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ERGONOMICS IN THE CONSTRUCTION INDUSTRY

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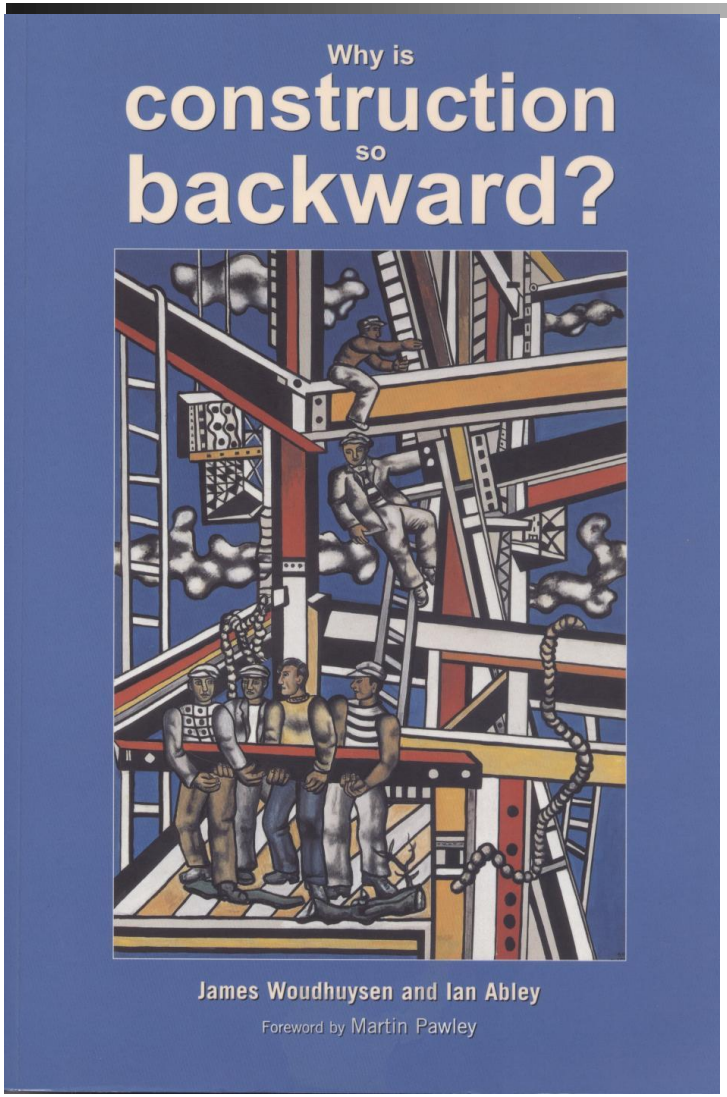
Why is construction so backward?



(Woudhysen and Abley, 2004)

Introduction

- Definition: the study of work, or the work system, including the worker, his / her tools, and his / her workplace
- Construction, by its very nature, is a problem in ergonomics:
  - Work above shoulder level and below knee height
  - Materials may be heavy and/or inconveniently sized and shaped
- Rates of sprains and strains in U.S. Construction - 2nd highest (all industries)
- Sprains and strains predominate among nature of injuries and illness (days off work)
- Back injuries in U.S. construction - 2nd highest (all industries)

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OH hazards in construction (1)

Problem	II				Rank			
	GCs	SAIB	Workers	Mean	GCs	SAIB	Workers	Mean
Chemicals:								
Acids / Alkalis	0.44	1.44	0.63	0.84	28	21	23=	25
Bitumen / Pitch / Tar	0.94	0.82	0.30	0.69	22	28	28	28
Epoxy-resins	0.83	1.07	0.56	0.82	23	25	26	27
Fumes:								
Metal cutting	1.73	2.00	1.23	1.65	14=	1=	20	16
Soldering / Welding	1.35	1.85	0.63	1.28	19	15=	23=	19
Waterproofing	0.75	1.11	0.63	0.83	25	24	23=	26
Mineral wools	0.25	0.78	-	0.52	29	29	-	29
Oils / Petrol	1.73	2.00	1.72	1.82	14=	11=	14	13
Vapours (Adhesives / Paints / Solvents)	1.42	1.82	1.61	1.62	17=	17	16	17
Cold	1.06	1.00	1.36	1.14	20	27	19	22
Dusts:								
Asbestos	0.65	1.56	0.39	0.87	26	20	27	24
Block / Brick	2.06	2.56	1.95	2.19	11	3	12	12
Cement	2.65	2.70	2.46	2.60	1=	1	10	4
Concrete	2.50	2.30	2.28	2.36	4	8=	11	10
Quartz	0.78	1.06	1.71	1.18	24	26	15	20

Table 1: Occupational health problems according to management and workers (II: 0-4) (adapted from Smallwood and Ehrlich, 1999) (Part A).

OH hazards in construction (2)

Problem	II				Rank			
	GCs	SAIB	Workers	Mean	GCs	SAIB	Workers	Mean
Ergonomic: Bending / Twisting the back	2.46	2.30	3.34	2.70	5	8=	1	2
Climbing and descending	2.65	2.63	3.16	2.81	1=	2	3	1
Handling heavy loads	2.56	2.44	2.87	2.62	3	4=	8	3
Reaching away from the body	2.19	2.22	3.08	2.50	8	10	4	7
Reaching overhead	2.15	2.41	2.98	2.51	9=	6	7	6
Repetitive movements	2.21	1.89	3.22	2.44	7	13=	2	8
Use of body force	2.15	1.85	3.01	2.34	9=	15=	5	11
Vibration	1.85	1.59	1.57	1.67	13	19	17	15
Heat	1.42	1.89	1.88	1.73	17=	13=	13	14
Illumination (Poor)	1.00	1.30	1.21	1.17	21	23	21	21
Noise	2.04	2.44	2.66	2.38	12	4=	9	9
Sun exposure	2.40	2.37	2.99	2.59	6	7	6	5
Ventilation (Poor)	0.56	1.41	0.90	0.96	27	22	22	23
Wet or damp work	1.44	1.74	1.44	1.54	16	18	18	18

Table 1: Occupational health problems according to management and workers (II: 0-4) (adapted from Smallwood & Ehrlich, 1999) (Part B).

Nature of ergonomic problems (1)

- Six trades in the USA (top five scored / 10) (Zimmerman et al., 1997):
  - Working in the same position for long periods - 5.67 (1st)
  - Bending or twisting the back - 5.46 (2nd)
  - Working in awkward/cramped positions - 5.00 (3rd)
  - Working when injured or hurt - 4.69 (4th)
  - Handling heavy materials or equipment - 4.63 (5th)

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Nature of ergonomic problems (2)

Problem	GC*		Worker*		Worker**		Mean	
	II	Rank	II	Rank	II	Rank	II	Rank
Repetitive movements	3.29	1	3.56	1	2.97	3	3.27	1
Climbing and descending	2.88	2	3.01	4	3.23	1	3.04	2
Use of body force	2.80	3	2.82	8	2.77	5	2.80	3
Handling heavy materials	2.63	4=	2.68	10=	3.00	2	2.77	4
Exposure to noise	2.53	7	2.93	6	2.65	6	2.70	5
Bending or twisting the back	1.96	11	3.47	2	2.38	7	2.60	6
Reaching away from the body	2.41	8	3.19	3	2.03	12	2.54	7
Reaching overhead	2.61	6	2.99	5	2.00	13	2.53	8
Working in hot conditions	2.29	9	2.68	10=	2.15	10	2.37	9
Handling heavy equipment	2.03	10	2.17	13	2.87	4	2.36	10
Working in awkward positions	1.70	12	2.85	7	2.30	9	2.28	11
Staying in the same position for long periods	1.29	17	2.76	9	2.30	8	2.12	12
Working in cramped positions	1.46	15	2.48	12	2.13	11	2.02	13
Vibrating tools and equipment	2.63	4=	1.43	16	1.96	14	2.01	14
Working in cold conditions	1.38	16	1.80	14	1.85	15	1.68	16
Working in humid conditions	1.60	13	1.53	15	1.66	17	1.60	16
Working in wet conditions	1.57	14	1.21	17	1.70	16	1.49	17
Working while injured or hurt	0.19	18	0.84	18	0.48	18	0.50	18

Table 2: Ergonomic problems encountered in construction according to management and workers (II: 0-4) (adapted from Smallwood, 1997*; Smallwood, Deacon and Venter, 2000).**

Nature of ergonomic problems (3)

Problem	Response (%)						II	Rank
	Daily	Daily to weekly	Weekly to fort-nightly	Fort-nightly to monthly	Never	Don't know		
Repetitive movements	77.8	22.2	0.0	0.0	0.0	0.0	3.78	1
Climbing and descending	55.6	44.4	0.0	0.0	0.0	0.0	3.56	2
Handling heavy materials	44.4	55.6	0.0	0.0	0.0	0.0	3.44	3
Bending or twisting the back	66.7	11.1	22.2	0.0	0.0	0.0	3.22	4=
Working in awkward positions	44.4	44.4	0.0	11.2	0.0	0.0	3.22	4=
Reaching overhead	33.3	55.5	0.0	11.2	0.0	0.0	3.11	6=
Vibrating tools and equipment	33.3	55.6	11.1	0.0	0.0	0.0	3.11	6=
Exposure to noise	33.4	44.4	22.2	0.0	0.0	0.0	3.11	6=
Use of body force	33.3	33.3	33.4	0.0	0.0	0.0	3.00	9
Handling heavy equipment	44.4	11.2	22.2	22.2	0.0	0.0	2.78	10
Working in cramped positions	22.2	44.4	11.2	22.2	0.0	0.0	2.67	11
Reaching away from the body	25.0	37.5	12.5	25.0	0.0	0.0	2.63	12
Working in hot conditions	22.2	22.2	22.2	33.4	0.0	0.0	2.33	13
Staying in the same position for long periods	22.2	11.1	33.4	22.2	11.1	0.0	2.11	14
Working in humid conditions	11.1	22.2	22.2	33.4	11.1	0.0	1.89	15
Working in wet conditions	0.0	22.2	22.2	55.6	0.0	0.0	1.67	16
Working in cold conditions	0.0	22.2	0.0	55.6	22.2	0.0	1.22	17
Working while hurt or injured	11.1	0.0	11.1	55.6	22.2	0.0	0.44	18

Table 3: Frequency at which ergonomic related problems are encountered by both GC and SC workers according to GCs (II: 0-4) (Smallwood, 2002).

Ergonomic problems related to trades and solutions (1)

Team of industrial hygienists observed 15 month 4-storey office building - hazards and design / construction solutions (Schneider and Susi, 1994):

- Concreting:
  - P: shoveling
  - S: plasticisers
- Reinforcing:
  - P: rapid repetitive twisting of the wrist and bending
  - S: fabric reinforcing or trestles
- Formwork:
  - P: bending, twisting and body force
  - S: composite systems (standardisation of design) precast and pre-stressing

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Ergonomic problems related to trades and solutions (2)

Tying reinforcing – bending, rapid repetitive movements etc. (Deacon, 2004)

Ergonomic problems related to trades and solutions (3)

- **Structural steelwork:**
  - **P: awkward postures, repetitive movements and use of pneumatic tools and lifting**
  - **S: preassembly, simplified joints and integral safety features**
- **Masonry:**
  - **P: lifting / trunk-twist flexions**
  - **S: waist high materials platform and hand holds in blocks**
- **Roofing:**
  - **P: materials handling**
  - **S: sheet type materials and ladder type tile lifts**

Ergonomic problems related to trades and solutions (4)

- **Building fabric:**
  - **P: hand-arm vibration (bush-hammering) and handling heavy materials (natural stone)**
  - **S: curtain walling**
- **Plumbing and drainage/pipefitting:**
  - **P: reaching overhead and awkward postures (among other)**
  - **S: prefabrication of stacks, and suitable ducts**
- **Electrical:**
  - **P: bending of the wrist and working in cramped spaces**
  - **S: coordination of and adequate provision for services**

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Ergonomic problems related to trades and solutions (5)

- Floor finishes:
  - P: kneeling and bending, handling heavy materials and considerable hand and wrist motion
  - S: specify finishes requiring limited work
- Suspended ceilings:
  - P: reaching overhead
  - S: 'drop-in' tiles versus 'screw-up' and mobile tower scaffolds
- Painting and decorating:
  - P: reaching away and overhead
  - S: specify self-finishes where possible

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Impact of various stages of a project on construction ergonomics

Stage	Response (%)						II	Rank
	Minor……Major					Don't know		
	1	2	3	4	5			
Structure:								
Structural steel	0.0	0.0	22.2	33.4	44.4	0.0	3.22	1
Reinforced concrete	0.0	11.1	0.0	55.6	33.3	0.0	3.11	2
Roof	0.0	0.0	22.2	55.6	22.2	0.0	3.00	3
Cladding/External fabric	0.0	0.0	33.3	55.5	11.1	0.0	2.78	4
Installation of services (structure)	0.0	11.1	33.4	44.4	11.1	0.0	2.56	5=
Ceilings	11.1	33.4	22.2	22.2	33.4	0.0	2.56	5=
Walling / Partitions	11.1	11.1	44.4	33.4	11.1	0.0	2.11	7=
External works	0.0	33.3	33.3	22.2	11.1	0.0	2.11	7=
Finishes	11.1	33.4	22.2	33.3	0.0	0.0	1.78	9
Site clearance and earthworks	22.2	22.2	33.4	22.2	0.0	0.0	1.56	10

Table 4: The impact of various stages of a project on construction ergonomics according to GCs (II: 0-4) (Smallwood, 2002).

Ergonomics and cost

- Inadequate / poor ergonomics → injuries & fatalities
- Workers' compensation (WC) insurance covers direct cost of accidents (COA)
- Indirect COA e.g. reduced productivity, overtime etc. can be up to 20 times direct costs
- COA = + / - 6.5% value of completed construction (USA)
- COA = 8.5% of tender price (UK)
- WC insurance is a labour overhead

Ergonomics Case Study (1)

UPE Main Building (Smallwood, 2001)

Ergonomics Case Study (2)

UPE Main Building 'spalling' concrete repairs:

- Issues:
  - Work at elevated heights
  - High wind speeds
  - Need to access every cm2
  - Administration building – need to mitigate disruption to work
- Solution:
  - Double–decker perimeter scaffold
  - Design included in contract documents
  - Item included in BoQs
- Cost:
  - R 1.049m (20.3% of project value)

Ergonomics Case Study (3)

- **Benefits:**
  - **No fatalities or disabling injuries**
  - **Project completed on schedule**
  - **Optimum access:**
    - **Work**
    - **Inspections**

Multi-stakeholder influence (1)

- Clients:
  - Select (often) type of structural frame, fabric, materials and finishes (direct)
  - Choice of procurement system, select site, decide on project duration and pre-qualify contractors (indirect)
- Designers:
  - Design, select type of structural frame, detail, materials and finishes (direct)
  - Choice of procurement system, select site, and coordinate design (indirect)
- Contractors:
  - Planning:
    - Programming
    - Site layout

Multi-stakeholder influence (2)

- Select methods
- Budget resources
- Select plant and equipment
- Mechanisation:
  - Circulation routes
  - Circulation roads
- Walkways / Platforms
- Materials handling
- SWPs
- Organising of work place e.g. scaffolding
- Maintenance
- Housekeeping
- Optimum coordination
- Innovation

Multi-stakeholder influence (3)

- **Manufacturers (material):**
  - **Unit size, mass, centroid, surface area, sectional area, constituents, texture and edges**
  - **Form of packaging affects off-loading and site handling**
  - **Provision of hand-holds**

Designing for ergonomics and H&S (1)

Precast concrete stair flights, Port Elizabeth (Smallwood)

Designing for ergonomics and H&S (2)

Precast concrete stair flights, Port Elizabeth (Smallwood)

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Designing for ergonomics and H&S (3)

Plank and hollow-block composite slab, Plettenberg Bay (Hamp-Adams, 1994)

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Designing for ergonomics and H&S (4)

Pre-cast pre-stressed hollow core slab section (SA Builder Bouer, 2004a)

Designing for ergonomics and H&S (5)

Pre-cast pre-stressed hollow core slab section (SA Builder Bouer, 2004b)

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Designing for ergonomics and OH (1)

‘Bush-hammered’ concrete, Port Elizabeth (Smallwood)

Designing for ergonomics and OH (2)

Thermal Lance, Mount Road Police Station, Port Elizabeth (Smallwood, 1987)

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Contractor interventions (1)

Empire State Building (Smallwood, 2011)

Contractor interventions (2)

Trolleys, Empire State Building (Berman, 2003)

Contractor interventions (3)

Trolleys, Empire State Building (Berman, 2003)

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Contractor interventions (4)

‘Ladder’ hoist, Delft, Netherlands (Haupt, 2004)

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Contractor interventions (5)

Toolbox hoist, Melbourne (Smallwood, 1992)

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Contractor interventions (6)

Lowering of brick page over pallet for hoisting to the required floor level, Port Elizabeth (Smallwood, 1991)

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Contractor interventions (7)

Pallet trolley used to move pallets of bricks at level of use, Port Elizabeth (Smallwood, 1991)

Contractor interventions (8)

Kerb lifter, United Kingdom (Godfrey, 2004)

Aspects which impact on construction ergonomics

Aspect	Response (%)						II	Rank
	Minor……..…..…….Major					Don't know		
	1	2	3	4	5			
Standard of site house keeping	0.0	0.0	11.1	66.7	22.2	0.0	3.11	1
Amount of work relative to project duration	0.0	22.2	0.0	44.4	33.4	0.0	2.89	2=
Format of materials	0.0	0.0	44.4	22.2	33.4	0.0	2.89	2=
General design	0.0	0.0	44.4	44.4	11.2	0.0	2.67	4=
Degree of contractor awareness relative to ergonomics	0.0	11.2	33.3	33.4	22.2	0.0	2.67	4=
Details	11.1	11.1	22.2	33.4	22.2	0.0	2.44	6=
Specification	11.1	11.1	22.2	33.4	22.2	0.0	2.44	6=
Degree of contractor planning	0.0	11.1	44.4	33.4	11.1	0.0	2.44	6=
Degree of mechanisation	0.0	11.1	44.4	33.4	11.1	0.0	2.49	9
Type of procurement system	0.0	44.4	33.4	22.2	0.0	0.0	1.78	10

Table 5: Extent to which various design, procurement and construction aspects impact on construction ergonomics according to GCs (II: 0-4) (Smallwood, 2002).

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Aspects / Interventions which could contribute to an improvement in ergonomics

Aspect	Response (%)						II	Rank
	Minor……Major					Don't know		
	1	2	3	4	5			
Awareness	0.0	0.0	0.0	33.3	66.7	0.0	3.67	1
Constructability (general)	0.0	0.0	0.0	44.4	55.6	0.0	3.56	2
Safe working procedures	0.0	0.0	11.1	33.3	55.6	0.0	3.44	3
General design	0.0	0.0	22.2	33.3	44.5	0.0	3.22	4=
Design of equipment (construction)	0.0	0.0	33.3	11.1	55.6	0.0	3.22	4=
Mechanisation	0.0	11.1	11.1	33.3	44.5	0.0	3.11	6=
Reengineering	0.0	11.1	11.1	33.3	44.5	0.0	3.11	6=
Details	0.0	0.0	33.3	22.2	44.5	0.0	3.11	6=
Contractor planning	0.0	0.0	22.2	44.5	33.3	0.0	3.11	6=
Design of tools	11.1	0.0	22.2	11.1	55.6	0.0	3.00	10
Prefabrication	0.0	11.2	22.2	33.3	33.3	0.0	2.89	11
Workshops on site	0.0	0.0	44.5	33.3	22.2	0.0	2.78	12
Specification	0.0	11.2	33.3	33.3	22.2	0.0	2.67	13

Table 6: Extent to which various design and construction aspects could contribute to an improvement in construction ergonomics according to GCs (II: 0-4) (Smallwood, 2002).

Barriers to an improvement in ergonomics

Material	Response (%)	No response (%)	Responses within range (%)
Solid clay brick	82.1	17.9	23.4
Two-cell concrete block	83.3	16.7	1.5
Precast concrete kerb	83.3	16.7	9.2
Double Roman concrete roof tile	83.3	16.7	10.8
m^2 glass 5 mm thick	76.9	23.1	3.4
Concrete	73.1	26.9	19.6
Marble	66.7	33.3	17.3
Sandstone	66.7	33.3	5.8
Steel	64.1	35.9	8.2
Mean	75.5	24.5	11.0

Table 7: Summary of response and responses within a 10% range of the actual mass or density (Smallwood, 2011)

Key points (1)

- Construction constitutes a challenge in terms of ergonomics
- Ergonomics impacts on cost, productivity, quality, and time
- Bending or twisting the back, climbing and descending, exposure to noise, handling heavy materials, repetitive movements and use of body force, predominate among the nature of ergonomics problems
- Structure and roof predominate in terms of the impact of stages of a project on construction ergonomics
- Ergonomics enhances productivity, quality, time, profitability and reduces project risk

Key points (2)

- All stakeholders influence construction ergonomics: clients; designers; PMs; QSs; contractors, and manufacturers
- Design, procurement and construction related issues impact on construction ergonomics
- Numerous design and construction interventions can contribute to an improvement in construction ergonomics

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