUENCE OF THE DESIGNER ON THE RISK OF FALLING FROM HEIGHTS AND OF EXPOSURE TO EXCESSIVE WORKLOADS ON TWO CONSTRUCTION SITES

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ABSTRACT

Workers on construction sites are exposed to an excessive risk of being injured at work.

This study identifies occupational hazards on two construction sites – hazards that were related to the design of the building – and undertakes an analysis of the basis upon which related design decisions were made.

Risks of falling from heights were related to the shape of the building. Risks related to an excessive workload were related to the weight of building products and possibilities to use equipment to avoid manual transports.

The hazards were discussed at focus group meetings. During these meetings, the participants showed an increased understanding of safety issues in the project, each other's views and difficulties, and their own ability to facilitate acceptable risk levels for others.

Some hazards were not foreseen during the design and planning phase. According to the architects, their knowledge about construction methods was not sufficient to predict hazards related to the shape of the building.

Other hazards were foreseen, though considered to be primarily the contractor's responsibility.

Consultants in the design and planning phase, on behalf of the client, were focused on quality, time schedule and economy, more than on occupational safety.

There were building products on the market which were designed to fulfil functional regulatory requirements and requests from consumers, but not sufficient enough to ensure that they could be handled without exposure to an excessive workload.

The demands and routines in the project did not ensure that project-specific hazard information was given to the contractor.

Keywords: design, construction, safety, management, hazard.

1. INTRODUCTION

The rate of serious work-related injuries compensated in the building and civil engineering industry is more than twice the average. The rate of approved work-related diseases is five times the average (Larsson et al., 2011). The most frequent types of occupational accidents on building and civil engineering sites are losing control or a person falling, either from a height or on the same level. Two-thirds of the reported occupational diseases are to the musculoskeletal system, resulting from excessive workload (AFA Insurance, 2011; Byggindustrins Centrala Arbetsmiljöråd, 2010; Swedish Work Environment Authority, 2011). Furthermore, accident analyses show that the design of the building influences the construction safety (Behm, 2005; Gambatese et al., 2008; Haslam et al., 2005).

The separation of design and construction is a barrier to the implementation of construction safety in the industry (Behm, 2005).

Architects, engineers and others who take part in the design and planning phase of a building or construction project shall, according to Swedish law, prevent injuries on construction sites (AFS 1998:01; AFS 1999:03; The Swedish Work Environment Act, 2011).

Construction safety is, however, not of high priority in the design and planning phase of building projects (Baxendale and Jones, 2000; Gambatese et al., 2005; Haslam et al., 2005; Smallwood, 2004).

Designers have an insufficient knowledge in construction worker safety (Gambatese and Hinze, 1999; Smallwood, 2002; Weinstein et al., 2005). Knowledge and experience are key aspects of risk control (Baxendale and Jones, 2000; Hollnagel and Woods, 2005). Designers argue that their influence on on-site safety is limited, because they lack the skills and training to address construction worker safety. Designers have even contended that they do not know how to change their designs to improve or ensure safety (Behm, 2005; Gambatese and Hinze, 1999).

The aim of this study was to develop an increased understanding of the origin of working conditions that managers and workers on site considered hazardous and possible to prevent during the design and planning phase.

The research questions were:

2. Were there any specific hazards on the construction site which could have been possible to eliminate or reduce during the design and planning phase of the project?
3. Was there an awareness of the hazardous consequences of the designs amongst the design and planning team?
4. Which decisions during the design and planning phase had an influence on the actual hazards, and what were the reasons for those decisions being made?
5. Was it possible to have designed in another, safer way?

2. METHOD

Two medium-sized building projects were included in the case study. Both projects had contractors who were charged with the responsibility of designing, planning and constructing apartment buildings of just over 100 apartments. Production started in 2008, and the study was made during 2009, when one of the projects was in the phase of erecting the framework, and the other was in the finishing stage. The projects were of a size and character that made it possible to contact a wide range of those involved.

In the first research phase, workers and managers on the construction sites were asked to point out hazards - that is, unsafe conditions with potential occupational risks - that might have been possible to prevent during the design and planning phase.

The selection of informants in the initial phase was strategic, and was undertaken in order to secure information from people in different roles, working with different tasks. The on-site managers assisted the interviewer in getting in contact with suitable key informants. One of the projects, in the finishing stage, involved a larger number of subcontractors. People working for the subcontractors were randomly selected – the interviewer walked through the building and asked those who were working that day if they were available to participate in an interview. This continued until people working for almost all the subcontractors had been interviewed. In one of the building projects, 12 people (6 managers and 6 workers), out of a total number of 45 during the period of the study, were interviewed; in the other, 16 people (4 managers and 12 workers) out of 30 were interviewed. In both projects, those interviewed included the on-site manager, the safety representative, foremen and workers employed by the design and construction contractor, as well as subcontractors. All relevant categories of workers on both sites were therefore represented in the interviews, with the exception of ventilation fitters in the finishing stage and sheet-metal workers. The interviews began by asking the informant to broadly identify the kind of work operations in the on-going project that implied a risk of occupational injury or disease (either acutely or after a period of exposure). The informant was then asked to reflect on whether the hazards could have been avoided or handled in a safer way if the planners and designers had made other decisions or acted differently. The interviews, which lasted for between 10 and 40 minutes, were made by the first author of this article and documented through notes. The hazards were documented in photographs. The interviews with all the managers, and seven of the interviews with workers, took place indoors at the site office, with access to drawings and other documents related to unsafe conditions. The majority of the interviews with the workers (11) took place inside the building under execution at the site of the work. A list of hazards was compiled, in a document that included descriptions and photographs, and detailed the types of injuries each hazard might cause. To ensure that the descriptions were correct, they were presented to the on-site managers and the safety representative before the next step was taken.

The second research phase took place at the respective headquarters of the two building companies. The main author of this article invited people who had taken part in the project's design and planning phase to attend focus group meetings. Personnel internal to the project (on-site managers, clients, project manager, lead designer and consultants), as well as external supervisors to the project (safety managers, the principal safety representative, the manager of the technical department, the manager of the purchasing department, the project developer and the quality and environmental coordinator), were invited. Two focus group meetings were held in each project, with 23 participants in total (12 in one project and 11 in the other). Separate meetings with two persons, who could not attend any of the meetings, were held afterwards.

The hazards were presented at the meetings. The participants, who had different roles in the projects, were asked with respect to each hazard:

- Why the design was chosen
- Whether they had been aware of the occupational consequences of the design
- How the risk of being injured on the construction site could have been reduced

The meetings were documented in meeting notes, which were put in order afterwards and then sent to the participants for corrections. The corrected notes were used to form a new document with information about each hazard, detailing: whether there was an awareness of the hazard during the design and planning phase, decisions related to the hazard, reasons for taking those decisions and the participants' opinions about possible preventative measures that could have been taken during the different stages of the project. Additional interviews were made in order to check data and to gather further information, which was incorporated into the document.

The content was further analysed in the following manner. In the first round, hazards which the participants agreed could be left to be handled by the contractor were excluded. Then the hazards which had developed due to insufficient cooperation were excluded. The reason for these exclusions was that this study is not about leadership. The remaining hazards were all related to the design of the buildings. All but two implied a risk of either falls from heights or an excessive workload, or even both. These two categories of hazards were considered to be the most interesting. On a national basis these risks are high, and in the two projects they were frequently reported. They also represent two principally different kinds of risks. Falls from height represent trauma risks. An excessive workload can cause either acute injuries or injuries that become apparent after a longer period of exposure.

These two groups of hazards, as well as the reasons for the design solutions, will be presented in separate tables in order to find similarities and differences.

3. RESULTS

The total number of hazards observed in the two building projects was 30. One third implied a risk of falls from height and/or injury due to an excessive workload.

The latter group included hazards which involved a risk of either falling from a high level (Table 1) or getting injured due to an excessive workload (Table 2). After a time of discussion and reflection at focus group meetings, the on-site managers, as well as the designers and planners, agreed that for all these hazards, the risk of being injured could have been reduced both by measures in the design and planning phase, and measures in the execution phase.

Table 1: *Hazards which implied a risk of falls from heights*

	Reasons for the architects' and engineers' design solutions/influencing actors	**Construction consequences**	**Occupational consequences**
1. Stairwell 	Aesthetic reasons. Town planning department (design program): The external walls of the stairwell shall be glazed.	The glazed wall elements were mounted later than normal external wall units. The façade remained open until the framework was erected.	Work at a height, standing on a ladder above the guardrail, without any fall protection.
2. Bay roof 	Aesthetic reasons. Town planning department: There shall be variation in the façades.	No possibility to attach guardrails on the separate bay roofs.	Work at a height without any fall protection.
3. Garage with high ceiling 	Functional reasons. Town planning department (detailed development plan): It must be possible for a garbage truck to pass through the garage to collect waste from a nearby building.	High ceiling.	Work on a high ladder, when working on walls in places where there was no room for a hydraulic lift platform.
4. Entrance niche 	Aesthetic reasons. Town planning department: There shall be variation in the facades.	The facades were designed with niches at the entrances.	Work on unstable scaffolds under the entrance roofs, where limited space made it difficult to build scaffolds.

Examples 1-4 in the table demonstrate various project-specific designs relating to the building's shape, framework and exterior. The architects explained that, in these cases, they were not aware of the occupational consequences of their designs. They explained that it requires considerable knowledge of production methods to foresee occupational consequences of this kind. They stated that such knowledge is found among the construction managers, and not among the architects.

In two of the examples presented in Table 1 (Examples 2 and 4), the design was changed in similar buildings that were built subsequently.

Table 2: *Hazards which implied a risk of overload*

	Reasons for the architects' and engineers' design solutions/influencing actors	**Construction consequences**	**Occupational consequences**
5. Large tiles 	Aesthetic reasons.	Heavy (4 kg) tiles.	Excessive workload when transporting and mounting tiles standing in a bent position.
6. Balcony doors with large windows 	Aesthetic reasons.	Balcony doors with large windows are heavier than balcony doors with a smaller glass section.	Excessive workload when transporting and mounting.

7. Apartment doors 	Functional reasons. Requirements related to fire protection, soundproofing and burglary protection.	Heavy (80-100 kg) apartment doors.	Excessive workload when transporting and mounting.
8. Prefabricated cassette 	Functional reasons. Client: Pipes for heating and tap water shall pass through prefabricated cassettes which make it possible to measure the water consumption.	Heavy and clumsy cassettes.	Excessive workload when transporting and mounting.
9. Garage with high ceiling (same as 3) 	See Table 1.	Long (4.5 m) and heavy (24 kg) shores.	Excessive workload when the shores were handled.
10. Ground in the garage 	Economic reasons. Asphalt is cheaper than concrete.	The ground in the garage where the workers had their stores was graveled. It was not asphalted until late in the execution phase.	Excessive workload when material was manually transported. The gravel ground made it difficult to use trolleys.
11. Ditch 	Functional reasons and the character of the site. / Town planning department (detailed development plan): There shall be a specified number of parking places under the ground. Great difference in ground level at the site.	The road in front of the building, on top of the garage, was a bridge construction. The ditch in front of the building was not filled until late in the project.	The unfilled ditch, with a great number of different ground levels, reduced the possibilities to use trolleys.

The architects and others involved in the design part of the project were well aware of the connection between the weight of products and the work environment, though they had not considered the possibility of choosing lighter products. They expected the construction managers and construction workers to be responsible for the safe handling of heavy products without any information from the designers about the product's weight or suggestions for safe handling.

In Examples 5-7, the problem lay in the heavy building products available on the market. Such products were specified without any further reflection about their weight, and no information on the occupational consequences was communicated to the construction managers.

Examples 8 and 9 constitute project-specific overload problems. The cassette in Example 8 was developed in the design and planning phase of the project. Occupational consequences of the design were not a high priority in the innovation process. This subgroup (Examples 8 and 9) did not communicate any safety information to the construction managers.

Example 10 is somewhat different. In this case, the problem lay in insufficient conditions for the transport of heavy products. The architects and engineers were not aware of the occupational consequences.

In Example 11, the engineer had planned for another production order in which the ditch would have been filled at an earlier stage. However, information about safety measures and the production order was not transmitted to the construction managers.

In two cases, Examples 8 and 10, changes were made in similar buildings which were built subsequently. These changes were made when those who took part in the design and planning phase, thanks to feedback from the construction managers, became aware of the problems.

The architects, engineers and others who participated in the design and planning phase said that they were mainly focused on quality, time and costs. While the work environment during the user phase was considered, the work environment on the building site was considered to be mainly the contractor's responsibility.

In the design and planning phase of the projects, no meetings had been held whereby actors in different stages of the project could have discussed designs for safety.

There was no project-specific information regarding occupational risks communicated by those involved in the design and planning phase to the construction managers. The risk information in the occupational safety and health plans was general.

4. DISCUSSION

The architects in the study considered that they did not have enough knowledge in construction methods to be able to identify the hazards which were related to the shape, framework and the exterior of the building. When the different phases of a building project are separated from each other (various actors and separated in time), insufficient execution knowledge and experience in the design team may lead to late awareness of hazards and limited possibilities to reduce them. The results in this study indicate that construction knowledge and experience is important in order to identify occupational consequences of designs related to the shape, framework and exterior of the building, especially when the design deviates from the regular construction.

The people who took part in the design and planning phase of the two projects first argued that the construction managers and workers were solely responsible to take measures to avoid the hazards in most examples. Such measures could be "to use safety belts" (Examples 1 and 2) or "to use lifting equipment" (Examples 5-8).

During the focus group meetings, the participants showed an increased understanding of safety issues in the process, each other's views and difficulties and their own possibilities to facilitate for others to achieve an acceptable risk level. Safety discussions, like those had during the focus group meetings, where people with different roles in the building project identify hazards and discuss alternative designs and safety measures, could be a useful part of safety management in the projects and generate competence for future projects.

Project-specific information about expected occupational risks was not given from the designers to the contractor in any of the projects. As a consequence, the construction managers' foresight was reduced. Decreased foresight implies decreased possibilities to plan for safe work. Construction workers often refer to a lack of time as the reason for not taking necessary safety measures.

The designers in the two projects focused mainly on quality, end-user safety, costs and schedule, not on the work environment on site. This confirms results from earlier studies (Gambatese et al., 2005; Haslam et al., 2005; Smallwood, 2004).

A limitation to the study lies in the consequences of relying upon the on-site workers and managers to define "hazards". The workers' and managers' concept of what a hazard is might differ from the expert concept, which is based on statistical injury data. The strength of using the present method is that "hazard" is defined by those who are exposed to the hazards and have to manage them.

Further studies are needed in order to obtain a broader understanding of architects' and engineers' awareness and handling of different kinds of hazards, across different kinds of projects.

5. CONCLUSION

The results show several links between the design of the building and occupational hazards on site which imply a risk of injury due to falls from a height or exposure to an excessive workload. Risks of falling from heights were related to the shape of the building. Risks related to an excessive workload were related to the weight of building products and possibilities to use equipment to avoid manual transports.

Some occupational hazards were not foreseen. According to the architects, their knowledge about construction was not sufficient enough to predict hazards related to the shape of the building. Other hazards were foreseen, though considered to be primarily the contractor's responsibility.

Consultants in the design and planning phase, on behalf of the client, were focused on quality, time schedule and economy, more than on occupational safety.

There were building products on the market which were designed to fulfil functional regulatory requirements and requests from consumers but not to ensure possibilities to be handled without an exposure of an excessive workload. The demands and routines in the project did not ensure that project-specific hazard information was given to the contractor.

The participants felt that their attendance at focus group meetings increased their understanding of safety issues in the project.

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