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DESIGNING FOR CONSTRUCTION ERGONOMICS

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Introduction (1)

- **The South African Construction Regulations (2014) state that during the design stage, designers must take cognisance of ergonomic design principles in order to minimize ergonomic related hazards in all phases of the life cycle of a structure**
- **Amplifies the need for ‘designing for safety’, which Behm (2006) defines as “The consideration of construction site safety in the preparation of plans and specifications for construction projects”**
- **Thorpe (2006) states that there is no more important stage in the construction process than that of design, as at this stage conceptual ideas are converted into constructable realities:**
 - **‘Designing for H&S’ being one of the designing for constructability principles**

Introduction (2)

- A variety of considerations need to be balanced simultaneously, inter alia, designing for H&S, which is an integral part of the wider design process
- Therefore, needs to be included in design planning as doing so will result in safer construction and maintenance of structures and facilities
- Hecker *et al.* (2006) contend that H&S through design is a fundamental principle of ergonomics:
 - Architects and engineers regularly address ergonomics in their designs, but the concerns apply almost exclusively to the end-user of a facility, rather than the workers who construct it
- Gambatese (1998) states that historically, the design professions have not addressed construction H&S

Introduction (3)

- **The aforementioned highlight the relevance of designing for H&S and ergonomics, and the rationale for the study reported on, the objectives being to determine:**
 - **Designers' perceptions relative to construction H&S and ergonomics, and designing for construction H&S, and ergonomics**
 - **Whether the training had an impact on the designer delegates attending a seminar or not**

Construction Regulations (1)

Clients required to:

- **5 (1) (a) Prepare a baseline risk assessment (BRA)**
- **5 (1) (b) Prepare an H&S specification based on the BRA**
- **5 (1) (c) Provide the designer with the H&S specification**
- **5 (1) (d) Ensure that the designer takes the H&S specification into account during design**
- **5 (1) (e) Ensure that the designer carries out the duties in Regulation 6 ‘Duties of designers’**
- **5 (1) (f) Include the H&S specification in the tender documents (Republic of South Africa, 2014)**

Regrettably, it is not stated that the H&S specification must be revised to include amendments required in terms of the designer report

Construction Regulations (2)

Designers of a structure must:

- **(a) ensure that the H&S standards incorporated into the regulations are complied with in the design**
- **(b) take the H&S specification into consideration**
- **(c) include in a report to the client before tender stage:**
 - **all relevant H&S information about the design that may affect the pricing of the work**
 - **the geotechnical-science aspects**
 - **the loading that the structure is designed to withstand**
- **(d) inform the client of any known or anticipated dangers or hazards relating to the construction work, and make available all relevant information required for the safe execution of the work upon being designed or when the design is changed**

Construction Regulations (3)

- **(e) modify the design or make use of substitute materials where the design necessitates the use of dangerous procedures or materials hazardous to H&S**
- **(f) consider hazards relating to subsequent maintenance of the structure and make provision in the design for that work to be performed to minimize the risk (Republic of South Africa, 2014)**

Designing for construction ergonomics

Hecker *et al.* (2006)

- **Contend that H&S through design is a fundamental principle of ergonomics, and that the hierarchy of controls is fundamental to the process of hazard reduction i.e. elimination or substitution to mitigate hazards**
- **Although architects and engineers regularly address ergonomics in their designs, they do so almost exclusively relatively to the end-user of a facility, rather than the workers who undertake the construction thereof**

Impact of designers on construction ergonomics

- Behm (2006) analysed 450 reports of construction workers' deaths and disabling injuries in the USA - in 151 cases (33.6%), the hazard that contributed to the incident could have been eliminated or reduced if 'design-for-H&S' measures had been implemented

Obstacles to designing for construction ergonomics

- **Hecker *et al.* (2006) cite the following:**
 - The narrow specialisation of design and construction practice
 - Limited pre-construction collaboration between the designer and constructor due to the traditional construction procurement system (TCPS)
 - The limited availability of ergonomics-in-design tools, guidelines and procedures
 - Limited education architects and engineers receive regarding construction ergonomics
- **Construction Industry Development Board (cidb) (2009) report states that at the tertiary level, not all construction related programmes in South Africa include H&S within their curricula, especially designer programmes**

Potential of designers to contribute to construction ergonomics

South African built environment practitioners (Smallwood, 2006a) - the extent in terms of a mean score ranging between 1.00 and 5.00 is:

- **Constructability (general) (4.53)**
- **Awareness (4.52)**
- **Mechanisation (4.45)**
- **Prefabrication (4.31)**
- **General design (4.22)**
- **Reengineering (4.19)**
- **Specification (4.09)**
- **Details (4.03)**

Importance of H&S / ergonomics

- Historically, cost, quality, and time, have taken precedence over H&S in terms of the importance of project parameters
- An 'image of contractors' study conducted among clients by Smallwood (2010) required respondents to indicate the importance of twenty-six image related aspects. The mean scores recorded between parentheses are between 1.00 (lower limit) and 5.00 (upper limit)
 - Quality (4.75) and remaining within budget (4.75) ranked joint 1st
 - Time performance (4.25) 8th
 - Health (4.00) 11th
 - Safety (3.75) 13th

Accidents and related issues (1)

- **Schwartz (1995) cites a traffic engineer's contention that there is no such a thing as a true accident**
- **An accident is a result of human or mechanical failure, or a combination of both – nothing happens without a cause**
- **Mainstream literature, invariably defines an accident as an unplanned event**
- **Given that management is responsible for planning, organising, leading, controlling, and coordinating, and accidents are unplanned events, then accidents effectively constitute a failure of management**
- **Hinze (2006) contends that all accidents are preventable and that construction is not inherently dangerous**

Accidents and related issues (2)

- **Strategies, systems, procedures, and protocol can mitigate or eliminate ‘accidents’**
- **A multi-stakeholder approach and ‘designing for H&S’ are examples of strategies**
- **Documented H&S management systems and quality management systems are examples of systems**
- **The provision of an H&S specification to designers by clients, a report to clients by designers, and the provision of an H&S specification to the PC is an example of a procedure. Design HIRAs are a further example**
- **The protocol of including H&S as the first item on a project progress meeting agenda raises the status of H&S**

The Cost of Accidents (COA) and the benefits of optimum H&S

- **Costs:**
 - COA is estimated to be between 4.3% and 5.4% of the value of completed construction
 - Cost of implementing H&S is estimated to be between 0.5% and 3% of project costs
 - Clearly H&S is a 'profit centre' (Smallwood, 2004)
- The synergy between construction H&S and the other eleven project parameters results in further financial benefits: environment; cost; developmental criteria; environment; productivity; public H&S; quality; time; client satisfaction; design team satisfaction, and worker satisfaction (Smallwood, 2006b)

Reduction of risk through design and specification (1)



(Steel Construction, 2004)

Reduction of risk through design and specification (2)



(Steel Construction, 2004)

Reduction of risk through design and specification (3)



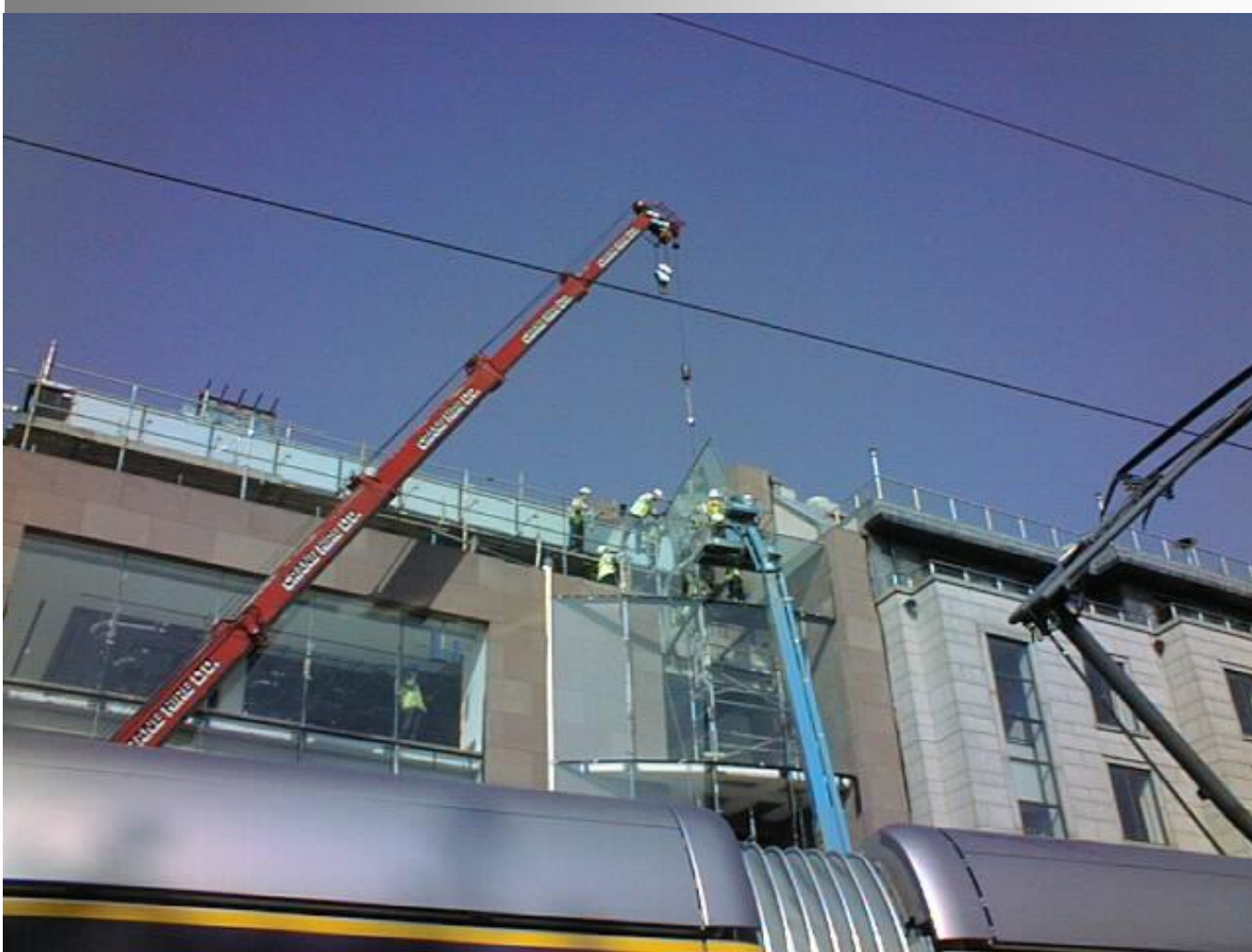
(Steel Construction, 2004)

Reduction of risk through design and specification (4)



Externally installed full fenestration, Dublin (Smallwood, 2004)

Reduction of risk through design and specification (5)



Externally installed full fenestration, Dublin (Smallwood, 2004)

Reduction of risk through design and specification (6)



'Melting' mastic asphalt, Canal Walk, Cape Town (Smallwood, 2000)

Research – Sample stratum and method

- **19 Delegates attending a one-day ‘designing for construction H&S’ seminar in Port Elizabeth, South Africa**
- **Effectively constituted a convenience or captive sample**
- **A 28 five-point likert scale type question questionnaire survey was conducted at the inception and the end of the seminar**
- **Objective being to determine the culture of the delegates prior to the training intervention, and whether the training intervention had an impact or not**
- **Mean scores (MSs), a measure of central tendency, are between 1.00 (lower end) and 5.00 (upper end), 3.00 being the midpoint**

Research – Findings (1)

Statement	Response (%)						MS
	Unsure	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
Designers should consider their designs relative to construction	0.0	0.0	0.0	0.0	68.4	31.6	4.32
Evaluation of project performance should include H&S	0.0	0.0	0.0	0.0	73.7	26.3	4.26
H&S is concerned with preventing injuries	0.0	0.0	0.0	5.3	68.4	26.3	4.21
Tertiary designer education should include construction H&S	0.0	0.0	0.0	0.0	78.9	21.1	4.21
Design influences construction	0.0	0.0	5.3	0.0	68.4	26.3	4.16
Design influences H&S	0.0	0.0	0.0	10.5	78.9	10.5	4.00
Design can positively influence H&S	0.0	0.0	0.0	10.5	89.5	0.0	3.89
Designers can mitigate hazards at design stage	0.0	0.0	0.0	15.8	78.9	5.3	3.89
H&S is related to constructability	0.0	0.0	0.0	15.8	84.2	0.0	3.84
Designers should conduct constructability reviews	5.3	0.0	0.0	15.8	63.2	15.8	3.79
Design can negatively influence H&S	0.0	0.0	0.0	21.1	78.9	0.0	3.79
Construction is inherently dangerous	0.0	5.3	10.5	10.5	52.6	21.1	3.74
Designers can identify hazards at design stage	5.3	0.0	5.3	10.5	68.4	10.5	3.68
‘Designing for H&S’ is a designer competency	0.0	0.0	5.3	26.3	63.2	5.3	3.68

Table 1A: Pre-seminar responses

Research – Findings (2)

Statement	Response (%)						MS
	Unsure	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
Accidents are unplanned events	0.0	0.0	16.7	11.1	61.1	11.1	3.67
H&S is concerned with compliance with legislation	0.0	0.0	15.8	10.5	68.4	5.3	3.63
H&S is more important than cost, quality, and time	0.0	0.0	26.3	10.5	47.4	15.8	3.53
Procurement influences construction H&S	15.8	0.0	0.0	10.5	52.6	21.1	3.47
'I am my brother's keeper'	15.8	0.0	0.0	15.8	63.2	5.3	3.26
The benefits of H&S exceed the costs thereof	10.5	5.3	10.5	5.3	57.9	10.5	3.26
Designers can quantify risk at design stage	10.5	0.0	5.3	26.3	52.6	5.3	3.26
Design contributes to accidents	0.0	0.0	21.1	36.8	36.8	5.3	3.26
H&S is concerned with the sustainability of the industry	21.1	0.0	0.0	5.3	68.4	5.3	3.16
Designers can eliminate hazards at design stage	10.5	0.0	10.5	21.1	57.9	0.0	3.16
All accidents are preventable	5.3	5.3	36.8	5.3	31.6	15.8	3.00
H&S should be a value and not a priority	5.3	5.3	42.1	21.1	15.8	10.5	2.68
Accidents are part of the job	0.0	15.8	42.1	26.3	15.8	0.0	2.42
Cost, quality, and time are more important than H&S	0.0	15.8	73.7	10.5	0.0	0.0	1.95

Table 1B: Pre-seminar responses

Research – Findings (3)

Statement	Response (%)						MS
	Unsure	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
Tertiary designer education should include construction H&S	0.0	0.0	0.0	0.0	52.6	47.4	4.47
'I am my brother's keeper'	0.0	0.0	0.0	0.0	57.9	42.1	4.42
Evaluation of project performance should include H&S	0.0	0.0	0.0	0.0	63.2	36.8	4.37
Design influences construction	0.0	0.0	0.0	0.0	63.2	36.8	4.37
H&S is concerned with the sustainability of the industry	0.0	0.0	0.0	5.3	57.9	36.8	4.32
Design influences H&S	0.0	0.0	0.0	0.0	68.4	31.6	4.32
Designers should conduct constructability reviews	0.0	0.0	0.0	0.0	73.7	26.3	4.26
Designers should consider their designs relative to construction	0.0	0.0	0.0	0.0	78.9	21.1	4.21
Design can positively influence H&S	0.0	0.0	0.0	5.3	68.4	26.3	4.21
Designers can identify hazards at design stage	0.0	0.0	0.0	0.0	78.9	21.1	4.21
Designers can mitigate hazards at design stage	0.0	0.0	0.0	5.3	73.7	21.1	4.16
Procurement influences construction H&S	0.0	0.0	0.0	5.3	73.7	21.1	4.16
All accidents are preventable	0.0	0.0	5.3	5.3	63.2	26.3	4.11
H&S is concerned with preventing injuries	0.0	5.3	0.0	5.3	57.9	31.6	4.11

Table 2A: Post-seminar responses

Research – Findings (4)

Statement	Response (%)						MS
	Unsure	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
H&S is more important than cost, quality, and time	0.0	0.0	5.3	15.8	47.4	31.6	4.05
Designers can quantify risk at design stage	0.0	0.0	0.0	5.3	84.2	10.5	4.05
H&S is related to constructability	5.6	0.0	0.0	0.0	77.8	16.7	3.94
The benefits of H&S exceed the costs thereof	5.3	0.0	5.3	0.0	68.4	21.1	3.89
Designers can eliminate hazards at design stage	5.3	0.0	5.3	5.3	63.2	21.1	3.84
'Designing for H&S' is a designer competency	0.0	0.0	5.3	15.8	68.4	10.5	3.84
Design can negatively influence H&S	0.0	0.0	15.8	10.5	63.2	10.5	3.68
Design contributes to accidents	0.0	0.0	15.8	26.3	52.6	5.3	3.47
H&S is concerned with compliance with legislation	0.0	15.8	15.8	0.0	52.6	15.8	3.37
Accidents are unplanned events	0.0	11.1	22.2	5.6	44.4	16.7	3.33
Construction is inherently dangerous	0.0	5.6	33.3	0.0	44.4	16.7	3.33
H&S should be a value and not a priority	0.0	10.5	31.6	10.5	26.3	21.1	3.16
Accidents are part of the job	0.0	15.8	63.2	21.1	0.0	0.0	2.05
Cost, quality, and time are more important than H&S	0.0	31.6	63.2	0.0	5.3	0.0	1.79

Table 2B: Post-seminar responses

Research – Findings (5)

Statement	MS		Diff (%)
	Pre	Post	
All accidents are preventable	3.00	4.11	37.0
H&S is concerned with the sustainability of the industry	3.16	4.32	36.7
'I am my brother's keeper'	3.26	4.42	35.6
Designers can quantify risk at design stage	3.26	4.05	24.2
Designers can eliminate hazards at design stage	3.16	3.84	21.5
Procurement influences construction H&S	3.47	4.16	19.9
The benefits of H&S exceed the costs thereof	3.26	3.89	19.3
H&S should be a value and not a priority	2.68	3.16	17.9
H&S is more important than cost, quality, and time	3.53	4.05	14.7
Designers can identify hazards at design stage	3.68	4.21	14.4
Designers should conduct constructability reviews	3.79	4.26	12.4
Design can positively influence H&S	3.89	4.21	8.2
Design influences H&S	4.00	4.32	8.0
Designers can mitigate hazards at design stage	3.89	4.16	6.9

Table 3A: Pre-seminar versus post-seminar responses

Research – Findings (6)

Statement	MS		Diff (%)
	Pre	Post	
Design contributes to accidents	3.26	3.47	6.4
Tertiary designer education should include construction H&S	4.21	4.47	6.2
Design influences construction	4.16	4.37	5.0
‘Designing for H&S’ is a designer competency	3.68	3.84	4.3
Evaluation of project performance should include H&S	4.26	4.37	2.6
H&S is related to constructability	3.84	3.94	2.6
H&S is concerned with preventing injuries	4.21	4.11	(2.4)
Designers should consider their designs relative to construction	4.32	4.21	(2.5)
Design can negatively influence H&S	3.79	3.68	(2.9)
H&S is concerned with compliance with legislation	3.63	3.37	(7.2)
Cost, quality, and time are more important than H&S	1.95	1.79	(8.2)
Accidents are unplanned events	3.67	3.33	(9.3)
Construction is inherently dangerous	3.74	3.33	(11.0)
Accidents are part of the job	2.42	2.05	(15.3)

Table 3B: Pre-seminar versus post-seminar responses

Conclusions

- **Given the pre-seminar MSs, delegates did have an understanding and appreciation of construction H&S and the role of designing for construction H&S**
- **However, given that they attended the seminar they are likely to constitute the more committed and possibly more knowledgeable designers in terms of construction H&S and ergonomics**
- **The seminar did have an impact in terms of inducing a change in the delegates' culture - training can induce a change in culture**
- **However, training needs to identify misperceptions and focus on correcting such misperceptions**
- **Important to quantify the impact of training interventions as it is important to assess the impact of H&S induction**

Recommendations

- **Tertiary designer built environment education should address construction H&S and ergonomics, and highlight the role thereof in overall project performance**
- **‘Designing for construction H&S and ergonomics’ should be included in such programmes, and the assessment and evaluation of design projects should include construction H&S and ergonomics as a criterion**
- **Accreditation panels should review the extent to which construction H&S and ergonomics is addressed in such programmes**
- **Design practices should evolve a formal ‘designing for construction H&S and ergonomics’ process:**
 - **Follow a documented process in terms of design HIRAs**
 - **Record the residual risk remaining after the raw risk has been addressed in the ‘design’ report submitted to the client for amendment of the client’s H&S Specification**

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