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RESIDENTIAL WALL PANEL DESIGNERS' KNOWLEDGE AND ATTITUDES TOWARD ERGONOMICS

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There is increasing use of panelized (prefabricated) wall systems in residential construction, requiring construction workers to handle larger and heavier components. Panel designers can make a substantial impact on ergonomic exposures of on site workers if ergonomics is considered in the design phase. A survey and a semi-structured interview were conducted to assess current knowledge and opinions of ergonomics among panel designers. Twelve panel designers from 11 different panel companies participated in the study. Results of the survey and the interview suggested that panel designers are rather resistant to the inclusion of ergonomics in their design, and they generally lack training in ergonomics. Designers considered themselves least responsible for construction worker safety and health, likely because they are disconnected from on site workers. Thus, it is essential that panel designers are supported with ergonomic assessment tools that can evaluate ergonomic exposures and provide alternative (improved) designs.

INTRODUCTION

The construction industry as a whole has high numbers of occupational injuries, with non-fatal injuries reported as the 4th highest and fatal injuries the highest in the private industry sector (BLS, 2003, 2004). The prevalence and severity of occupational injuries in residential building construction may be higher than the Bureau of Labor Statistics (BLS) reports: 1) BLS data may substantially undercount occupational injuries due to underreporting of minor injuries, company-paid cases, etc. (Glazner et al., 1998; Morse et al., 2005; Morse et al., 2001); and 2) BLS data provide little information specific to residential building construction (Dement & Lipscomb, 1999; Methner et al., 2000). Furthermore, a new trend in residential construction is the increasing use of industrialized-housing techniques that require construction workers to handle larger and heavier pieces on the construction site. This trend could lead to an increase in injuries unless careful ergonomic evaluation and planning is conducted.

The department of Housing and Urban Development (HUD) indicated that the residential construction industry is moving towards industrialized-housing techniques from conventional housing techniques (Michael et al., 2000). Industrialized-housing techniques differ from conventional housing techniques (i.e., lumber "stick-built" framing) in that they involve more factory-built components. A representative example is wall panels, which are prefabricated in a manufacturing facility and arrive at the construction site more completely assembled than traditional "stick-built" framing materials.

Panel designers make decisions on several panel design variables, such as size and stacking order, which means on site workers' tasks and demands are influenced by panel design choices. Therefore, panel designers can have a substantial impact on the ergonomic exposures of on site workers, which is parallel to the concept of designing for construction safety (Hecker & Gambatese, 2003; Hinze & Wiegand, 1992). A recent study (Behm, 2005) demonstrated that worker safety can be influenced by decisions made by design professionals in the design process.

Development of ergonomic assessment tools for panelization is critical for panel designers to have a positive impact on the ergonomic exposures of on site workers. Thus, the purpose of this study is to gain initial knowledge for development of ergonomic assessment tools for panelization, by assessing designers' knowledge, thoughts, opinions and experience on several aspects of panel design and ergonomics.

METHOD

A two-part study was conducted to gather general knowledge and opinions from panel designers in the

residential construction industry regarding: 1) panelization design, principles, and practices; 2) ergonomics; 3) perceptions of incorporating ergonomics into construction design; and 4) promotion of the inclusion of ergonomics in design. The methods involved a questionnaire followed by a semi-structured interview.

A 56-item questionnaire including simple "yes/no" questions, Likert-type ratings, and open-ended questions was distributed to designers using an online format through the Virginia Tech online survey tool (http://survey.vt.edu). Participants could complete the questionnaire in less than one hour.

A semi-structured interview script was developed to have: 1) questions that were too time-consuming for the questionnaire; 2) participant-specific clarifications developed based on individual responses to the questionnaire for further clarification; and 3) hypothetical scenarios allowing participants to "walk-through" their thought process with us. The underlying interview script contained 33 questions with additional questions added based on the participant's responses to the questionnaire. All interviews were conducted at participants' places of employment and lasted 40 - 70 minutes, following an informed consent procedure approved by the local IRB. All interviews were voice recorded.

In order to assure breadth and depth of ideas, 12 panel designers from 11 different companies completed the questionnaire (10 males and 2 females). Designers were first contacted by phone to see if they were willing to participate, and to verify that they were the correct person within their organization to complete the questionnaire. Seven of the 12 questionnaire respondents participated in the interview. All participants worked for companies that are panel suppliers to production home builders. They reported having 3 ~ 30 total years of experience in the construction industry. In particular, they have practiced panelized wall design for 1.5 to 30 years (four participants had less than 5 years of experience in panel design).

RESULTS

Questionnaire results, combined with the interview results, were organized into four categories (Panelization design, Ergonomics, Perception of incorporating ergonomics, Promotion of the inclusion of ergonomics in design). Results in each are presented below.

Panelization design, principles and practices

Panel designers indicated that decisions regarding panel design are most constrained by the floor plans for a house, followed closely by panel installation, location of openings (for windows and doors), panel size, and transportation. They ranked panel weight and crew size as having the lowest importance in panel design.

Three major concerns noted by designers in creating a panel design for a house are: 1) how to divide a wall into multiple panels; 2) how panels will be shipped (> 10-foot-wide cargo requires special permits in most areas); and 3) how panels are stacked on pallets. For a given floor plan, the locations of openings and the lengths or heights of walls are given to panel designers. Dimensional lumber is available in two foot length increments, ranging from 8 - 20 feet. Sheathing, which is a covering nailed directly to an exterior panel to distribute loads and strengthen the wall, is most commonly available as 4 by 8 feet, but the lengths can increase in increments of two feet.

The designers responded that efficiency of panel installation on site is most influenced by the panel size (height and length), followed by the stacking order (Figure 1). The designers typically plan the stacking order for panels on pallets separately for interior and exterior walls and further divided by floor. Panel designers indicated during the interviews that panel stacking order could impact on site productivity, which will be addressed further in the discussion. In addition, designers are required to consider waste and efficiency of their panel designs from a manufacturing production point of view. The ideal panel sizes (from a materials waste perspective) start at 8 feet and increase in increments of 4 feet; these panels do not require any parts to be cut.

Ergonomics

None of the respondents ranked their knowledge of ergonomics as "high"; and the mode response was "moderate". Most respondents (80%) were unaware of ergonomics in the context of construction. When asked to identify ergonomic principles during the interview, the panel designers were unable to provide specific examples. Some respondents made mention that 'workers should lift with the legs and not the back'. One of the respondents mentioned proper working heights, and when questioned more on this topic, he was quick to mention that the company had just raised tables in the panel plant to improve work heights.

Of the 12 respondents, only one had formal ergonomic training, but this was regarding the office environment. Interestingly, some of the panel designers were required to participate in safety training for the panel manufacturing plant, but no safety instruction was offered for the on site panel installation process.

In the questionnaire participants were asked, "For a person who spends years as a construction worker, what body parts will most likely give them problems?" The panel designers responded that the lower back is the most likely, followed by the knee and upper extremity. It was

found during the interview that the designers selected these body regions in part because people complain about these areas as they age, and in part because these body regions are addressed during the safety training for the plant.

Perception of incorporating Ergonomics into construction design

Half of the respondents replied that designers should consider ergonomics in the design phase, and the other respondents replied that ergonomics would not be their responsibility. Some respondents (42%) believed that ergonomic concerns are already reflected in their panel designs, in that they divide a panel in two small panels if they feel the panel is extremely long.

When asked to rank the level of responsibility for work-related injuries, the panel designers gave themselves the least amount of responsibility and gave the construction worker the highest amount of responsibility. Designers stated that their ranking was based on the fact that they have little influence upon workers because they are not in direct supervision of them.

When asked to indicate their level of resistance or acceptance to incorporating ergonomics in panel design, the panel designers replied that they would be rather resistant to incorporation since they believed it would make designing more difficult. Designers expected that the workers would be the most accepting because they have the most to gain.

Promotion of the inclusion of Ergonomics in design

The panel designers, in general, took a neutral stance (37%) or a slightly negative stance (27%) toward the feasibility of incorporating ergonomics in panel design, although they agreed on the necessity of ergonomics to reduce workers' risk of injury. The reasons for a slightly negative stance were that the panel designers mainly thought that ergonomics should be considered at job sites and/or ergonomics in panel design would increase their workload. The panel designers regarded "decreasing injuries" as the best reason to incorporate ergonomics when asked to rank reasons to incorporate ergonomics into design.

To the question of expected outcomes of incorporating ergonomics in their design, the panel designers replied that "less injuries to workers" would be the most expected outcome, and "more regulations to follow" and "more time consuming construction process at the site" would be the second most expected outcomes (tied), as shown in Figure 2. "Lower worker's compensation costs" was also considered by the panel designers as a major expected outcome.

Panel designers mentioned that one of the reasons for the success of their product is the speed of installation when compared to 'stick-built' construction. The increase in on site productivity due to the use of wall panels was something the panel designers felt needed to be preserved in order for the incorporation of ergonomics in design to be a success.

DISCUSSION

These results indicate that design concerns among panel designers are centered on manufacturing and transportation of panels. Further, panel designers generally lacked training in ergonomics and considered themselves disconnected from on site workers. Although the designers accepted the need for ergonomics in design (to reduce work-related injuries), they revealed some resistance to the inclusion of ergonomics in their design process. A contrast was found in that the designers generally regarded their knowledge of ergonomics as moderate, while reporting essentially no awareness of ergonomics in construction.

Panel designers had little understanding of ergonomics in construction, in that they were uncertain how their design choices could impact ergonomic exposures of on site workers. For instance, designers indicated that panel stacking order could affect on site productivity by reducing double-handling of panels. The reason that the designers gave is that the workers need fewer handlings of panels to find the correct panel to be erected if panels are properly stacked. Panel designers, however, failed to see how a reduction in double-handling of panels could be linked to the ergonomic exposure of workers. This is comparable to how designers (or architects) in construction responded regarding safety in their design (Gambatese et al., 1997; Hinze & Wiegand, 1992).

As shown in Figure 2, panel designers expected that the incorporation of ergonomics in panel design would lead to more regulations and a more time-consuming construction process on site. This could account for their resistance to incorporation of ergonomics in their design process, and a neutral or slightly negative stance toward the feasibility of ergonomics in their design. Panel designers appeared to consider the incorporation of ergonomics to be more feasible at the job site level rather than at the design level. They felt ergonomics in design would add more workload for the panel designers by adding more regulations. However, ergonomic assessment tools could effectively provide design alternatives that potentially minimize ergonomic exposures of on-site workers with little or no increase in panel designers' workload, assuming that ergonomic assessment tools can conform to panel designers' working conditions.

During the interviews, several panel designers mentioned that home builders are paying a premium to use wall panels instead of on-site stick framing. When asked why builders were willing to pay this premium, they gave four answers: 1) the installation of wall panels is significantly faster than traditional stick framing; 2) there are rarely any framing / structural code violations when wall panels are used; 3) the assembled wall panels are more straight and level than traditional framing; and 4) using wall panels reduces on-site theft. These advantages of panel walls may be strengthened by incorporating ergonomics in panel design. The installation process will become faster as assessment tools are used to reduce double-handling of panels and to increase the safety and productivity of construction workers.

In conclusion, panel designers have great potential for reducing ergonomic risks to construction workers through the design of wall panels. In the future, support should be provided to evaluate panelization designs for ergonomic impact on construction workers. By incorporating ergonomics into the early stages of residential housing design, the number of injuries and illnesses experienced by construction workers may be reduced. As noted by Weinstein (2005), design changes intended to improve material handling may be particularly challenging to address in early design stages, compared to design changes for safety. Therefore, a comprehensive study on the on-site panel installation process, in terms of the ergonomic exposures, is needed for success in the incorporation of ergonomics in panel design.

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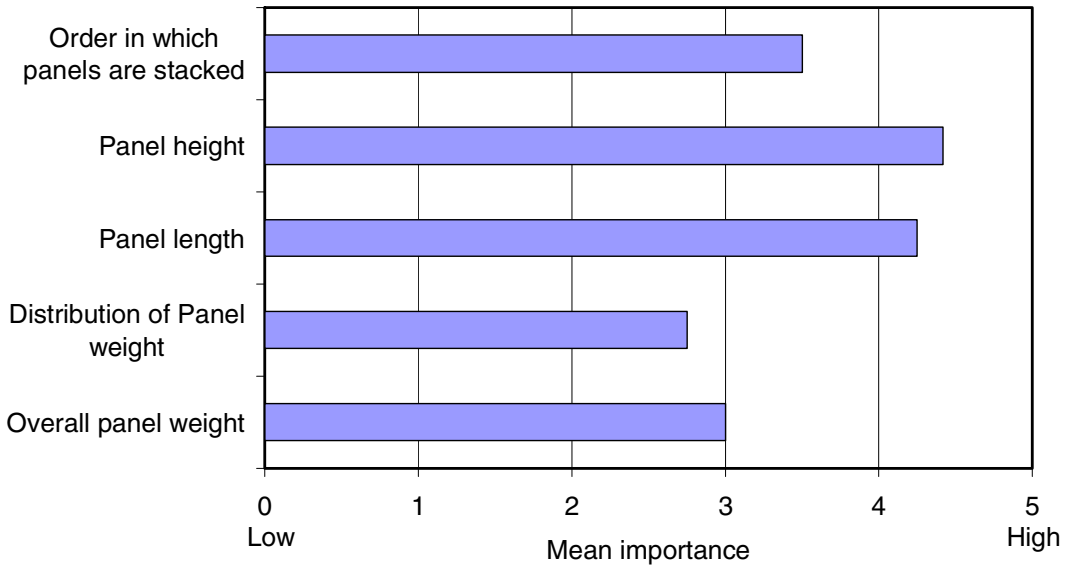

Figure 1: Designers' perceptions of factors that influence efficiency of panel installation.

Figure 2: Expected outcomes of incorporating ergonomics in panel design — panel designers were asked to select all that apply.