Construction Ergonomics: Temporary Works' Manufacturers' Perceptions and Practices

John Smallwood(✉)

Department of Construction Management, Nelson Mandela University,
PO Box 77000, Port Elizabeth 6031, South Africa
john.smallwood@mandela.ac.za

Abstract. Temporary works designers influence construction ergonomics directly and indirectly. The direct influence is because of design, details, and method of connecting, and depending upon the type of procurement system, supervisory, and administrative interventions. The indirect influence is because of the type of procurement system used, pre-qualification, project duration, partnering, and the facilitating of pre-planning. A questionnaire survey was administered among attendees attending an in-house support work designer and supplier 'designing for construction ergonomics' workshop. Findings include: a range of temporary works design related aspects impact on construction ergonomics, and the respondents' organisation considers/refers to such aspects frequently, and on a range of design, procurement, and construction occasions. Experience predominates in terms of how ergonomics knowledge was acquired. It is concluded that respondents contribute to construction ergonomics, but there is potential for enhanced contributions. Recommendations include that tertiary-built environment education should address temporary works design and construction H&S and ergonomics, temporary works design standards should highlight designing for construction H&S and ergonomics, and practice notes, and continuing professional development (CPD) should be evolved.

Keywords: Construction · Designers · Ergonomics · Temporary works

1 Introduction

The definition of 'designer' in the South African Construction Regulations [1] includes, inter alia, a competent person who designs temporary work, including its components. According to the South African Construction Regulations [1], designers must take cognisance of ergonomic design principles during the design stage to minimise ergonomic related hazards in all phases of the life cycle of a structure. This alludes to the term 'designing for safety', which Behm [2] defines as "The consideration of construction site safety in the preparation of plans and specifications for construction projects." Thorpe [3] in turn contends that design is an important stage of projects, as it is at this stage that conceptual ideas are ideally converted into constructable realities. Furthermore, 'designing for H&S' is one of the designing for constructability principles. Thorpe [3] further states that designing for safety is one of a range of considerations that need to be balanced simultaneously during design.

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The Construction Regulations and international literature highlight the relevance of designing for H&S and ergonomics, which resulted in a study that was conducted among staff of a major multinational temporary works designer and supplier, the objectives being to determine relative to their organisation and personally:

- Importance of ergonomics during seven temporary works stages of projects;
- Frequency at which construction ergonomics is considered on various occasions and relative to various temporary works design related aspects;
- Extent to which various temporary works design related aspects impact on construction ergonomics, and
- Rating, and source of ergonomics knowledge.

2 Review of the Literature

2.1 Health and Safety Legislation and Recommendations Pertaining to Designers

Prior to the promulgation of the Construction Regulations, all designers were required to address H&S, as in terms of Section 10 of the Occupational H&S Act [4] designers are allocated the responsibility to ensure that any 'article' is safe and without risks when properly used. This includes buildings and structures. In terms of the South African Construction Regulations [1], clients and designers, including temporary works designers, have responsibilities with respect to construction H&S and ergonomics.

Clients are required to, inter alia, prepare an H&S specification based on their baseline risk assessment (BRA), which is then provided to designers. They must then ensure that the designer takes the H&S specification into account during design, and that the designers carry out their duties in terms of Regulation 6 'Duties of designers'. Thereafter, clients must include the H&S specification in the tender documentation, which in theory should have been revised to include any relevant H&S information included in the designer report as discussed below.

Designers in turn are required to, inter alia: consider the H&S specification; submit a report to the client before tender stage that includes all the relevant H&S information about the design that may affect the pricing of the work, the geotechnical-science aspects, and the loading that the structure is designed to withstand; 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; modify the design or make use of substitute materials where the design necessitates the use of dangerous procedures or materials hazardous to H&S, and consider hazards relating to subsequent maintenance of the structure and make provision in the design for that work to be performed to minimise the risk. To mitigate design originated hazards, requires hazard identification and risk assessment (HIRA) and appropriate responses, which process should be structured and documented.

In terms of the Draft Ergonomics Regulations [5] '5.1 Designers of machinery, equipment or articles for use at work, must: eliminate ergonomic risk factors from the design, or where this is not reasonably practicable, must minimise the ergonomic risk factors that workers may be exposed to in each possible use of the items; provide information regarding the ergonomic risk factors identified and the controls to the manufacturer, so that the manufacturer may take action where reasonably practicable to eliminate or minimise residual ergonomic risk factors, and provide information to the manufacturer for potential users involved in each phase of the lifecycle regarding the ergonomic risk factors that he/she could not eliminate, and the conditions for safe use. Although these are draft regulations, they are not onerous, and merely require design HIRAs, and appropriate responses.

Furthermore, the International Labour Office (ILO) [6] as early as 1992 recommended that designers should: receive training in H&S; integrate the H&S of construction workers into the design and planning process, and not include anything in a design which would necessitate the use of dangerous structural or other procedures or hazardous materials which could be avoided by design modifications or by substitute materials.

3 Research

A questionnaire survey was administered among staff of a major international temporary works designer and supplier attending an in house 'designing for construction ergonomics' workshop presented by the author.

A previous study conducted among engineers in South Africa to determine their perceptions and practices with respect to construction H&S investigated the: frequency at which construction H&S is considered on various occasions and relative to various design related aspects; extent to which various design related aspects impact on construction H&S; source of H&S knowledge, and the potential of various aspects to contribute to an improvement in construction H&S [7]. The study reported on constitutes a replication of this prior study, which study in turn constitutes the origin of the occasions, aspects, and sources.

Table 1 indicates the importance of ergonomics to respondents' organisations during seven temporary works stages of projects in terms of percentage responses to a scale of 1 (not important) to 5 (very important), and a MS ranging between 1.00 and 5.00. It is notable that the MSs are all above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the parameters as important to their organisation. However, given that the MSs for all the parameters are $>4.20 \leq 5.00$, the respondents can be deemed to perceive them to be between more than important to very important/very important. It is notable that supply of equipment is ranked first and detailed design (Stage 3) second. Concept and feasibility (Stage 2), and project initiation and briefing (Stage 1) are ranked third and fourth respectively.

Table 1. Importance of ergonomics to respondents during seven temporary works stages of projects.

Stage	Response (%)						MS	R
	Unsure	Not……Very						
		1	2	3	4	5		
Supply of equipment	8.7	0.0	0.0	4.3	26.1	60.9	4.62	1
Detailed design	4.3	0.0	0.0	8.7	26.1	60.9	4.55	2
Concept and feasibility	13.0	0.0	0.0	13.0	17.4	56.5	4.50	3
Project initiation and briefing	17.4	0.0	0.0	8.7	26.1	47.8	4.47	4
Construction documentation and management	8.7	0.0	4.3	4.3	39.1	43.5	4.33	5
Project close out	13.0	0.0	4.3	17.4	13.0	52.2	4.30	6
Tender documentation and procurement	13.0	0.0	0.0	13.0	39.1	34.8	4.25	7

Table 2 presents the frequency at which the respondents' organisation considers or refers to construction ergonomics on fourteen occasions in terms of percentage responses to a frequency range, never to always, and a MS ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint of the range, namely 3.00, which indicates the consideration of or reference to construction ergonomics on these occasions can be deemed to be prevalent.

It is notable that 6/14 (42.9%) occasions have MSs $>4.20 \leq 5.00$ – between often to always/always. 3 are upstream, 1 is midstream, 1 is downstream, and 1 is triple-stream. 7/14 (50%) of the occasions have MSs $>3.40 \leq 4.20$ – between sometimes to often/often. 3 are 'upstream', 1 is 'midstream', 2 are 'downstream', and 1 is triple-stream. Only one MSs is $>2.60 \leq 3.40$ – between rarely to sometimes/sometimes, namely discussion of H&S plan, which is midstream.

Table 2. Frequency at which respondents' organisation considers/refers to construction ergonomics on various occasions.

Occasion	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Always		
Design (U)	4.3	0.0	0.0	0.0	30.4	65.2	4.68	1
Detailed design (U)	4.3	0.0	0.0	0.0	39.1	56.5	4.59	2
Discussions with the principal contractor (U, M, D)	4.3	0.0	0.0	0.0	52.2	43.5	4.45	3
Site visits/inspections (D)	4.3	0.0	0.0	8.7	39.1	47.8	4.41	4
Working drawings (U)	4.3	0.0	4.3	8.7	34.8	47.8	4.32	5
Equipment delivery (M)	4.5	0.0	9.1	0.0	40.9	45.5	4.29	6
Client (Contractor) meetings (U, M, D)	8.7	0.0	4.3	13.0	34.8	39.1	4.19	7
Project progress meetings (D)	13.0	0.0	0.0	21.7	43.5	21.7	4.00	8
Design coordination meetings (U)	9.1	0.0	13.6	4.5	40.9	31.8	4.00	9

(*continued*)

Table 2. (*continued*)

Occasion	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Always		
Project close out reports (D)	26.1	0.0	8.7	13.0	30.4	21.7	3.88	10
Deliberating project duration (U)	8.7	4.3	4.3	17.4	39.1	26.1	3.86	11
Preparing project documentation (M)	4.3	4.3	4.3	26.1	43.5	17.4	3.68	12
Constructability reviews (U)	27.3	0.0	4.5	40.9	9.1	18.2	3.56	13
Discussion of H&S plan (M)	14.3	4.8	19.0	28.6	9.5	23.8	3.33	14

Table 3 presents the frequency at which the respondents' organisation considers/refers to construction ergonomics relative to fifteen temporary works design related aspects, in terms of percentage responses to a frequency range, never to always, and a MS ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint of 3.00, which indicates consideration of/reference to H&S relative to these temporary works design related aspects can be deemed to be prevalent.

It is notable that 5/15 (33.3%) MSs fall within the range $>4.20 \leq 5.00$ – between often to always/always, and 9/15 (60%) MSs are $>3.40 \leq 4.20$ – between sometimes to often/often. The remaining MS, which is virtually in the upper range, is $>2.60 \leq 3.40$ – between rarely to sometimes/sometimes.

The top six ranked occasions predominate, namely method of connecting, method of fixing, details, specification, mass of components, and design of temporary works (general).

Table 3. Frequency at which respondents' organisation considers/refers to construction ergonomics relative to various temporary works design related aspects.

Problem	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Always		
Method of connecting	8.7	0.0	0.0	8.7	43.5	39.1	4.33	1
Method of fixing	8.7	0.0	0.0	8.7	43.5	39.1	4.33	2
Details	4.3	0.0	4.3	13.0	26.1	52.2	4.32	3
Specification	8.7	0.0	4.3	13.0	30.4	43.5	4.24	4
Mass of components	8.7	0.0	4.3	17.4	21.7	47.8	4.24	5
Design of temporary works (general)	4.5	0.0	4.5	13.6	36.4	40.9	4.19	6
Surface area of components	8.7	0.0	8.7	13.0	34.8	34.8	4.05	7
Finish of components	4.3	0.0	4.3	17.4	43.5	30.4	4.05	8
Elevations	4.3	0.0	8.7	21.7	26.1	39.1	4.00	9
Position of components	8.7	0.0	8.7	17.4	30.4	34.8	4.00	10
Plan layout	4.3	0.0	17.4	8.7	26.1	43.5	4.00	11
Sectional area of components	13.0	0.0	8.7	17.4	30.4	30.4	3.95	12
Site location	8.7	4.3	4.3	26.1	34.8	21.7	3.71	13
Edge (s) of components	17.4	0.0	17.4	17.4	26.1	21.7	3.63	14
Texture of components	21.7	4.3	17.4	21.7	13.0	21.7	3.39	15

Table 4 indicates the perceived impact of fifteen temporary works design related aspects on construction ergonomics, in terms of percentage responses to 'does not' and a scale of 1 (minor) to 5 (major), and a MS ranging between 0.00 and 5.00. Given that a 'does not' option was provided, the scale effectively consists of six points, and hence the MS range. It is notable that all fifteen MSs are above the midpoint of 2.50, which indicates the respondents perceive the design related aspects to impact on construction ergonomics.

It is notable that 7/15 (46.7%) MSs are $>4.17 \leq 5.00$ - between a near major to major impact/major impact. The remaining 8/15 (53.3%) aspects' MSs are $>3.34 \leq 4.17$, which indicates that they have between an impact and a near major impact/near major impact on construction ergonomics.

Table 4. Extent to which various temporary works design related aspects impact on construction ergonomics.

Aspect	Response (%)							MS	R
	Unsure	Does not	Minor…….. Major						
			1	2	3	4	5		
Details	4.3	0.0	0.0	4.3	4.3	30.4	56.5	4.45	1
Method of connecting	8.7	0.0	0.0	0.0	13.0	26.1	52.2	4.43	2
Method of fixing	8.7	0.0	0.0	0.0	13.0	26.1	52.2	4.43	3
Specification	8.7	0.0	0.0	0.0	17.4	30.4	43.5	4.29	4
Plan layout	4.3	0.0	0.0	4.3	13.0	30.4	47.8	4.27	5
Design of temporary works (general)	4.3	0.0	0.0	8.7	4.3	34.8	47.8	4.27	6
Mass of components	4.3	0.0	0.0	0.0	26.1	21.7	47.8	4.23	7
Elevations	8.7	0.0	0.0	4.3	17.4	30.4	39.1	4.14	8
Surface area of components	13.0	4.3	0.0	4.3	21.7	21.7	34.8	3.85	9
Finish of components	9.1	4.5	0.0	4.5	22.7	31.8	27.3	3.75	10
Site location	8.7	8.7	0.0	4.3	17.4	26.1	34.8	3.71	11
Position of components	13.0	4.3	8.7	0.0	17.4	26.1	30.4	3.65	12
Sectional area of components	17.4	4.3	8.7	0.0	17.4	26.1	26.1	3.58	13
Edge (s) of components	21.7	4.3	4.3	4.3	21.7	17.4	26.1	3.56	14
Texture of components	8.7	4.3	4.3	4.3	34.8	21.7	21.7	3.43	15

Experience (39.1%) predominates in terms of respondents' source of ergonomics knowledge, followed by workshops (26.1%), tertiary education (17.4%), magazine articles (13.1%), and other (13.1%). Post graduate qualifications were only identified by 4.1% of respondents, and conference papers, CPD seminars, journal papers, and practice notes by no respondents. Respondents' source of ergonomics knowledge is informal as opposed to formal.

Table 5 indicates the respondents' self-rating of their knowledge of ergonomics, construction ergonomics, and 'designing for ergonomics' skills in terms of percentage responses to a scale of 1 (limited) to 5 (extensive), and a MS ranging between 1.00 and

5.00. Given that the MSs are ≤ 3.00, the knowledge can be deemed to be limited as opposed to extensive. However, all three MSs are >2.60 $\leq$ 3.40 – less than average to average/average.

Table 5. Respondents' self-rating of their knowledge with respect to ergonomics aspects.

Aspect	Response (%)						MS	R
	Unsure	Limited……. Extensive						
		1	2	3	4	5		
Ergonomics	4.3	21.7	0.0	56.5	13.0	4.3	2.77	1
Designing for construction ergonomics	4.3	21.7	8.7	43.5	13.0	8.7	2.77	2
Construction ergonomics	4.3	17.4	8.7	56.5	8.7	4.3	2.73	3

4 Conclusions

Construction ergonomics is more important during the supply of equipment, detailed design, concept and feasibility, and project initiation and briefing temporary works stages of projects, than the midstream and downstream stages of construction documentation and management, project close out, and tender documentation and procurement. Therefore, it can be concluded that the respondents' organisation understands and appreciates that ergonomics can be influenced more during the upstream than downstream stages. This is underscored by the extent the respondents' organisation could influence construction ergonomics during the detailed design, supply of equipment, and concept and feasibility temporary works stages of projects.

The respondents' organisation does consider construction ergonomics on various occasions, however, more so during upstream phases than mid-stream phases, design (upstream), detailed design (upstream), and discussions with the principal contractor (upstream, midstream, downstream). Therefore, it can be concluded that the cited importance thereof does manifest itself. Furthermore, the MSs relative to the top 6/14 (42.9%) indicate a frequency of often to always/always.

The respondents' organisation considers/refer to construction ergonomics relative to fifteen temporary works design related aspects. The top five (33.3%) aspects, namely method of connecting, method of fixing, details, specification, and mass of components, have MSs, which indicate a frequency of often to always/always. The frequency relative to mass of components is notable due to the manual handling of components, and relative to the other aspects, which impact on construction ergonomics.

Respondents do appreciate the extent to which various temporary works design related aspects impact on construction ergonomics in that they maintain 7/15 (46.7%) aspects have between a near major to major impact/major impact, and 8/15 (53.3%) an impact to near major impact/near major impact thereon.

Given the sources of respondents' ergonomics knowledge it can be concluded that the sources are more informal than formal. It can also be concluded that tertiary built environment education and the related professions are not addressing ergonomics to the extent that they should. These conclusions are reinforced by the respondents' 'below average' self-rating of their knowledge of 'ergonomics', 'designing for construction ergonomics', and 'construction ergonomics' skills.

5 Recommendations

Tertiary built environment education should address temporary works design and construction H&S and ergonomics and highlight the role thereof in overall project performance. Furthermore, designing for construction H&S and ergonomics, temporary works design included, should be introduced and more importantly, embedded in tertiary built environment education programmes.

Temporary works design standards should highlight designing for construction H&S and ergonomics, and practice notes, and continuing professional development (CPD) should be evolved. The Ergonomics Regulations should be promulgated the soonest.

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