
Safe Design in Construction: Perceptions of Engineers in Western Australia

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ABSTRACT

In 2008, WorkSafe Western Australia and the Western Australia Commission for Occupational Safety and Health developed and implemented a Code of Practice for the Safe Design of Buildings and Structures to provide guidance for construction designers in meeting safe design regulations.

Design engineers were surveyed and participated in focus groups to evaluate the Western Australia construction industry's perspective on the new code of practice and to understand the effects of construction safety in design.

The research concluded that engineers generally believe the regulations and code of practice are sensible and almost all believe construction worker safety and health is being positively impacted. Furthermore the research indicates that the regulations and code of practice have made a positive impact on the design engineers' duty of care, thinking, and actions towards affecting the safety and health of construction workers.

The work was carried out to understand the effects in Western Australia and also to inform the current National Institute for Occupational Safety and Health (NIOSH) Prevention through Design approach and a long-term strategy to adoption in the United States.

INTRODUCTION

SAFE DESIGN IN CONSTRUCTION

Influences on the eventual safety and health outcomes during a construction project are multifaceted and vast. The design of a construction project can have an influence on the safety and health of workers involved throughout the project's life cycle including during construction, operation, maintenance, refurbishment, and decommissioning. In recent years design has become a focal point of researchers and regulators.

This paper addresses the question of how design engineers conceptualise their role in the sphere of what is known as 'safe design'. Specifically the inquiry is concentrated on the construction industry in Western Australia and the messages for programs in other places such as that of the National Institute for Occupational Safety and Health (NIOSH) in the United States.

In 2007, NIOSH set forth a Prevention through Design (PtD) initiative in the United States. At the same time the United Kingdom revamped its Construction Design and Management (CDM) regulations (for background and literature reviews on this topic see Aires et al (2010), Breslin (2007), Behm (2005), and Driscoll et al (2005)). The material available on safe design stresses why it is useful and what people should do in order to get it done. Methods are being developed to assist in the process of safe design such as the CHAIR process (WorkCover NSW 2001) and more recent tools (e.g. Gengolells, et al.) including those arising from the building sector (Fleming, et al. 2007).

The initiatives have been driven by the occupational health and safety community including regulatory bodies. However it is intended that a different group

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put these ideas into action; being the design and engineering community. What we know little about are the conceptual underpinnings of people like engineers who are supposed to engage in this process and how this affects their response. We do not know if they are interested in this topic, whether they see it as part of their role or whether the process useful for them.

Fadier (2003) postulates that at one time it was the job of an engineer simply to make things work. However, to achieve better safety throughout product lifecycles, or in construction and, more specifically, the built environment and its lifecycle, it is recognised that the role is a much bigger. How the abilities of engineers can be harnessed to this effect raises a number of questions such as the conceptualisation of design, the possibilities for integration of safety in design, the prediction of human actions downstream of design decisions and design methods (Fadier 2003). These questions tackle the concepts that underpin the work of engineers and their response. Their way of thinking really is key to whether the benefits that those in the occupational health and safety arena envisage can actually be delivered and by what means.

One recent approach that attempts to shape the thinking and actions of the design community including engineers is a recent Code of Practice for Safety Design in Western Australia. This instrument and the response of the design community is the subject of this paper.

THE WESTERN AUSTRALIA CONSTRUCTION INDUSTRY SAFE DESIGN DUTIES

Since its inception, the Western Australia Occupational Safety and Health Act 1984 has included specific “upstream” duties in the construction environment. The duty of designers of buildings and structures is as follows (s23(3a)):

“A person that designs or constructs any building or structure, including a temporary structure, for use at a workplace shall, so far as is practicable ensure that the design and construction of the building or structure is such that —

- a) persons who properly construct, maintain, repair or service the building or structure; and
- b) persons who properly use the building or structure, are not, in doing so, exposed to hazards”.

These duties however did not feature in the original sub-ordinate Occupational Safety and Health Regulations 1996. It is evident in discussions with the coordinating body in Western Australia (The WA OSH Commission as described later) that over recent years it was recognised that although the provisions in the Act had been in place since inception, they were not well understood by the duty holders. In 2007 the Regulations were amended to introduce specific safe design duties. Under Division 12

Table 1. Total Design engineers' response

Thinking generally, when designing an “item” (structure, machine, material, process, tool, work system, etc), it is a designer's responsibility to design/allow for ...	Rank	Mean	Std. Dev.
Making the item reliable, e.g. avoiding structural failure, overbalancing, breakdowns, overheating, etc)	1	4.85	0.362
The item's purpose - e.g. capacity, power, size, output	2	4.75	0.588
Information that will be needed to use the item safely	3	4.67	0.478
Access for workers who repair or maintain the item	4	4.65	0.533
How safe the item will be to manufacture/build	5	4.33	0.859
Keeping the design to budget	6	4.17	0.675
How the item will be refurbished	7	4.07	0.797
Eventual users/workers who don't have their mind on the job	8	3.82	1.130
What will happen with the item when it is no longer needed	9	3.65	1.027
Workers/users who take short cuts when using the item	10	3.33	1.207
Uses to which the item could be put other than the original purpose	11	3.12	0.992

Based on Likert Scale, 5 = Strongly agree through 1 = Strongly disagree

the regulations now detail the responsibilities of the following: clients (consult with the designer/main contractor regarding worksite safety); designers (provide a hazard report to the client); and contractors (record hazard report information and prepare occupational health and safety management plans, obtain or prepare safe work method statements for high risk work and monitor compliance).

The Regulations were based on a model developed in Australia at a national level. In 2005 the National Occupational Health and Safety Commission (now Safe Work Australia www.safeworkaustralia.gov.au) developed a National Standard for Construction Work. Safe Work Australia is a non-regulatory Australian national institution.

The National Standard followed recommendations of the 2003 Royal Commission into the Building and Construction Industry that concerned safe design in the construction industry. The National Standard is non-regulatory. However its development established the

state of knowledge at the time and provided a basis for regulation by the jurisdictions such as Western Australia. The National Standard covers: duty holders including clients, designers, people in control of construction projects and construction sites and people engaged to undertake construction work; hazard identification and risk assessment processes; high risk construction work; and construction project health and safety management plans.

The National Standard employs the principles of practicability and the hierarchy of control (discussed below). The safe design features incorporated in the 2007 changes to the Western Australian Regulations were drawn from the National Standard. The Regulations have since been supported by the 2008 Code of Practice for Safe Design of Buildings and Structures. The Code of Practice is advisory in nature. Its purpose is to provide guidance to assist duty holders to understand and perform their obligations:

“This code of practice applies to all

Table 2. Comparison of consulting firm and community forum respondents – designers’ responsibility (as percentages)

Thinking generally, when designing an “item” (structure, machine, material, process, tool, work system, etc), it is a designer’s responsibility to design/allow for ...	Agree	Neutral	Disagree	Mean	P-value
Making the item reliable, e.g. avoiding structural failure, overbalancing, breakdowns, overheating, etc)	100 100	0 0	0 0	4.81 4.89	0.457
The item’s purpose - e.g. capacity, power, size, output	95 100	0 0	5 0	4.71 4.79	0.938
Information that will be needed to use the item safely	100 100	0 0	0 0	4.75 4.58	0.264
Access for workers who repair or maintain the item	100 95	0 5	0 0	4.81 4.47	0.052
How safe the item will be to manufacture/build	90 84	5 16	5 0	4.48 4.16	0.049
Keeping the design to budget	86 95	14 0	0 5	4.10 4.26	0.283
How the item will be refurbished	90 74	10 16	0 10	4.33 3.79	0.037
Eventual users/workers who don’t have their mind on the job	81 58	5 21	14 21	4.05 3.58	0.115
What will happen with the item when it is no longer needed	67 53	24 21	9 26	3.90 3.37	0.104
Workers/users who take short cuts when using the item	62 42	14 32	24 26	3.43 3.21	0.410
Uses to which the item could be put other than the original purpose	47 21	29 37	24 42	3.38 2.84	0.087

TOP – Large Design and Construction Consulting Firm (n=21)

BOTTOM – Community Forum (n=19)

workplaces in Western Australia covered by the OSH Act. It is intended to assist those involved in designing buildings or other structures to meet the requirements of the OSH Act and the Occupational Safety and Health Regulations 1996 (the OSH Regulations). In particular, this code of practice aims to:

- explain the legal obligations applicable to a person who is in control of, or who may have influence over, the design of a building or structure; and
- provide guidelines for ways in which these obligations can be met by providing practical guidance on ways of maximising the safety of the design”¹

The Code of Practice uses discussion and examples to explain the ideas behind safe design. The case is made for safe design, terms are defined and principles are outlined. The Western Australia (WA) Act, Regulations and Code of Practice are now seen (Breslin 2009) as a set of comprehensive construction safety in design instruments in Australia because of the requirements on all stakeholders (clients and designers as well as constructors) and

due to the code of practice which explains the requirements.

The broader context of Australian Occupational Safety and Health (OSH) legislation.

For an international audience to better understand the Western Australian regulations, it is helpful to place these in the broader context of Australian OSH legislation. This is necessary in two ways; firstly that the concepts in occupational health and safety regulation can vary from those that underpin building regulation and from occupational health and safety regulation in the other places such as the United States.

Within Australia the approach to occupational health and safety legislation has been to follow that found in the United Kingdom (Johnstone 2004). This style of legislation followed the transformational changes that stemmed from the review in the United Kingdom beginning in 1970 and concluding in 1972 with the report titled Safety and Health at Work known as the Robens’ Report after the Chair, Lord Alfred Robens (Committee on Safety and Health at

Table 3: Comparison of consulting firm and community forum respondents – recent design work (as percentages)

Thinking about your work over the last year and perhaps a recent job or project	Agree	Neutral	Disagree	Mean	P-value
Clients were interested in safe design	95 74	5 21	0 5	4.43 3.74	0.002
Client/s took the lead on safe design	52 33	33 22	15 45	3.57 2.89	0.040
I was comfortable with my role in safe design	81 78	14 17	5 5	3.95 3.72	0.240
I made design decisions that improved construction work safety and health.	81 84	19 11	0 5	4.29 3.95	0.139
I have done extra training about safe design.	67 39	24 39	9 22	3.62 3.22	0.106
I helped prepare safe work method statements (SWMS) for high risk work	50 68	35 21	15 11	3.65 3.79	0.704
Preparing SWMS lead me to change design to improve safety	69 53	25 41	6 6	3.81 3.59	0.384
I used the 2008 WA Code of Practice	35 53	25 0	40 47	2.90 3.06	0.679
Safe design was more about paperwork than making design changes	0 11	5 26	95 63	1.71 2.37	0.047
Safe design worked best with a collaborative effort (e.g. safety, construction, design)	90 89	10 11	0 0	4.48 4.22	0.191
I have the proper formal education to implement safe design	71 42	24 26	5 32	3.76 3.26	0.158

TOP – Large Design and Construction Consulting Firm (n=21)

BOTTOM – Community Forum (n=19)

¹ From the Scope and Application section in the non-paginated introduction to the Code of Practice

Work 1972). The regulation of health and safety had developed from the times of the industrial revolution. This approach dealt with notable concerns as they arose leading to large body of prescriptive standards. The Committee found that a new system needed to move away from externally imposed health and safety solutions toward a self-regulated model. They wrote that the "... traditional approach based on ever-increasing, detailed statutory regulation is outdated, over-complex and inadequate." (at para 452). They envisaged legislation that would enliven creativity within industry. Recommendations to achieve this change were put into effect with the 1974 United Kingdom Act and later by similar legislation in the Australian jurisdictions which continues today.

PROMOTING A DESIGN PHILOSOPHY THROUGH THE HIERARCHY OF CONTROL

The Australian occupational health and safety law promotes creative thinking in the development of safety solutions. The Western Australian Act begins this theme in its objects where it lists one of the seven objects of the Act as being: "...to reduce, eliminate and control the hazards to which persons are exposed at work"². The elimination of hazards requires a creative approach (for a discussion see Culvenor 1997a,b). Many and perhaps most hazards at work are part

of the production processes. The hazards are intrinsic to what is happening in the workplace. Often they were put in place deliberately in order to perform a function. The aim to eliminate hazards therefore often runs counter to decisions taken in the past. This objective challenges the status quo. Given hazards are often and perhaps mostly in place to serve a function, their elimination requires a new way of getting the job done. This requires a creative effort. From this effort there is potential not only to solve the safety problem but to create a better way of working; perhaps more effective, more productive, cheaper or easier.

The hierarchy of control is set out in various places throughout the Western Australian regulations as it is in other Australian jurisdictions. The hierarchy of control is intended to cause an examination of any problem with a view to prompting more reliable solutions. The model is drawn historically from studies of occupational hygiene by founders in the field such as Alice Hamilton (1929). The model aims to draw attention from easy, "quick fixes" such as rules and procedures and personal protective equipment to more fundamental adjustments of the hazard levels built into a system. The low order solutions (administrative and personal protective equipment) aim at gaining a higher level of control over behaviour and increasing personal resistance to hazards

Table 4: Comparison of consulting firm and community forum respondents – opinion on regulations (as percentages)

Thinking about the WA construction safe design regulations	Agree	Neutral	Disagree	Mean	P-value
I know my obligations	81 47	14 37	5 14	3.95 3.53	0.134
The regulations are sensible	81 37	19 47	0 14	3.95 3.42	0.042
I worry about being fined or prosecuted	14 42	38 26	48 32	2.62 3.21	0.075
The regulations are making a positive impact on construction worker safety and health	67 44	33 44	0 12	3.76 3.33	0.074
The regulations unfairly target my profession	0 11	14 26	76 63	2.19 2.42	0.403
Safe design was driven by good practice rather than legislation	0 11	21 26	0 11	3.90 3.79	0.795

TOP – Large Design and Construction Consulting Firm (n=21)

BOTTOM – Community Forum (n=19)

² Section 5

within a work system. The higher order solutions aim to gain control of a work system. The low-order solutions essentially aim to ameliorate the impact of a system with known weaknesses. This is necessary and useful but the limitations must be understood. These low-order solutions have no potential to generate anything particularly new or innovative or fundamentally change the work. If the attention to rule-following or use of personal protective equipment falters or is ineffective then the hazards remain. This kind of solution is a reactive and rule-following approach focused on failures at the very end of the chain (construction site) rather than the contributing circumstances (design).

In contrast, the high-order solutions tend to be the domain of those who control the design of a work system, not those who control behaviour within a work system. Through the enactment in legislation of the hierarchy of control, the primacy of the high-order solutions is recognised. The high-order solutions present a great opportunity. They demand a high level of thinking that can result in changes to the system. The hierarchy of control model as far as construction safety is concerned therefore encapsulates the

philosophy of safe design. Rules, procedures, and personal protective equipment abound on construction sites. This environment is the outcome of site managers attempting to gain control over hazards that are contained within the construction process. To gain control of the system rather than within the system, we need often to look beyond site management to site planning, programming, construction methods, materials choices, etc. This is aimed at better safety. However the benefits of rethinking a material choice, work process, design detail, and so on might be much more diverse. A simpler design may result, or a more durable material may be found, potential clashes in the work schedule may be identified and removed, etc.

METHODS

OBJECTIVES

The objectives of this research endeavour were to evaluate the Western Australia construction industry's perspective on the 2007 additions to the Regulations and 2008 Code of Practice, understand the impacts that construction safety in design practice has on the work of professionals, identify the impact that these changes have had on the industry in general.

Table 5: Respondents who agree the regulations are sensible compared with those who did not agree the regulations are sensible – designer's responsibility

Thinking generally, when designing an "item" (structure, machine, material, process, tool, work system, etc), it is a designer's responsibility to design/allow for ...	Answer to "The regulations are sensible"	N	Mean	P-value
The item's purpose - e.g. capacity, power, size, output	Did not agree	16	4.50	0.024
	Agree	24	4.92	
Access for workers who repair or maintain the item	Did not agree	16	4.38	0.058
	Agree	24	4.83	
How safe the item will be to manufacture/build	Did not agree	16	3.94	0.026
	Agree	24	4.58	
How the item will be refurbished	Did not agree	16	3.81	0.058
	Agree	24	4.25	
Eventual users/workers who don't have their mind on the job	Did not agree	16	3.06	0.001
	Agree	24	4.33	
What will happen with the item when it is no longer needed	Did not agree	16	3.25	0.050
	Agree	24	3.92	
Workers/users who take short cuts when using the item	Did not agree	16	2.69	0.050
	Agree	24	3.75	
Uses to which the item could be put other than the original purpose	Did not agree	16	2.75	0.069
	Agree	24	3.38	

TOP – Large Design and Construction Consulting Firm (n=21)

BOTTOM – Community Forum (n=19)

These objectives were both within the local context and in order to appreciate lessons for application of similar ideas in other places such as the NIOSH Prevention through Design program. To meet this objective, a written survey and focus group interviews were undertaken in October 2009, just a little over one year after the Code of Practice was released and two years since the 2007 safe design features were added to the Regulations.

DATA COLLECTION AND ANALYSIS

In order to meet the research objectives, a written survey was developed and administered to the study participants. Following the survey, a focus group forum was held in which qualitative information was discussed. The authors gave an overview of the NIOSH PtD approach in the U.S. and the objectives after the survey and before the forums. A script of questions were posed in an open forum style discussion asking about the participants' background and experience with safe design, organisational and individual impacts of safe design, barriers and enablers, impacts on practice, and the future perspectives.

Three groups participated in the research: WorkSafe Western Australia and WA Commission for OSH (n=15); design and OSH professionals at a large design and construction consulting firm in Perth (n=35); and a community forum on safe design which was advertised by WorkSafe and Engineers Australia (n=30). The study was conducted in Perth, WA and therefore was limited by its geography not including other areas of Western Australia. Participants were

not randomly selected but were self selected likely based on their interest in the code of practice and safety through design.

The survey was in the form of a 5-point Likert scale (strongly agree through strongly disagree). All dependent variables were tested for normality using the Kolmogorov-Smirnov Test procedure which compares the observed cumulative distribution function for a variable with a specified theoretical distribution, in this case a normal distribution. None of the dependent variables were normally distributed. Thus, nonparametric analyses {Mann-Whitney} were utilised. Means are provided within the tables of results to give the reader an indication of the results numerical value.

DEMOGRAPHICS COMMUNITY FORUM

Thirty participants attended the Community Forum held in the evening at the Perth offices of Engineers Australia. Twenty-one valid surveys were returned. The Community Forum was communicated by WorkSafe Western Australia and Engineers Australia. Nineteen participants were design engineers or who listed with design engineering experience and three were OSH professionals; one listed previous design engineering experience and was currently an OSH professional. The design engineers reported a range of experience between 2 and 40 years with an average of 18.94 years of experience. The design engineers reported a variety of primary construction projects, the most being heavy civil (n=7) followed by mining, residential, commercial, and industrial. The Community Forum respondents came from a variety of

Table 6: Respondents who agree the regulations are sensible compared with those who did not agree the regulations are sensible – recent design work

Thinking about your work over the last year and perhaps a recent job or project	Answer to "The regulations are sensible"	N	Mean	P-value
Clients were interested in safe design	Did not agree	16	3.81	0.054
	Agree	24	4.29	
I have done extra training about safe design.	Did not agree	15	3.13	0.080
	Agree	24	3.63	
I used the 2008 WA Code of Practice	Did not agree	13	2.31	0.015
	Agree	24	3.33	
I have the proper formal education to implement safe design.	Did not agree	16	2.94	0.003
	Agree	24	3.92	

firm based on size, with the most being over 1000 employees (n=7) followed by small firms less than 9 employees (n=4) with the remaining being somewhere in the middle.

LARGE DESIGN-CONSTRUCTION FIRM

Thirty-five participants attended the large design and construction consulting firm’s forum, with twenty-five valid surveys returned. Three client representatives attended the forum with one returning a survey. Twenty-one of the respondents were design engineers; they reported a range of design experience between 2 and 30 years with a mean of 15.5 years. The company has a focus on safe design and that is clear from their website which states, “Safety in Design is one area where we can use safety to gain a market edge and differentiate ourselves from our competitors”.

WORKSAFE WESTERN AUSTRALIA / OSH COMMISSION

Fifteen participants attended the focus group held at WorkSafe. Twelve of the attendees were regulators and three were on the OSH Commission. One of the Commission’s attendees was a union OSH representative; the other two were OSH professionals.

RESULTS

PERCEPTIONS OF DESIGN RESPONSIBILITIES

Participants were asked to respond to the statement, “thinking generally when designing an “item” (structure, machine, material, process, tool, work system, etc), it is a designer’s responsibility to design/allow for ...” with eleven potential responsibilities. This question provides insight into designers’ thinking when it comes to the various competing variables during the design phase. Responses for all 40

design engineers from both the community forum and the large design and construction consulting firm are ranked in Table 1. Table 2 shows the percent agreement among the two groups and provides a statistical comparison for each question.

Designing for reliability and purpose ranked highest. Designers are also thinking about ‘build-ability’ and safety. Encouragingly design objectives such as information for safe use, access, safety in manufacture/construction and refurbishment are all not far behind reliability and purpose and yield average levels of agreement around the issue of keeping a design to budget. Poorer agreement however is found as the time frame is extended (e.g. refurbishment and end-of-life) and in relation to non-ideal use (users/workers who don’t have their mind on the job, taking short-cuts or adaption for alternative uses). The analysis revealed a statistical difference in thinking about how safe the item will be to manufacture/build; the large firm engineers are in stronger agreement than the community forum engineers (p=0.049). There is also a difference on the issue of how the item will be refurbished. The large firm engineers are considering that part of their duty more so than the community forum members (p=0.037), although the figures in both cases are reasonably high.

EXPERIENCES WITH SAFE DESIGN

Questions were asked about experiences with aspects of safe design over the previous year. While the previous bank of questions were philosophical, these questions targeted actual experiences with all prefaced by “Thinking about your work over the last year and perhaps a recent job or project...”. The

Table 7: Respondents who agree the regulations are sensible compared with those who did not agree the regulations are sensible – opinion of WA regulations

Thinking about your work over the last year and perhaps a recent job or project	Answer to “The regulations are sensible”	N	Mean	P-value
I know my obligations	Did not agree	16	2.94	0.001
	Agree	24	4.29	
The regulations are making a positive impact on construction worker safety and health	Did not agree	15	3.27	0.047
	Agree	24	3.75	
The regulations unfairly target my profession	Did not agree	16	2.63	0.015
	Agree	24	2.08	

purpose was to tap into experiences since the adoption of the Code of Practice. The results are shown in Table 3.

Design engineers in the large design and construction consulting firm agreed more than the attendees of the community forum that client/s took the lead on safe design ($p=0.002$) and that clients were interested in safe design ($p=0.040$). This could be an indication that their focus on safe design as a market strategy is making its way to their clients. Designers at the community forum believed that safe design was more about paperwork than making design changes compared to the large firm ($p=0.047$) although they still overall disagreed with the statement ($\bar{x}=2.37$). Overall, the good news is that designers are seeking to make an impact on construction worker safety and health rather than creating risk assessment files that may not be utilised. We also analysed the variables based on the number of years of design experience using 15 years experience as a cut-off point. The only interesting variable that emerged was that

designers with 15 or more years of experience disagreed more than designers with less than 15 years of experience that safe design was more about paper work than making design changes ($p=0.053$). Although they both disagreed with the statement, this might indicate that designers with more experience see safe design more within their overall duty of care compared to newer designers.

VIEW OF THE REGULATIONS

Questions were asked about views of the regulations. These are shown in Table 4. Design engineers in the large design and construction consulting firm believe the regulations are more sensible when compared to the community forum attendees. ($p=0.042$). They also believe that the regulations are making a positive impact compared to the community forum attendees ($p=0.074$) and worry less about being prosecuted ($p=0.075$). The designers generally agree that safe design was driven by good practice rather than by legislation, and disagree with the statement that the

Table 8: How has design and construction changed due to safe design? (as percentages)

How has each of the following changed as a result of implementing safe design on projects?	Decrease (%)	No Change (%)	Increase (%)	Increase (%)
Design costs	0	14	76	10
	0	26	68	6
	0	20	73	8
Construction costs	13	29	29	29
	5	16	63	16
	10	23	44	23
Design duration	0	35	60	13
	0	32	63	16
	0	33	62	15
Construction duration	10	67	10	13
	16	47	21	16
	13	57	15	15
Construction quality	0	28	62	10
	16	36	32	16
	7	32	48	13
Construction worker productivity	0	35	30	35
	21	37	26	16
	10	36	28	26
Construction worker health and safety	0	0	90	10
	5	11	73	11
	2	5	83	10
End-user health and safety	0	0	86	14
	6	11	58	22
	2	5	73	18

Top – Large Design and Construction Consulting Firm (n=21)

Middle – Community Forum (n=19)

Bottom – Totals

regulations unfairly target their profession.

ARE THE REGULATIONS SENSIBLE?

Questions were asked about the participant's views of the regulations. We utilised the statement "thinking about the WA safe design regulations, the regulations are sensible" as a categorising variable. Two categories were created; one for those who agreed with that statement, and the other for those who did not agree (i.e. they were neutral or they disagreed). The purpose was to explore whether people who are in agreement that the regulations are sensible were different in their thinking compared to those who do not agree. Several significant results were found and are highlighted in Tables 5 – 7. We also included those results that approached $p=0.05$ to give the reader an idea of the breadth of the responses. Those who agreed that the regulations are sensible are designing for other aspects and thinking about safe design in a more proactive manner than those who did not agree with the sensibility of the regulations. One potential explanation is that the respondents who agree with the regulations' sensibility are simply more agreeable to all questions. This is certainly a strong possibility. However, other plausible explanations exist. Consider that not all variables were significant; ten of the 27 variables showed significance at or below the $p=0.05$ level. During the research the large design firm discussed examples of how individual designers made design changes thinking about construction worker safety that positively impacted cost, schedule, productivity and other business measures. These comments paralleled the survey responses in that those from the large design and construction consulting firm believed more strongly that the regulations are sensible when compared to the community forum attendees ($p=0.042$). These two observations could be linked. The business focus on safe design of itself and/or the subsequent practice of safe design could strengthen a belief that safe design regulations are sensible.

THE OUTCOMES OF SAFE DESIGN

The final bank of questions is shown in Table 8. These questions sought views on changes in construction variables due to implementing safety in design practices on projects. Responses were the categories of decrease, no change, increase and don't know. The results for the large firm and community forum are separated. The clearest views are found in the areas of design costs and duration and safety, quality, and productivity. There are strong views that design cost and duration have increased as a result of safe design activity. The result of this effort is thought to be in the areas of worker and end-user safety, worker productivity, and construction quality. Total project costs, depending on the magnitude of the design and construction costs, could be less and is an area to evaluate in the future. Clients and developers will be interested in this analysis.

WORKSAFE VIEW

The regulators that participated ($n=12$) believe the regulations are sensible ($\bar{x}=4.00$) and that they are making a positive impact on construction worker safety and health ($\bar{x}=4.00$). The obligations on design professionals for safe construction design have been in the WA Act since 1986. It is only since the Regulations and Code of Practice were developed in 2007-2008, that the regulators moved to enforce the legislation. WorkSafe also commented that the Code of Practice has helped establish a consistent message about the various parties' roles for safe design in construction. When asked about enforcement logistics, the regulators said they would not knock on a design professionals' door or utilise public bid notifications to enforce the regulations on designers. Rather, they would work through the contractors on construction sites and make a determination if it was necessary to backtrack into the design work.

DISCUSSION

THE REQUIRED INPUT AND USEFUL

OUTPUTS OF SAFE DESIGN

A majority of the participants believe that design duration and costs have increased.

This impact is an input into the safe design process. It should be expected. On the construction site, most believe that safe design has improved both worker productivity and worker safety. There are some who feel that construction costs have increased but construction duration has not changed. Most believe that construction quality has improved and that the safety of the end users has been improved. The strongest views are found in the level of agreement that the safety of the construction workers and end users has improved. These are the key goals. With these key aspects there is overall a positive mood reflected in the views on matters such as job quality.

A POSITIVE MOOD WAS EVIDENT

Generally there seemed to be a positive mood about the philosophy and general practice of safe design. A large majority of designers say that in the last year they have made decisions that improved safety for construction workers (83% agree). They say that safe design works best with a collaborative approach (89%), that clients have been taking the lead (85% agree) and that they are comfortable in their role (79%). They do not believe that safe design is just a paperwork exercise (5% agree). Of course these were people interested enough in the topic to attend the forum hence they are not necessarily representative of the broader construction community. A few comments illustrate this result:

“Code of practice helps with the learning process about safe design.”

“From an asset owner’s point of view the code of practice helped establish what they had wanted for some time.”

“If you bring in operators into the design then you achieve a better result.”

“In my experience the engagement of the operator and maintainer has been relatively easy because they are usually the client. Their involvement is useful.

However the builder is not usually known. So some extra process is needed to engage and perhaps pay (is the client happy to pay?) for someone to provide that input.”

Examples of changes mentioned included:

“... tilt up construction design perhaps done better”;

“...simple things like trying to remove confined spaces, provide spaces for chemical storage, etc”

The reasons are speculative but the possible factors for the positive mood could include the following. Safe design in Australia has developed as a matter of good practice rather than regulation – regulation is now underpinning good practice. The consultation period associated with the code of practice in Western Australia should be relevant in building support for safe design. Furthermore the broader Australian experience has enjoyed the benefit of the process having been previously implemented in the United Kingdom.

A TRICKLE-DOWN EFFECT

It has been a matter of policy in Australia to build safe design knowledge and practice through a trickle-down effect. The topic of safe design was introduced in a discussion paper (Durham et al 2002). Subsequent recommendations of the Royal Commission into the Building and Construction Industry (Cole 2003) were to use the purchasing power of publicly funded building and construction projects to influence safe design practice. Royal Commissioner Cole (para 170) wrote:

“Two considerations at least point to the value of the Commonwealth assuming the obligations of a model client in terms of occupational health and safety. The first relates to its substantial contribution to the industry as a client, directly or indirectly. Any occupational health and safety initiatives on Commonwealth projects inevitably will have direct and flow-on effects for the industry. The second – and perhaps the most significant – consideration

is that by attending to its own projects, and to those that it is in a position to influence, the Commonwealth can lead by example. It can demonstrate that real gains can be made, not simply by prescribing the conduct of others, but by practical demonstration of method and result.”

The regulator in Western Australia likewise believes that working with the bigger players and industry associations is the best approach at present – the big players will then influence the smaller players. An example of the influence of clients and of changing recognition of safe design was relayed at the WA OSH Commission forum. An inspector at the forum said that in the 1980’s an attempt was made with the designers of a large public building about the future difficulties of cleaning a glass roofed atrium. The discussion at that time gained no traction. A mobile elevating platform is now used which is an expensive and awkward solution in a public area. By contrast a story was related about the current development of a new hospital. The regulator contacted the client (government) who responded favourably and since there has been useful consultation between the architects, users and operators. This process it seems was initiated by the client. It can certainly be argued that this should be happening without prompting. The point however, was that the environment today meant that a small input at the right level met with useful action. This is a significant change from the 1980’s. Today the regulator can point toward a specific regulation which gives the suggestion a reference point. Furthermore the stakeholders in the project today have an awareness of the topic built up through a lengthy consultation period over the introduction of the code of practice and therefore understand the process. Evidence of this can be noticed in the responses of designers at the large consulting firm to those at the engineers’ community forum. The designers from the larger firm experienced clients that were (a) more interested in safe design and (b) taking the lead on safe design.

A WAY OF THINKING

The participants recognised some safe design aspects such as the provision of instructions and consideration of safe manufacturer and maintenance - but only it seems with ‘proper’ use. Distant factors (reuse) and perceived misuse are less well supported. However this is probably changing over time. We are hampered by a lack of baseline perceptual data, however the following comment was made at the community forum:

“An accident happened recently where a person fell 15 floors to their death after a plastic chair on which they were standing collapsed and they fell over a balcony (due to the location of a light). The problem could have easily been averted by a light fitting on the wall which any good designer should know about today.”

In this designer’s opinion the vision of the designer should now extend to the effects on users throughout the life of the structure – such as the people changing the light bulbs. Breslin (2007) discusses this balcony lights design issue in more detail. The reference to what a good designer should know “today” seems to indicate that perhaps in the not-too distant past a designer may have not taken this into account. In this person’s view it seems that perceptions are changing for the better in terms of safe design.

RESPONSE TO REGULATION

Most people think that the regulations are sensible (60% agree). This is not an overwhelming majority but most others are neutral (33%) which may be because they are not familiar with the legislation. Further those who do not agree that the regulations are sensible are also less inclined to agree with responsibilities like designing for eventual workers who might not have their mind on the job ($p=0.001$), workers or users who might take short cuts ($p=0.005$), and what happens when the item will no longer be needed ($p=0.050$) Hence the uncertainty about the value of the regulations is correlated with views about safe design philosophy. We are therefore more likely to gain support for and engagement with

regulatory approaches if the philosophy and reasoning is understood.

WHAT DOES IT MEAN – AN OPPORTUNITY FOR CREATIVITY

Overall, the results show that, in general, design engineers in Western Australia agree with and support the construction safety and health through design concept. Design engineers in the large firm gave a more favourable response but this is likely due to the emphasis within that firm on this ideology as a market differentiation or driver. For example, one engineer described his involvement with a telescopic column canopy for service stations. This idea was developed by thinking about construction worker safety and seeking to minimise work at height. By developing a hydraulic lifting process, the canopy could be constructed quicker and with less cost.

“The results from this particular innovation have been very encouraging; the total man hours required to work at height on canopy installations has been reduced by 95 per cent, almost eliminating the need to have workers exposed to risks associated with such work. The telescopic column canopy has also reduced the critical path of a construction timeline of a site by seven to 10 days on average.”³

By focusing on worker safety, the engineer was able to create a win for safety and a win for cost and schedule. It demonstrates the innovation and creativity that can develop when a designer focuses on something outside their original sphere of expertise. Another example provided was that of communicating design hazards in a steel column placement where large columns had to be installed within an existing building. The engineer communicated a method for the constructors to clamp and bolt the column into place. Additionally, the engineer communicated the potential hazard of high wind and specified a maximum wind speed which should not be exceeded during construction. This example

demonstrates the duty of care logic and how it carried over to means and methods of construction. In the United States, such means and methods would typically be left to the constructor without input from the design team. A frequent barrier listed by designers in the U.S. to implementing the design for construction safety and health concept is that of means and methods being solely the constructors’ responsibility (Gambatese et al 2005). We brought up the question during the focus group discussion of whether the role of design has changed. The designers brought up their duty of care frequently in the discussions stating that it is within their duty to consider construction workers and build-ability. The duty of care is not new and appears to be generally accepted that construction workers are included within that duty of care.

CONCLUSIONS

The regulations and code of practice for safe design of buildings and structures in Western Australia have made a positive impact on design engineers’ thinking and actions towards positively affecting the safety and health of construction workers. Designers are generally innovative and creative professionals. New innovative and creative thoughts have emerged by focusing on construction site safety and health. These design changes can sometimes impact more traditional construction business measures, such as quality, cost, and schedule in a positive way.

The design engineers were found to be generally supportive of the concept. They are not only willing to provide information to constructors regarding hazards and risk arising from and identified in the design phase but are actively seeking to make design changes that will positively affect construction safety and health. In other words, they are not simply conducting risk assessments and design reviews in a check-the-box manner. Rather, they have integrated creative thinking to construction safety just as they would any other project

³ www.skmconsulting.com/Knowledge-and-Insights/Achieve-Articles/2009/Innovating-Eliminate-Risks.aspx

goal. This ideology is best summed up by a quote from the large design and construction consulting firm's website:

“Understand how innovation can eliminate risks rather than just mitigate it, during project construction.”⁴

For jurisdictions seeking to diffuse the construction safety and health through design concept, such as the U.S. NIOSH through their PtD initiative, several recommendations were generated from this research.

First, the proper environment is needed to ensure a positive mood among the design community. Western Australia has the benefit of a long history involving the duty of care concept, which design engineers have largely bought into that this duty includes construction worker safety and health. NIOSH's approach within PtD seeks to positively impact education, practice, research, and policy and appears to be a proper long-term strategy to create the positive mood and momentum for diffusion within the design community. The proper environment for concept adoption must be created before regulations are sought.

Secondly, the trickle-down concept is appealing. The early adopters and champions of new concepts, such as construction PtD, can provide demonstration projects and case studies so that the design industry can learn about the methods that work and do not work. Incorporating the construction safety and health through design concept into large government projects would be a method to demonstrate effectiveness to the larger industry. Linking the construction safety and health through design concept to sustainable and green construction would be another method to introduce the concept to the industry.

Thirdly, the relationship between the construction safety and health through design concept and construction project business measures should be researched more thoroughly. Understanding the concept's impacts and limitations in business terms will aid the design community and the construction industry to identify enablers and

barriers to safe design.

Lastly, this research highlights that innovation and creativity can sometimes be stimulated by focusing on construction site safety and health. Finding the win-win situations and understanding how the processes that enable such innovation and creativity are keys to overall adoption. The strength of association between a view that the regulations are sensible and other metrics was also notable. Which comes first here – the conceptual understanding – or belief in the value of the regulations has not been established. The broad conversation and promotion of safe design in Australia has a longer history than the regulations. It seems likely then that a strong conceptual understanding in this case has led to acceptance of the regulations. For instance the development of the Code of Practice was a process involving community consultation over a number of years. The approach of building support for the concepts and practices first and then underpinning these with regulatory instruments would therefore be indicated. Jurisdictions considering methods to adopt construction safety and health through design should not rush into a regulatory approach; rather, this research demonstrates the benefits of a cooperative effort which can ultimately benefit workers and business value.

There are several areas for future research as a result of this study. Our research did not include architects and this is a limitation of the findings. A larger study should include architects as well as design engineers. Additionally, other geographic areas of Western Australia should be included in the scope. While this research serves as an indication of the impact the regulation and code of practice has had, a future study utilising a web-based survey among the Western Australia design community would be useful. During the study, several examples of the concept in practice were provided. It would be useful, especially for the practical implementation of construction safety and health through design concept, to document case studies that in turn could be used to

⁴ www.skmconsulting.com/Knowledge-and-Insights/Achieve-Articles/2009/Innovating-Eliminate-Risks.aspx

educate and spur innovation amongst the design community.

Overall, Western Australia provides an excellent opportunity to learn about the concept of construction safety and health through design and how regulation and a code of practice can reinforce the philosophy and practice of safe design. Follow-up research to evaluate the effects of the code of practice on the Western Australian construction industry safety and health metrics should be conducted. Jurisdictions seeking to revise or develop regulations in the area of designing for construction safety and health should consider evaluating Western Australia's approach.

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