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MASS AND DENSITY OF MATERIALS: CIVIL ENGINEERING STUDENTS' KNOWLEDGE AND PERCEPTIONS

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Introduction (1)

- Materials may be heavy and / or inconveniently sized and shaped, thus presenting manual materials handling problems (Schneider & Susi, 1994; Monk, 2005)
- 62% of back injuries are attributable to manual materials handling (Construction Safety Association of Ontario,1993)
- One-third of all construction industry accidents reported to the Health & Safety Executive (HSE) (2000) in the United Kingdom involve manual handling
- South African Construction Regulations (Republic of South Africa, 2014):
  - Regulation 5 (1) (g) requires that clients ensure that potential principal contractors (PCs) have made provision for the cost of H&S in their tenders. Clearly engineering designers need to facilitate such provision

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Introduction (2)

- Structures 6 (1) designers of a structure must, *inter alia*:
  - 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, and the geotechnical-science aspects
  - Furthermore, designers are required to modify the design or make use of substitute materials where the design necessitates the use of dangerous procedures or materials hazardous to H&S. Consequently designers need to conduct design hazard identification and risk assessments (HIRAs) before finalising a design, bills of quantities, and contract documentation
- Contractors in turn must identify the hazards and the risks to which persons may be exposed
- However, a pre-requisite for conducting of design or construction HIRAs is knowledge of the mass and density of materials

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Introduction (3)

- Handling heavy materials – ranked 3 / 18 ergonomics problems in three previous self-administered questionnaire based research studies conducted in South Africa (Smallwood, 1997; Smallwood *et al.*, 2000; Smallwood, 2002)
- Ergonomic aspects requiring attention - 92.6% of workers indentified materials handling (ranked 1 / 9) (Smallwood *et al.*, 2000)
- The aforementioned highlight the relevance of ergonomics and the mass and density of materials to the Civil Engineering discipline, whether it is practiced within the context of design or construction

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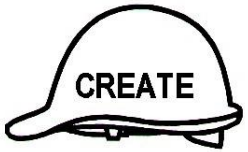
Designing for ergonomics (1)

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

Designing for ergonomics (2)



An example of a generic risk assessment form (GRA)				
NAME OF ORGANISATION				
NAME OF PROJECT				
ACTIVITY COVERED	Erecting precast plank and hollow block composite slab			
SIGNIFICANT HAZARDS		ASSESSMENT OF RISK		
		LOW	MEDIUM	HIGH
1	People falling			3 X 3 = 9
2	Materials falling			3 X 2 = 6
3	Collapse of structure	1 X 3 = 3		
4	Pinching	3 X 1 = 3		
5	Manual handling			3 x 2 = 6
6	Tripping			3 x 2 = 6
7	Failure of blocks (material)			2 X 3 = 6

Figure 1: Design HIRA for erecting precast plank and hollow block composite slab

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Designing for ergonomics (3)

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

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Designing for ergonomics (4)

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

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Objective

- Given the role of manual materials handling, and in particular, heavy materials, in the occurrence of injuries, the role of designers in mitigating, reducing, and controlling such injuries, and the importance of knowledge of the mass and density of materials in terms of conducting risk assessments, a study was conducted to determine civil engineering students':
  - Knowledge relative to the mass and density of materials
  - Perceptions relative to the mass and density of materials relative to construction ergonomics

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Research – Sample stratum

The sample stratum consisted of third-year BSc (Civil Engineering) students

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Research – Method

- The questionnaire consisted of six closed ended questions, two of which consisted of five and four sub-questions pertaining to the mass and density of materials respectively
- The other four questions were five-point likert scale type questions
- The survey was administered at the inception of the presentation of a health and safety (H&S) lecture at third year level
- 98 Responses were included in the analysis of the data
- Mean scores (MSs) are between 1.00 (lower end) and 5.00 (upper end), 3.00 being the midpoint

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Summary of mass and density responses

Material	Response (%)	No response (%)
Solid clay brick	99.0	1.0
Two-cell concrete block	99.0	1.0
Precast concrete kerb	93.9	6.1
Double Roman concrete roof tile	91.8	8.2
m^2 glass 5 mm thick	92.9	7.1
Concrete	98.0	2.0
Marble	95.9	4.1
Sandstone	96.9	3.1
Steel	94.9	5.1
Mean	95.8	4.2

Table 1: Summary of mass and density of materials responses

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Analysis of mass and density responses

Material	Actual	Mean response	Difference (%)	Responses within range (%)
Solid clay brick (kg)	3.0 – 3.5	2.3	(29.8)	14.3
Two-cell concrete block (kg)	17.5	6.4	(63.4)	1.0
Precast concrete kerb (kg)	95	54.5	(42.6)	7.1
Double Roman concrete roof tile (kg)	4.8	10.2	112.5	4.1
m^2 glass 5 mm thick (kg)	13.5	6.1	(55.0)	0.0
Concrete (kg / m^3)	2 400	1876	(21.9)	50.0
Marble (kg / m^3)	2 755	2773	0.7	24.5
Sandstone (kg / m^3)	2 323	1602	(31.1)	6.1
Steel (kg / m^3)	2 393	4102	71.4	4.1
Mean			(6.6)	12.4

Table 2: Actual and mean response mass / density, percentage difference, and summary of responses within a 10% range of the actual mass or density

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Extent of impact of mass and density of materials

Response (%)						MS
Unsure	Minor…….……. Major					
	1	2	3	4	5	
0.0	0.0	0.0	3.1	31.3	65.6	3.83

Table 3: Extent to which the mass and density of materials impacts on ergonomics

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Knowledge of the mass and density of materials

Response (%)						MS
Unsure	Limited……Extensive					
	1	2	3	4	5	
5.0	15.0	50.0	25.0	5.0	0.0	2.21

Table 4: Respondents' rating of their knowledge of the mass and density of materials

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Consideration of mass and density of materials

Discipline	Response (%)						MS	Rank
	Unsure	Never….. ……..... Always						
		1	2	3	4	5		
Engineers (Design)	0.0	0.0	0.0	5.0	5.0	90.0	4.85	1
Engineers (Construction)	0.0	0.0	0.0	0.0	50.0	50.0	4.50	2
Construction Managers	0.0	0.0	5.0	10.0	30.0	55.0	4.35	3
Quantity Surveyors	0.0	15.0	10.0	20.0	5.0	50.0	3.65	4
Architects	10.0	5.0	30.0	20.0	25.0	10.0	3.06	5
Project Managers	0.0	5.0	30.0	45.0	15.0	5.0	2.85	6

Table 5: Frequency at which built environment disciplines should consider the mass and density of materials when practicing their discipline

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Potential of the consideration of the mass and density of materials to contribute to an improvement

Response (%)						MS
Unsure	Minor….. ……..…Major					
	1	2	3	4	5	
5.3	0.0	10.5	31.6	31.6	21.1	3.67

Table 6: Potential of the consideration of the mass and density of materials to contribute to an improvement in construction ergonomics

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Conclusions (1)

- Respondents are lacking in knowledge relative to the mass and density of materials:
  - 95.8% of respondents attempted to record a mass or density
  - Only 12.4% of the 95.8% were within a 10% range of the actual mass or density
  - Reinforced by the respondents' rating of their knowledge of the mass and density of materials, namely 2.21 (between limited to below average / below average)
- Respondents appreciate, to a degree, the extent to which the mass and density of materials impact on construction ergonomics:
  - Actual impact (between some impact to a near major / near major impact)
  - Extent to which Engineers (Design and Construction), and Construction Managers should consider (between often to always / always)

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Conclusions (2)

- **Potential of the consideration of the mass and density of materials to contribute to an improvement (between some potential to near major / near major potential)**

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Recommendations

- **Tertiary built environment education should:**
  - **Address construction ergonomics, in particular civil engineering – graduates becomes designers or constructors**
  - **Engender an awareness of the mass and density of common construction materials**
  - **Optimise the level of awareness relative to construction ergonomics, and the role of mass and density of materials**
- **Continuing professional development (CPD) should address construction ergonomics and the role of mass and density of materials**

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