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THE ROLE OF ENGINEERS IN CONSTRUCTION HEALTH AND SAFETY (H&S)

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FEM

Introduction (1)

- Design occurs upstream of construction
- Designers are a construction industry stakeholder
- Designers advise clients
- Designers have a legal and moral responsibility
- Designers are exposed to hazards and risk when undertaking pre-project activities such as surveys and trial holes

Introduction (2)

Construction H&S occurs in a macro environment:

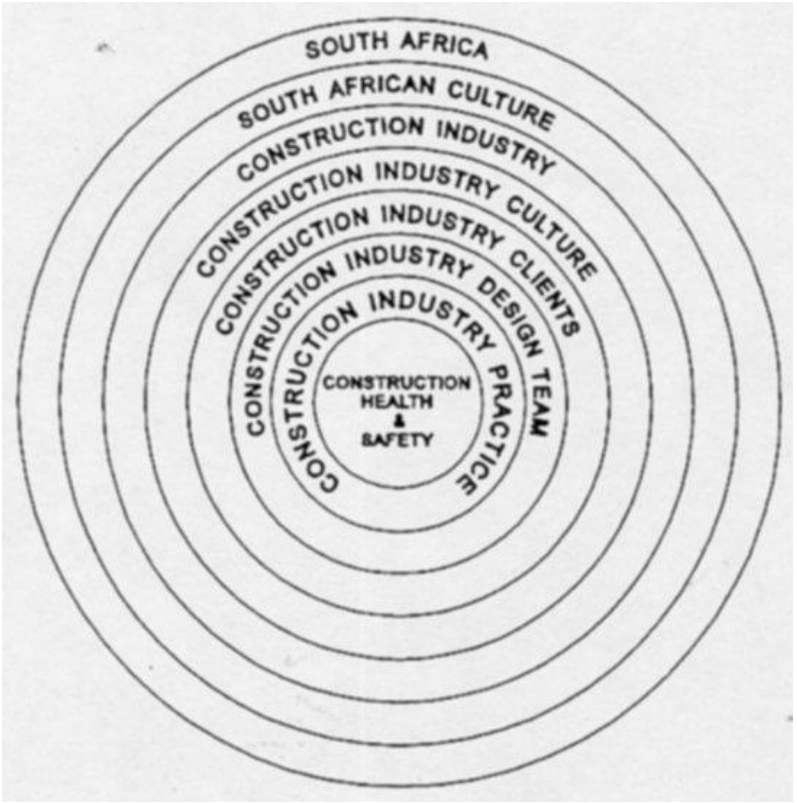


Figure 1: Construction H&S – the macro environment (Smallwood, 1995)

Introduction (3)

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

Injury statistics

- According to the Construction Industry Development (cidb) (2009), during visits to 1 415 construction sites by Department of Labour (DoL) inspectors:
  - 1 388 notices were issued, of which …. were:
    - 86 (6%) improvement notices
    - 1 015 (73%) contravention notices
    - 287 (21%) prohibition notices
  - Furthermore, 52.5% of contractors were non-compliant
- The disabling injury frequency rate (DIIR) is a rate, per 200 000 hours worked, of disabling injuries due to all causes i.e. per 100 workers x 2 000 hrs / yr:
  - 0.98 (cidb, 2009)
- Fatality rate per 100 000 workers: 25.5 (cidb, 2009)

Total cost of accidents

- Based upon the value of construction work completed in the year 2002, namely R 56 343m (South African Reserve Bank, 2003) the total COA could have been between 4.3% (R 2 401.2m / R 56 343m), and 5.4% (R 3 041.5m / R 56 343m) (Smallwood, 2004 in cidb, 2009)
- Cost of prevention is between 0.5% and 3% (Smallwood, 2004 in cidb, 2009)

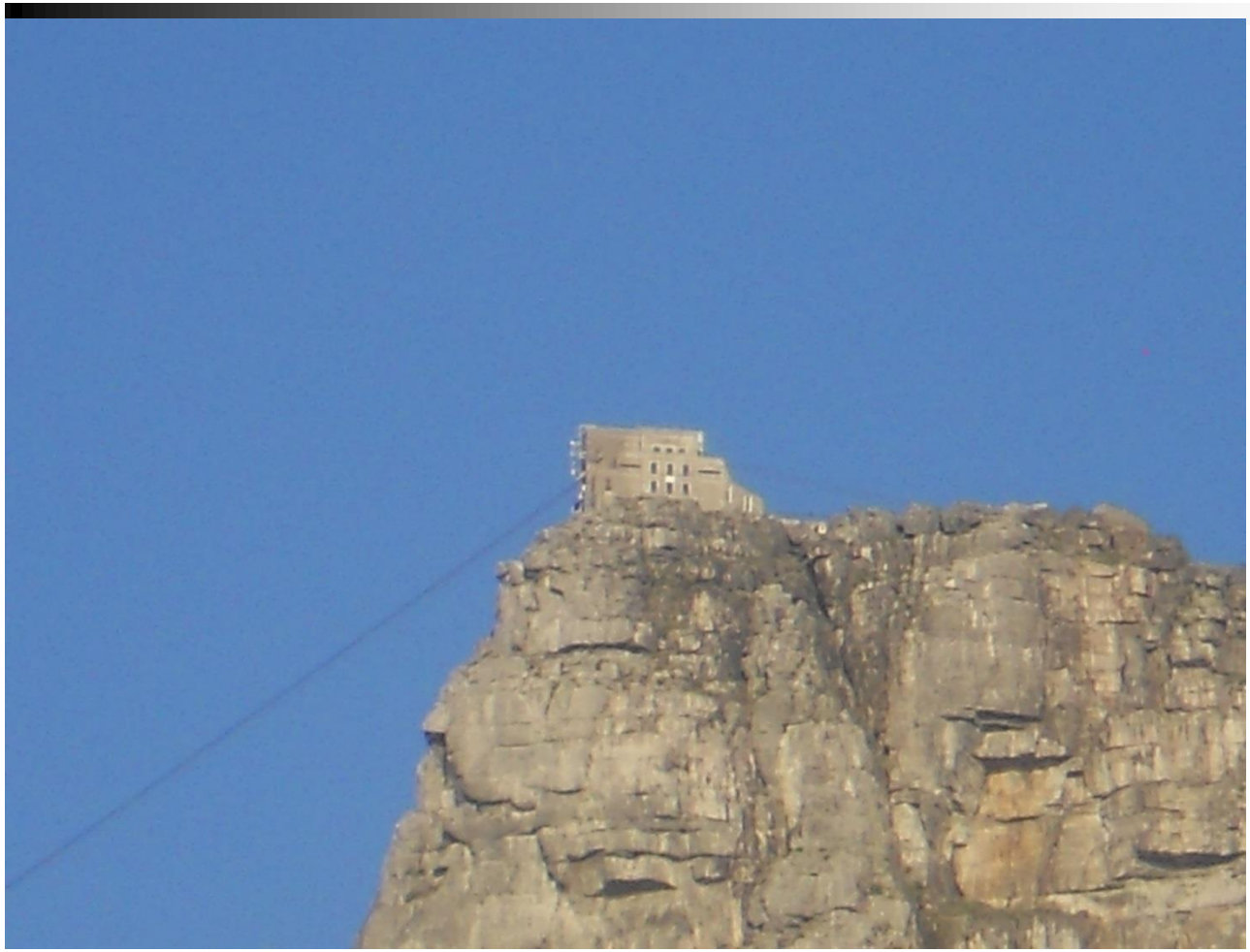
Impact of inadequate H&S

Aspect	Response (%)
Productivity	87.2
Quality	80.8
Cost	72.3
Client perception	68.1
Environment	66.0
Schedule (Time)	57.4

Table 1: Aspects negatively affected by inadequate health and safety according to project managers (Smallwood, 1996).

95.8% stated that inadequate or the lack of H&S increases overall project risk

Clients' needs (1)



Upper Aerial Cableway Station, Table Mountain (Smallwood, 2015)

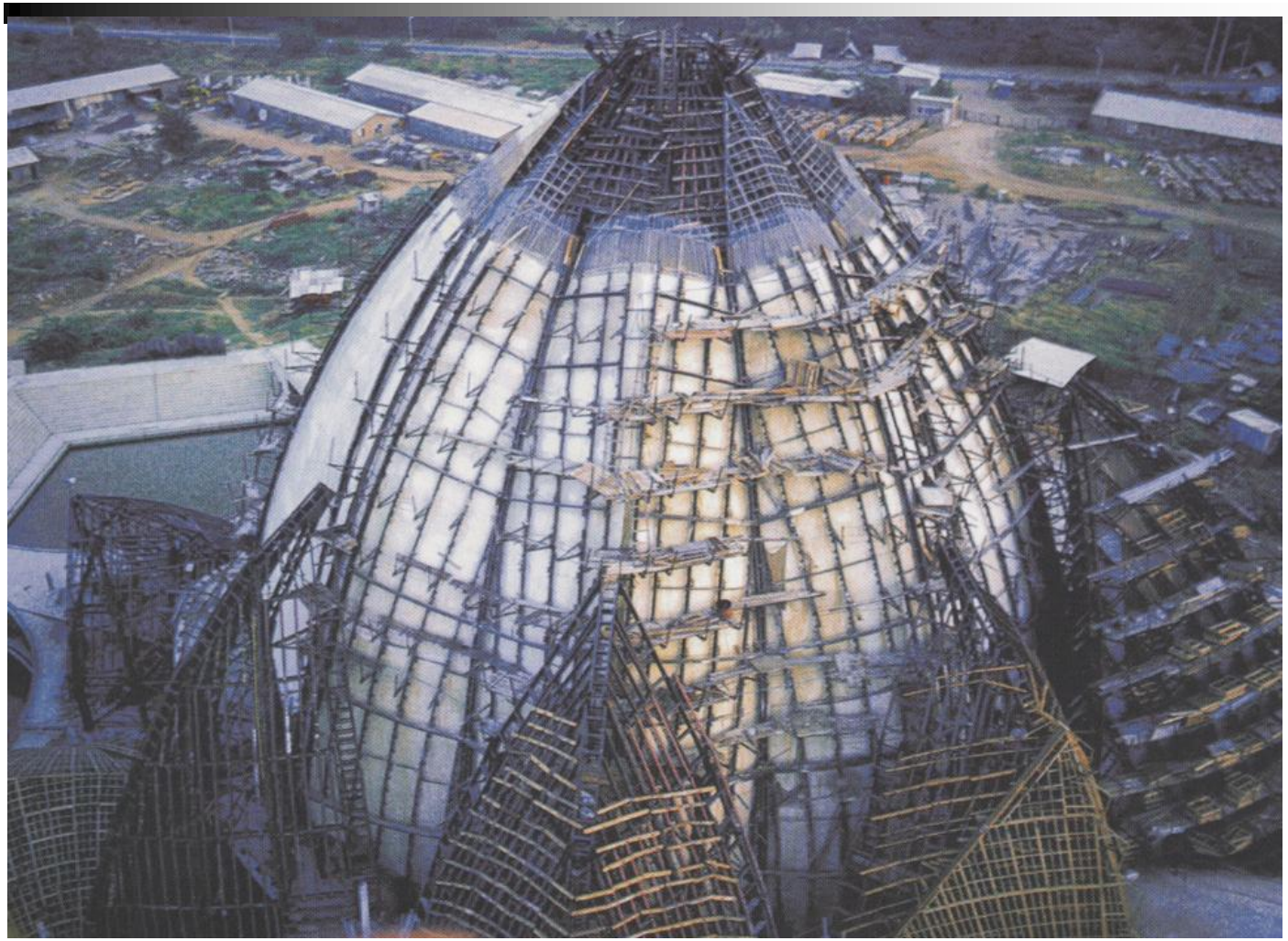
Clients' needs (2)

Upper Aerial Cableway Station, Table Mountain (Table Mountain Aerial Cableway, 2014)

General design (1)

Bahia Temple, Delhi, India (Smallwood, 2005)

General design (2)

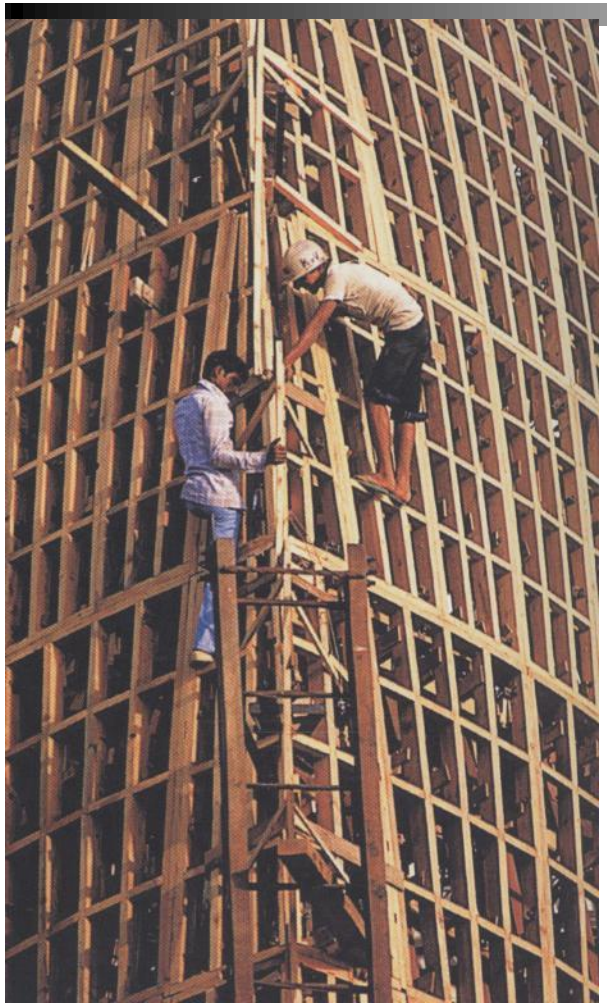


Bahia Temple, Delhi, India (The National Spiritual Assembly of the Bahia'is of India, 2002)

General design (3)

Bahia Temple, Delhi, India (The National Spiritual Assembly of the Bahia'is of India, 2002)

General design (4)



Bahia Temple, Delhi, India (The National Spiritual Assembly of the Bahia'is of India, 2002)

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)

Integrating design and construction ito H&S (1)

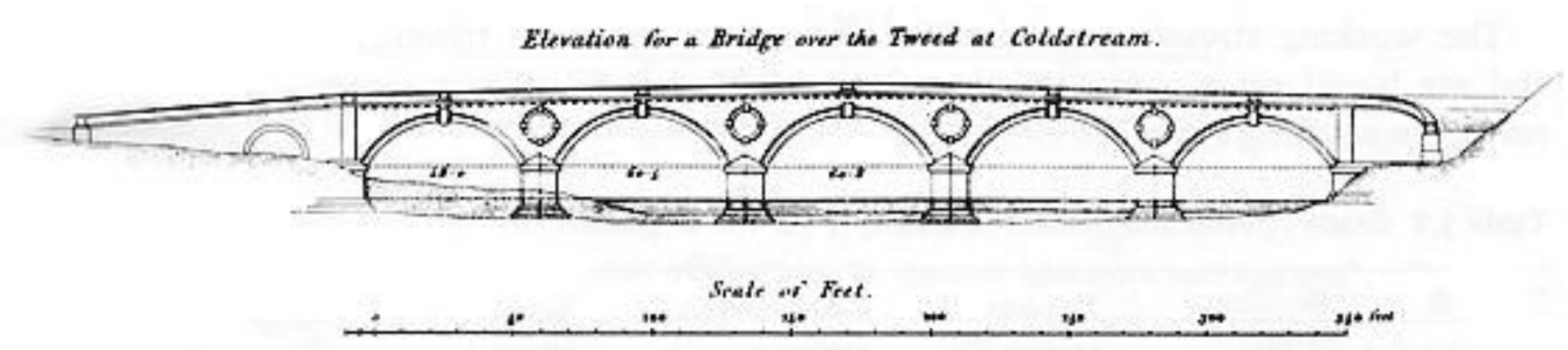


Figure 2: Elevation of masonry Bridge over the Tweed at Coldstream, 1866 (Irwin and Sibbald, 1983)

Integrating design and construction ito H&S (2)

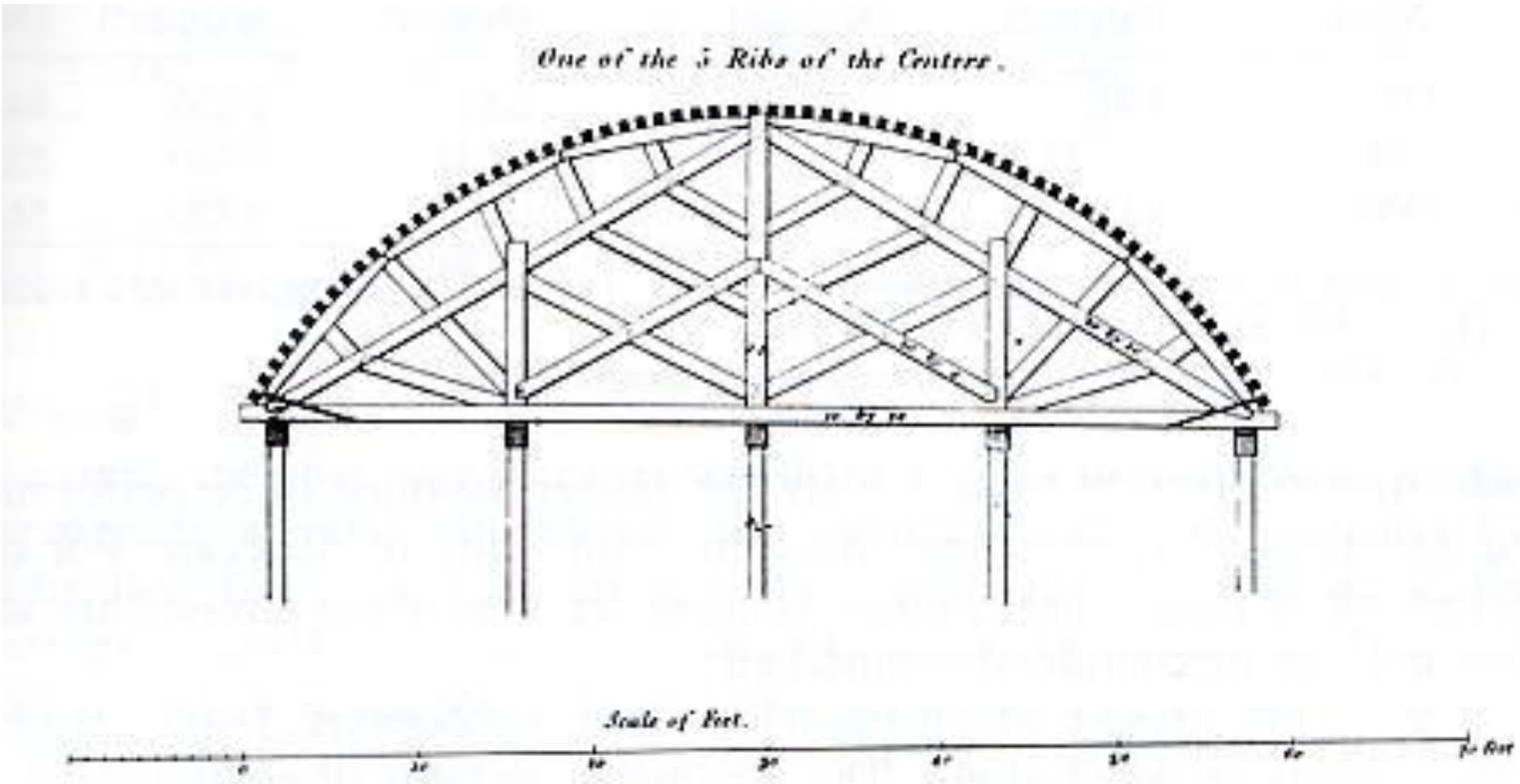
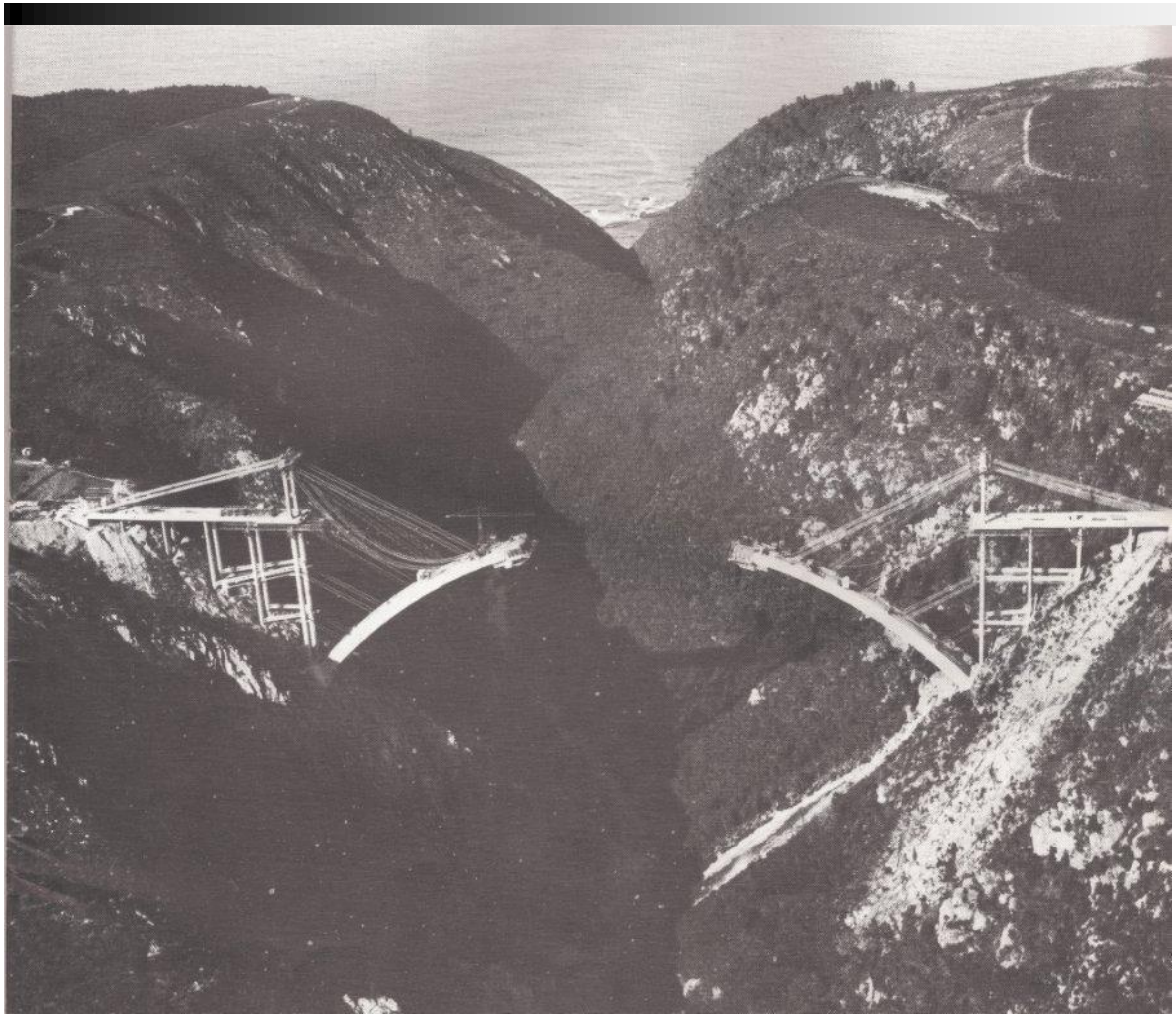


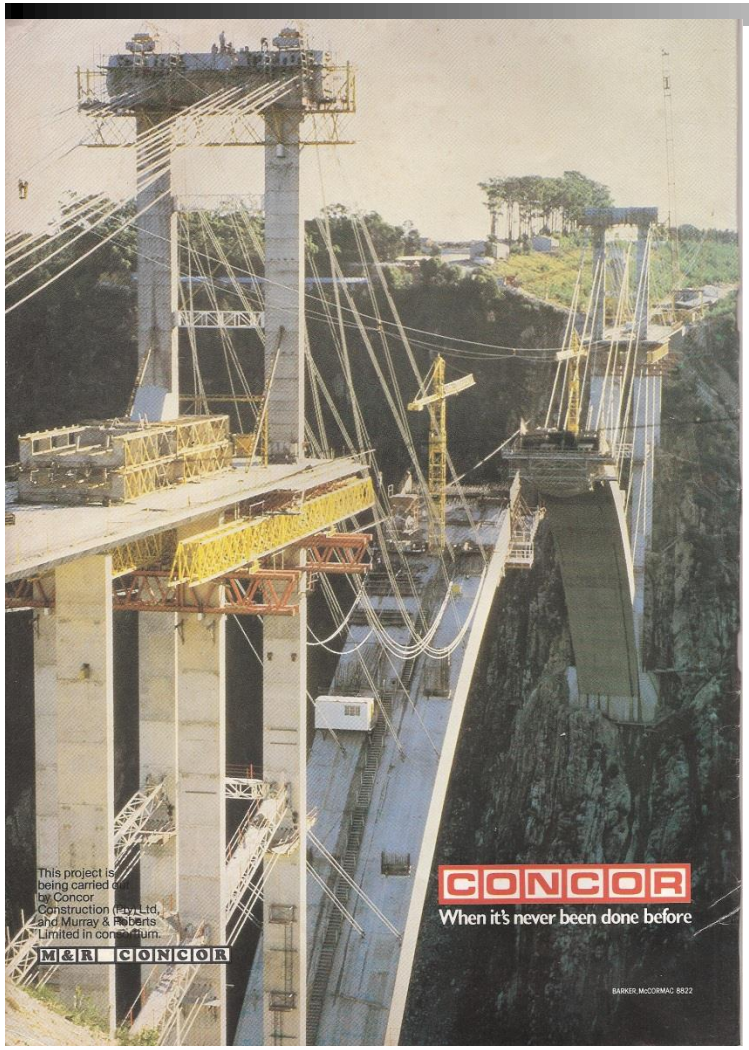
Figure 3: Centering for masonry Bridge over the Tweed at Coldstream, 1866 (Irwin and Sibbald, 1983)

Integrating design and construction ito H&S (3)



Bloukrans Bridge (p. 11, Concrete Beton, 1983)

Integrating design and construction ito H&S (4)



Bloukrans Bridge (Inside Front, Concrete Beton, 1983)

Integrating design and construction ito H&S (5)

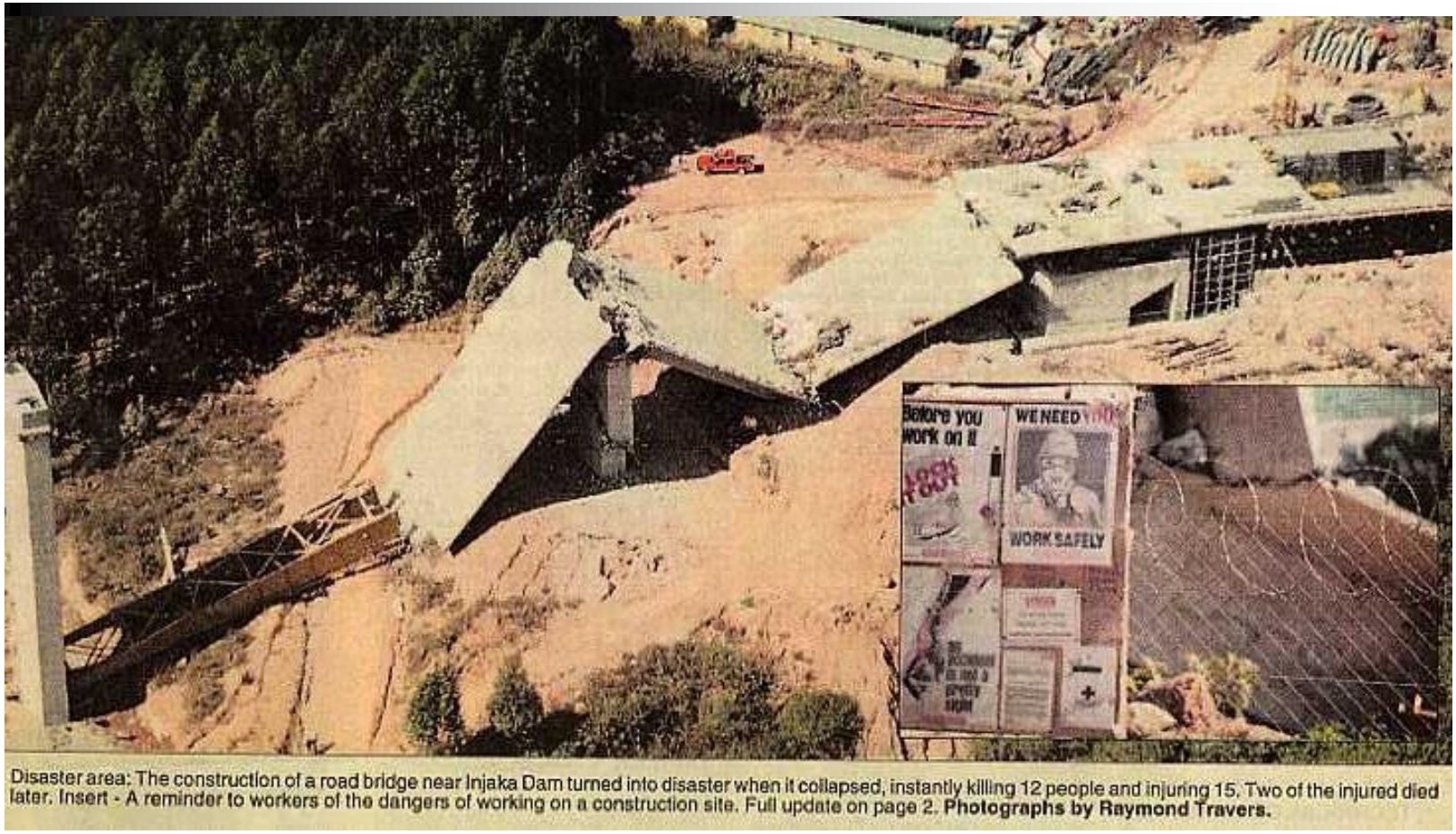
Bloukrans Bridge (Outside Back, Concrete Beton, 1983)

Integrating design and construction ito H&S (6)

Bloukrans bridge project (Steele, 1983):

- **"…notable for the close cooperation and team effort which were achieved by the consultant and contractor, and encouragement given by the client."**
- **"… consulting engineers had clearly indicated in their design how the task should be tackled and worked closely with the contractors in converting the drawings they had supplied to reality…"**

Injaka Bridge Collapse (1)



Disaster area: The construction of a road bridge near Injaka Dam turned into disaster when it collapsed, instantly killing 12 people and injuring 15. Two of the injured died later. Insert - A reminder to workers of the dangers of working on a construction site. Full update on page 2. **Photographs by Raymond Travers.**

Injaka Bridge collapse, Mpumalanga (Travers, 1998)

Injaka Bridge collapse (2)

- Causes (Department of Labour, 2002):
  - The slide path was not under the webs
  - The placing of the sliding pads between the deck and temporary bearings was not as specified
  - Insufficient reinforcement in the deck section, especially the bottom slab
  - The failure to fully appreciate the implications of the early cracks
  - The acceptance and approval of a launching nose which was substantially less stiff than that prescribed in the project specification
  - The deviation from the project specification regarding the automatic pier deflection monitoring at pier 2
  - The deviation from the project specification regarding the height tolerances of the temporary bearings on pier 3
  - The use of design and construction personnel, at decision-making level, without appropriate qualification and experience in incremental launched bridges

Injaka Bridge collapse (3)

- No independent design reviews were conducted of either the temporary or permanent works
- Contributory causes (Department of Labour, 2002):
  - The lack of experience on the part of design personnel in incremental launching techniques resulted in poor communications between the parties to clarify understandings and interpretations regarding the slide path position
  - The lack of clear instructions in the project specification and clear indications on the consulting engineers design drawings as to the position of the sliding path, resulted in incorrect interpretations being made

Construction Regulations (1)

Clients required to, among other:

- 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 (revised after the designers' reports?) in the tender documents
- 5 (1) (g) Ensure that potential PCs have made provision for the cost of H&S in their tenders
- 5 (1) (h) Ensure that the PC to be appointed has the necessary competencies and resources

Construction Regulations (2)

- 5 (1) (r) When changes are made to the design or construction work make sufficient H&S information and appropriate resources available to the PC
- 5 (2) When additional work is required the client must ensure that sufficient H&S information and appropriate additional resources are available to execute the work safely
- 5 (5) Where a construction work permit is required a client must appoint a competent person in writing as an agent
- 5 (6) Where notification of construction work is required the client may appoint a competent person in writing as an agent
- 5 (7) An agent must :
  - Manage the H&S on a construction project
  - Be registered with a statutory body

Construction Regulations (3)

- Relative to Structures 6 (1) 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 – may require 'design and construction' method statements
- (e) modify the design or make use of substitute materials where the design necessitates the use of dangerous

Construction Regulations (4)

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
- (g) when mandated by the client conduct inspections to ensure conformance of construction to design. If not mandated then the client's agent is responsible
- (h) when mandated by the client stop construction work not in accordance with the design's H&S aspects. If not mandated then the client's agent is responsible
- (i) when mandated by the client, during his / her final inspection of the structure include the H&S aspects of the structure, declare the structure safe for use and issue a completion certificate

Construction Regulations (5)

- To meet these requirements requires clients and designers (including PMs and QSs) to:
  - Identify hazards and assess the risk
  - Mitigate or eliminate the hazards and risks
  - Record the residual risk, if any (Designer Report and H&S Specification)
  - Document the BRA and design HIRA processes
- All project stages: project initiation and briefing; concept and feasibility; design development; tender documentation and procurement; construction documentation and management, and project close out
- Required following any redesign during construction phase
- Ergonomic related hazards require analysis, evaluation and to be addressed in the risk assessment

Baseline Risk Assessments (BRAs)

- Clients initiate projects
- Some clients may have H&S expertise
- Projects may be undertaken on existing facilities
- Clients' processes may be susceptible to inadequate H&S
- Clients through ownership of a facility should be aware of the hazards and challenges related thereto and their processes
- Identify the H&S, and environmental hazards and determine the risk
- Document the process

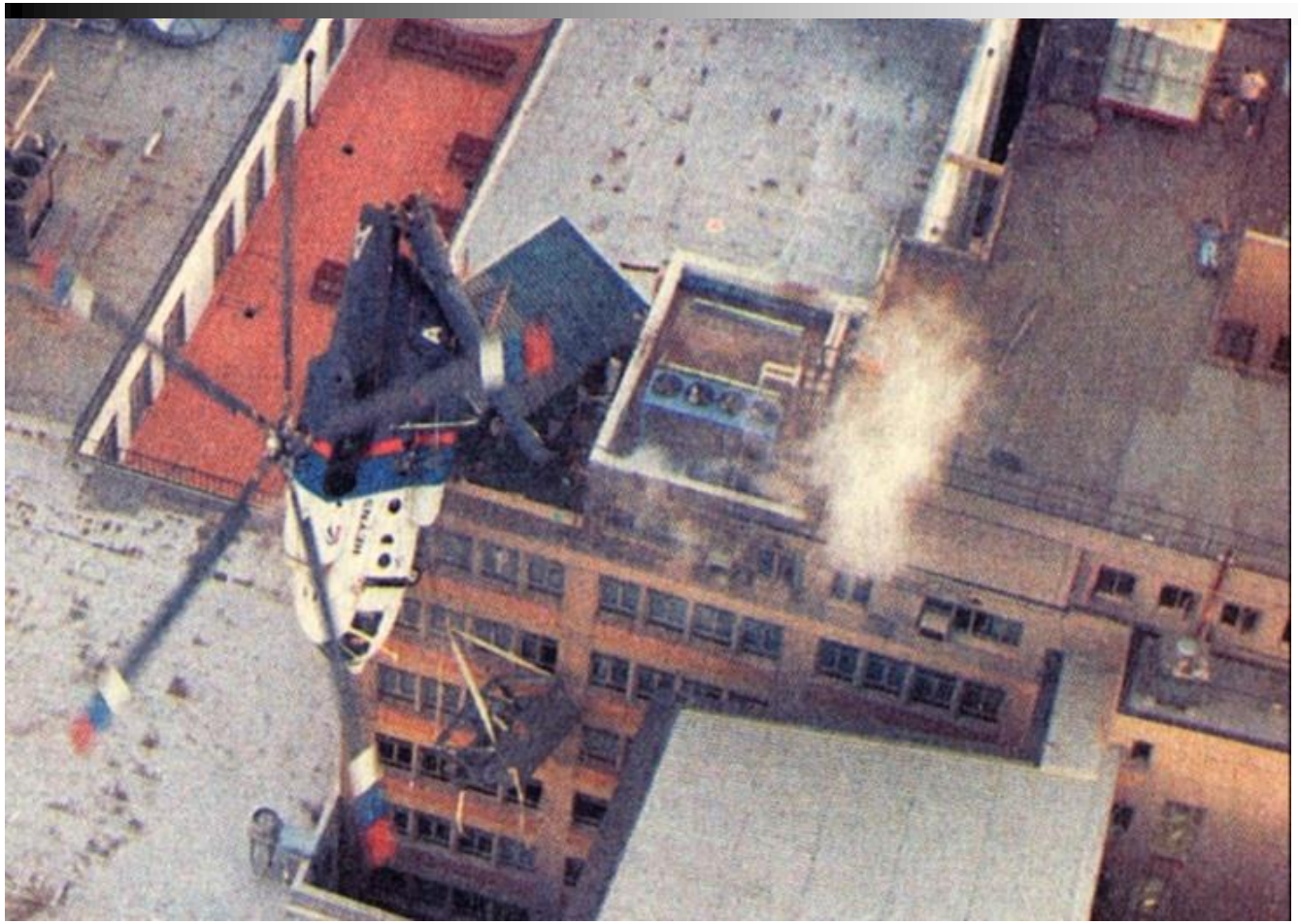
Helicopter crash (1)

Helicopter crash, Strand Street, Cape Town (Vosloo, 1999)

Helicopter crash (2)

Helicopter crash, Strand Street, Cape Town (Vosloo, 1999)

Helicopter crash (3)



Helicopter crash, Strand Street, Cape Town (Vosloo, 1999)

Helicopter crash (4)

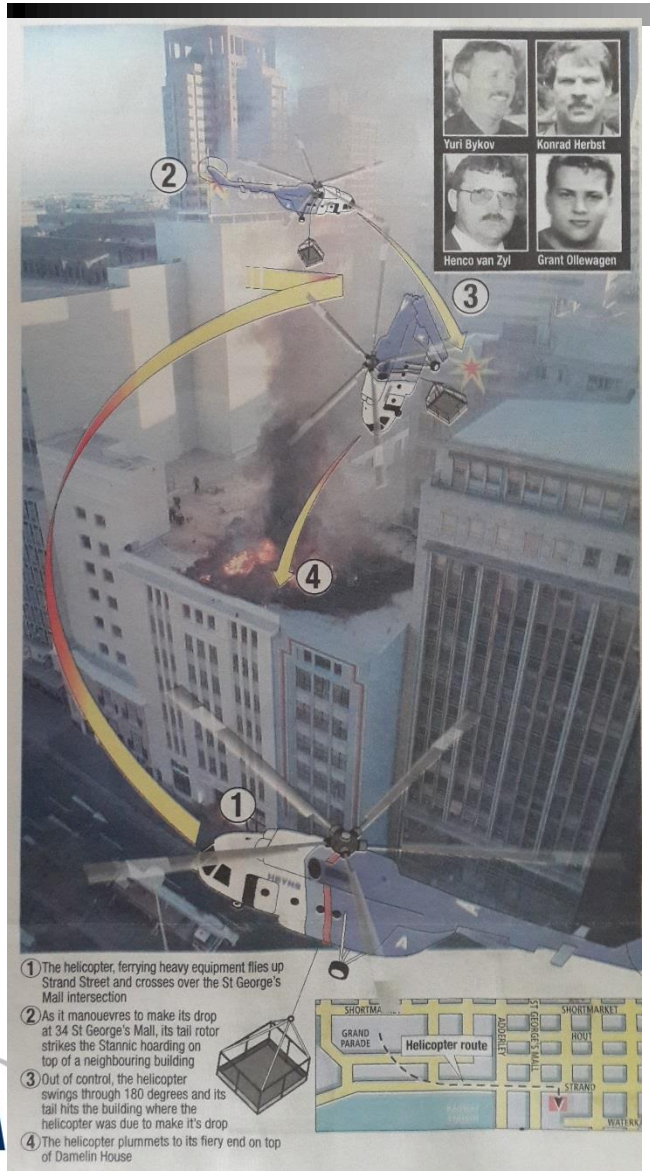
FLAMES OF DEATH . . . The Russian Mi-8 helicopter crashes into the roof of Boston House in Cape Town's central business district early yesterday. A professional photographer, who had been photographing the helicopter as it loaded airconditioning equipment onto the building, ended up capturing these images of a horrific accident in which four people died. Pictures: AP

Helicopter crash, Strand Street, Cape Town (Amalgamated Press, 1999)

Helicopter crash (5)

Helicopter crash, Strand Street, Cape Town (Ingram, 1999)

Helicopter crash (6)



Helicopter crash, Strand Street, Cape Town

(Blignaut, 1999)

Helicopter crash (7)

- As with all ‘accidents’ (failures of management) this was preventable
- A simple 3-D scan of the neighbourhood would have highlighted the hazards and risks
- Amplifies the role of planning in general, and specifically BRAs, ‘designer’ H&S specifications, ‘designer’ reports, ‘contractor’ H&S specifications, and H&S plans
- Construction is not a ‘Hollywood movie set’!

Rationale for H&S specifications (1)

Mist, Aerial Cableway Station, Table Mountain (Deacon, 1997)

Rationale for H&S specifications (2)

Site establishment, Aerial Cableway Station, Table Mountain (Deacon, 1997)

Rationale for H&S specifications (3)

Sheer-face construction, Aerial Cableway Station, Table Mountain (Deacon, 1997)

Rationale for H&S specifications (4)

Sheer-face construction, Aerial Cableway Station, Table Mountain (Deacon, 1997)

Rationale for H&S specifications (5)

Sheer-face construction, Aerial Cableway Station, Table Mountain (Deacon, 1997)

Rationale for H&S specifications (6)

Transportation of materials and waste / demarcated protected areas, Aerial Cableway Station, Table Mountain (Deacon, 1997)

Client provided 'Designer' and 'Contractor' H&S Specifications, and Designer 'Report

- 2014 Regulations require a client provided 'Designer' H&S Specification and a 'Contractor' version (implicitly), linked by a Designer 'Report'
- Client provided 'Designer' H&S Specification:
  - Project details
  - Client's considerations and management requirements
  - Environmental restrictions and existing on-site risks
- Designer 'Report':
  - Significant design and construction hazards
- Client provided 'Contractor' H&S Specification:
  - H&S file
  - Plus the other four sections included in the Client provided 'Designer' H&S Specification and Designer Report

Client provided 'Designer' H&S Specification - Project details

- Project location including:
  - Access e.g. Infrastructure such as railway routes and roads
  - Fauna and related e.g. crocodiles, malaria, and snakes
  - Services e.g. electricity, sewage, and water
  - Socio-economic issues such as crime, and vandalism
  - Weather e.g. precipitation, temperature, and wind
  - Other e.g. landmines
- Project description
- Phases and programme
- Details of client, designers, and other consultants
- Extent and location of existing records and plans

Client provided 'Designer' H&S Specification - Client's considerations and management requirements

- Structure and organisation – general including H&S
- H&S goals for the project
- H&S monitoring and review
- Permit and authorisation requirements
- Emergency procedures
- Site rules and other restrictions on designers, contractors, suppliers and others e.g. access arrangements to those parts of the site which continue to be used by the client, shift work, night work, restricted hours
- Mandatory client provided H&S training
- Activities on or adjacent to the site during the works
- Arrangements for liaison between parties

Client provided 'Designer' H&S Specification - Environmental restrictions and existing on-site risks

- Safety hazards, including:
  - Boundaries and access, including temporary access
  - Adjacent land uses
  - Existing storage of hazardous materials
  - Ground conditions e.g. geotechnical report may exist
  - Location of existing services – water, electricity, and gas
  - Existing structures – degree of stability, or fragile materials
- Health hazards, including:
  - Asbestos, including results of surveys
  - Existing storage of hazardous materials
  - Contaminated land, including results of previous or current surveys
  - Existing structures - hazardous materials e.g. asbestos containing
  - Health risks arising from client's activities e.g. sewage works

Designer 'Report' - Significant design and construction hazards

- Ground conditions e.g. geotechnical report
- Design assumptions and control measures e.g. design and construction method statements – composite slabs, and structural steel i.e. temporary support / bracing
- Arrangements for co-ordination of on-going design work and handling design changes e.g. Nominated subcontractors' shop drawings
- Information on significant hazards identified during design e.g. bush-hammered concrete
- Materials requiring particular precautions e.g. heavy blocks, and precast concrete kerbs

‘Contractor’ H&S Specification - H&S file

- ‘As built’ drawings and plans
- Design criteria e.g. design loadings
- Potential hazards included in the structure
- Construction methods and materials used
- Record of hazardous processes e.g. removal of asbestos containing materials (ACMs)
- Equipment and maintenance facilities
- Maintenance procedures and requirements
- Manuals (operating and maintenance) for plant and equipment
- Location and nature of utilities and services

Reduction of risk through design and specification (1)

- Optimum approach – prevent hazard arising and avoid risk – are there alternatives?
- If not reasonably practicable - then combat at source
- If not reasonably practicable - then priority for measures to control risk that provide communal protection
- Specification of PPE to control risk is a last resort (contractor)

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)

(Steel Construction, 2004)

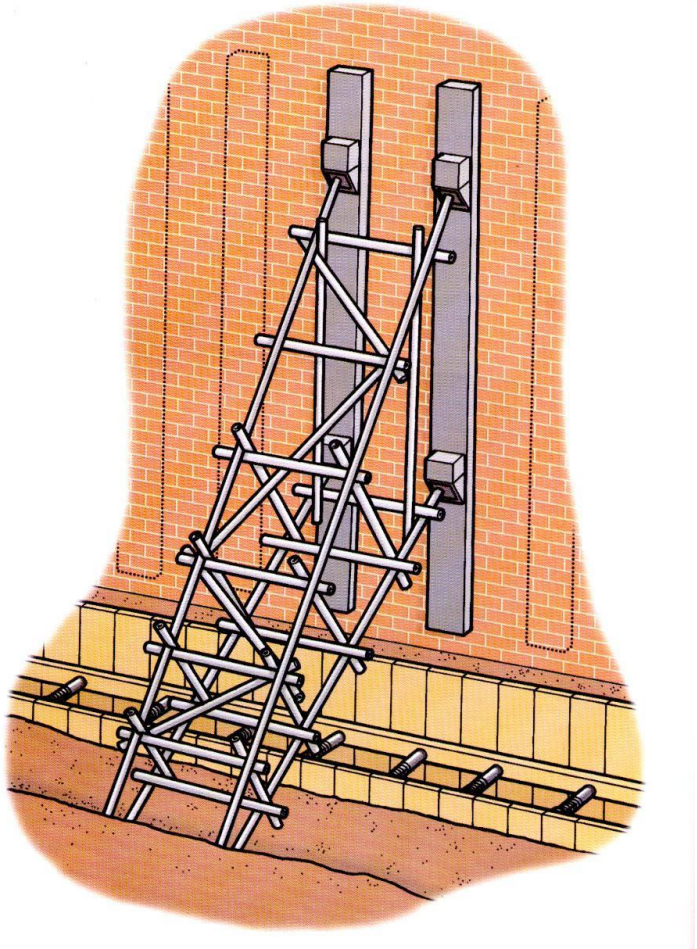
Reduction of risk through design and specification (5)

'Bush-hammered' concrete, Port Elizabeth (Smallwood)

Reduction of risk through design and specification (6)

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

Reduction of risk through design and specification (7)



Shoring of building with excavation at base of building (HSE, 1999)

Reduction of risk through design and specification (8)

Thermal Lance in lieu of mechanical breaking, Mount Road Police Station, Port Elizabeth (Smallwood, 1987)

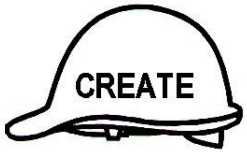
Design HIRA (1)

Precast planks / ribs and blocks to composite slab, Plettenberg Bay (Hamp-Adams, 1994)

Design HIRA (2)

Precast planks / ribs and blocks to composite slab, Plettenberg Bay (Hamp-Adams, 1994)

Design HIRA (3)



An example of a generic risk assessment form (GRA) -Page 1				
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 4: Design HIRA for erecting precast plank and hollow block composite slab using a 3 X 3 (Likelihood X Impact) template

Design HIRA (4)

Positioning pre-stressed precast hollow core slab using cranage and a lifting beam (SA Builder Bouer, 2004a)

Design HIRA (5)

Positioning pre-stressed precast hollow core slab using cranage and a lifting beam (SA Builder Bouer, 2004b)

Documentation of process

- Name(s) and function(s) of the assessor(s) / team
- Date of HIRA
- Work breakdown structure (WBS) / Elements / Finishes / Activities
- Hazards and risk / the above
- Response
- Client 'Designer' H&S specification and / or Designer report reference
- Details of subsequent monitoring arrangements e.g. Client 'Contractor' H&S Specification, H&S Plan, construction and requirements for further risk assessments

Indirect role of engineers (1)

- Design influences construction H&S directly
- However, construction H&S is influenced indirectly through: selection of procurement system; preparation of contract documentation; decision regarding project duration; pre-qualification of contractors in terms of H&S, and the status of design upon commencement of construction
- Selection of procurement system:
  - Design- Build is the ideal as it integrates design and construction
- Preparation of contract documentation:
  - Detailed reference to H&S
  - Facilitate optimum financial provision for H&S
- Decision regarding project duration:
  - Scope, value, and complexity of project compatible with H&S

Indirect role of engineers (2)

- Pre-qualification of contractors in terms of H&S:
  - Outcome measures e.g. DIIR and fatality rate
  - Performance measures e.g. H&S qualifications and or education / training of management, supervisors, and workers
- Status of design upon commencement of construction:
  - Ideally complete – variation orders 'complicate' H&S

Do engineers consider / refer to H&S? (1)

Occasion	Response (%)						MS	Rank
	Unsure	Never	Rarely	Some-times	Often	Always		
Site meetings	0.0	0.0	2.1	12.4	35.1	50.5	4.34	1
Site inspections / discussions	0.0	1.0	1.0	13.4	41.2	43.3	4.25	2
Site handover	1.0	1.0	6.3	12.5	28.1	51.0	4.20	3
Preparing project documentation	0.0	1.0	4.1	18.6	33.0	43.3	4.13	4
Detailed design	0.0	2.1	13.5	24.0	31.3	29.2	3.72	5
Working drawings	1.0	1.0	18.6	22.7	33.0	23.7	3.58	6
Pre-tender meeting	1.0	4.2	20.8	18.8	30.2	25.0	3.49	7
Constructability reviews	2.1	2.1	17.5	24.7	37.1	16.5	3.44	8
Concept (design)	0.0	4.1	14.4	35.1	28.9	17.5	3.41	9
Client meetings	0.0	4.1	12.4	41.2	32.0	10.3	3.32	10
Design coordination meetings	0.0	3.1	17.5	41.2	25.8	12.4	3.27	11
Evaluating tenders	0.0	9.4	29.2	22.9	25.0	13.5	3.04	12
Deliberating project duration	4.1	9.3	25.8	29.9	26.8	4.1	2.82	13
Pre-qualifying contractors	3.2	13.7	28.4	20.0	26.3	8.4	2.81	14

Table 2: Frequency at which Engineering practices consider / refer to H&S on various occasions (MS = 1.00 – 5.00) (Smallwood, 2004).

Do engineers consider / refer to H&S? (2)

Aspect	Response (%)						MS	Rank
	Unsure	Never	Rarely	Some-times	Often	Always		
Specification	1.0	3.1	8.2	8.2	35.1	44.3	4.07	1
Method of fixing	3.1	3.1	6.2	14.4	34.0	39.2	3.94	2
Design (general)	1.0	0.0	10.4	21.9	38.5	28.1	3.82	3
Details	1.0	4.2	14.6	19.8	33.3	27.1	3.63	4
Type of structural frame	10.4	8.3	8.3	15.6	19.8	37.5	3.49	5
Position of components	5.2	7.2	13.4	18.6	36.1	19.6	3.37	6
Content of material	5.2	7.2	9.3	32.0	25.8	20.6	3.33	7
Plan layout	6.2	7.2	11.3	22.7	35.1	17.5	3.32	8
Site location	4.1	9.3	17.5	18.6	27.8	22.7	3.29	9
Schedule	4.1	10.3	13.4	28.9	28.9	14.4	3.15	10
Elevations	7.2	9.3	18.6	19.6	28.9	16.5	3.10	11
Mass of materials	8.3	7.3	18.8	24.0	24.0	17.7	3.09	12
Edge of materials	8.2	8.2	15.5	32.0	22.7	13.4	3.01	13
Finishes	4.1	11.3	18.6	33.0	23.7	9.3	2.93	14
Surface area of materials	8.3	12.5	22.9	29.2	16.7	10.4	2.73	15
Texture of materials	9.3	11.3	25.8	29.9	14.4	9.3	2.66	16

Table 3: Frequency at which Engineering practices consider / refer to H&S relative to various design related aspects (MS: 1.00 – 5.00) (Smallwood, 2004).

Built environment construction H&S education

Discipline	Response (%)						MS	Rank
	Unsure	Hardly……. Very						
		1	2	3	4	5		
Construction management	0.0	0.0	0.0	0.0	0.0	100.0	5.00	1
Civil engineering	0.0	0.0	0.0	0.0	25.0	75.0	4.75	2
Electrical engineering	0.0	0.0	0.0	0.0	50.0	50.0	4.50	3
Mechanical engineering	0.0	0.0	0.0	25.0	25.0	50.0	4.25	4
Project management	0.0	0.0	25.0	0.0	0.0	75.0	4.25	5
Landscape architecture	0.0	0.0	20.0	40.0	20.0	20.0	3.40	6
Architecture	0.0	16.7	16.7	16.7	16.7	33.3	3.33	7
Quantity surveying	0.0	0.0	25.0	50.0	0.0	25.0	3.25	8
Interior design	0.0	20.0	20.0	40.0	20.0	0.0	2.60	9

Table 4 : The importance of the inclusion of construction H&S in the tertiary education programmes of built environment disciplines according to architectural academics (MS: 1.00 – 5.00) (Smallwood, 2015)

A model for architectural designers

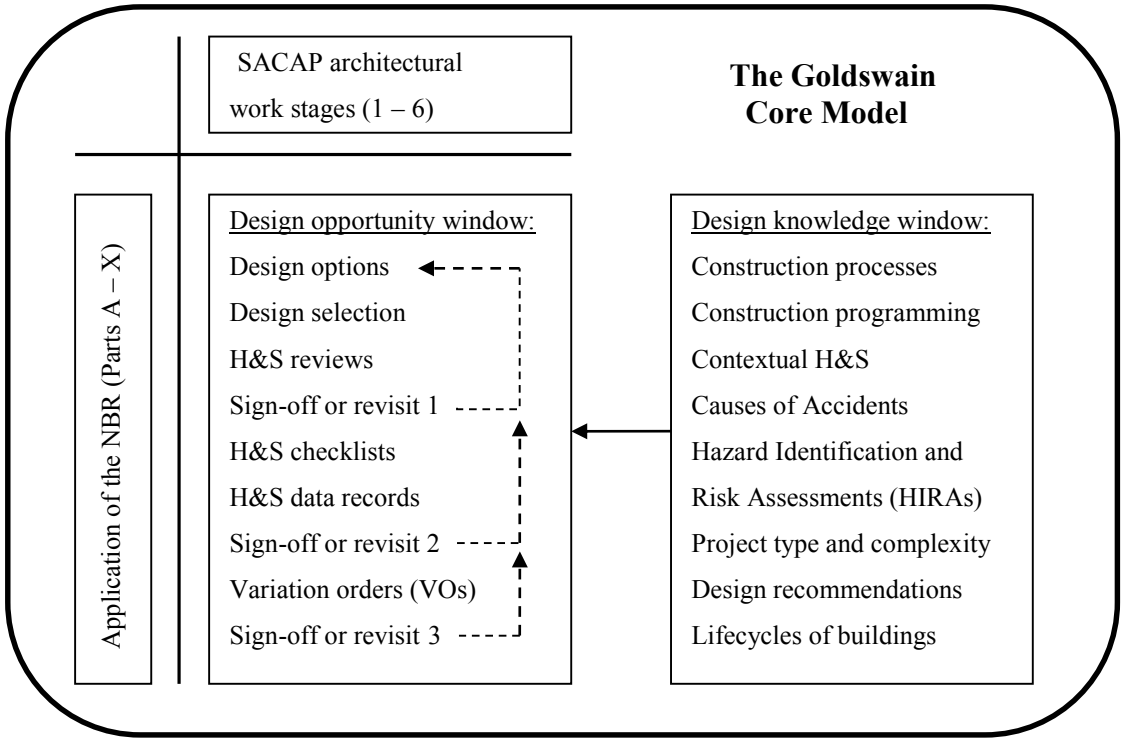


Figure 5: The Goldswain Core Model (Goldswain, 2014).

Key points

- Design occurs upstream of construction
- Designers influence H&S directly and indirectly
- Directly through: general design; choice of structural frame; details; method of fixing, and specification of materials and finishes
- Indirectly through: selection of procurement system; preparation of contract documentation; decision regarding project duration; pre-qualification of contractors on H&S, and status of design upon commencement of construction
- Designers are liable for the impact of design on construction H&S

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  - Established as a mutual insurer in 1936 and on the introduction of the Workmen's Compensation Act 1941 was granted a licence to continue to transact workmen's compensation insurance for the construction industry
  - It's business operations are essentially confined to the insurance of employers against their liabilities under the Compensation for Occupational Injuries and Diseases (COID Act 1993
  - In terms of the articles of association of the company, shareholding is restricted to policy holders

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