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PERI WORKSHOPS

CENTURION, 23 MAY 2017

PREVENTING THE COLLAPSE OF REINFORCED CONCRETE (RC) STRUCTURES, SUPPORT WORK AND FORMWORK DURING CONSTRUCTION

PRESENTED BY PROF JOHN SMALLWOOD
PROFESSOR OF CONSTRUCTION MANAGEMENT
DEPT. OF CONSTRUCTION MANAGEMENT
john.smallwood@nmmu.ac.za

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Introduction (1)

- 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:
    - 86 (6%) improvement notices
    - 1 015 (73%) contravention notices
    - 287 (21%) prohibition notices
  - Furthermore, 52.5% of contractors were non-compliant
- The disabling injury incidence 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) – 1 / 100 workers experiences a disabling injury / year
- Fatality rate per 100 000 workers: 25.5 (cidb, 2009)

Introduction (2)

The presentation and research is part of a journey - will it end?

- **Preventing 'Accidents' in Construction, http://www.cbe.org.za/PDF/Health_and_Safety_Preventing_Accidents_Article.pdf (requested by the Council for the Built Environment)**
- **Articles such as:**
  - **Constructing reinforced concrete frames without injury and fatality: The relationship between health and safety and quality, *The Civil Engineering and Building Contractor*, March, 1997**
  - **Large-scale construction accidents Is there a trend? *ProjectPro*, September, 1998**
  - **Slab and structural collapses can be prevented, *SA Builder / Bouer*, March, 2002**
  - **Construction slab collapses: Could we prevent the next one? *Safety Management*, March, 2002**

Introduction (3)

- Slab, deck, roof and ceiling collapses: Can they be prevented? *Building Africa*, May, 2003
- Twelve ingredients for optimum construction H&S…incident prevention, *Safety Management*, August, 2004
- Collapsing decks and related failures of management, *SA Builder / Bouer*, August, 2004
- Accidents will continue to occur in construction until ….. , *Specifier*, August, 2004

South Africans – take note! (1)

Cairns, Australia (Smallwood, July 2016)

South Africans – take note! (2)

Cairns, Australia (Smallwood, July 2016)

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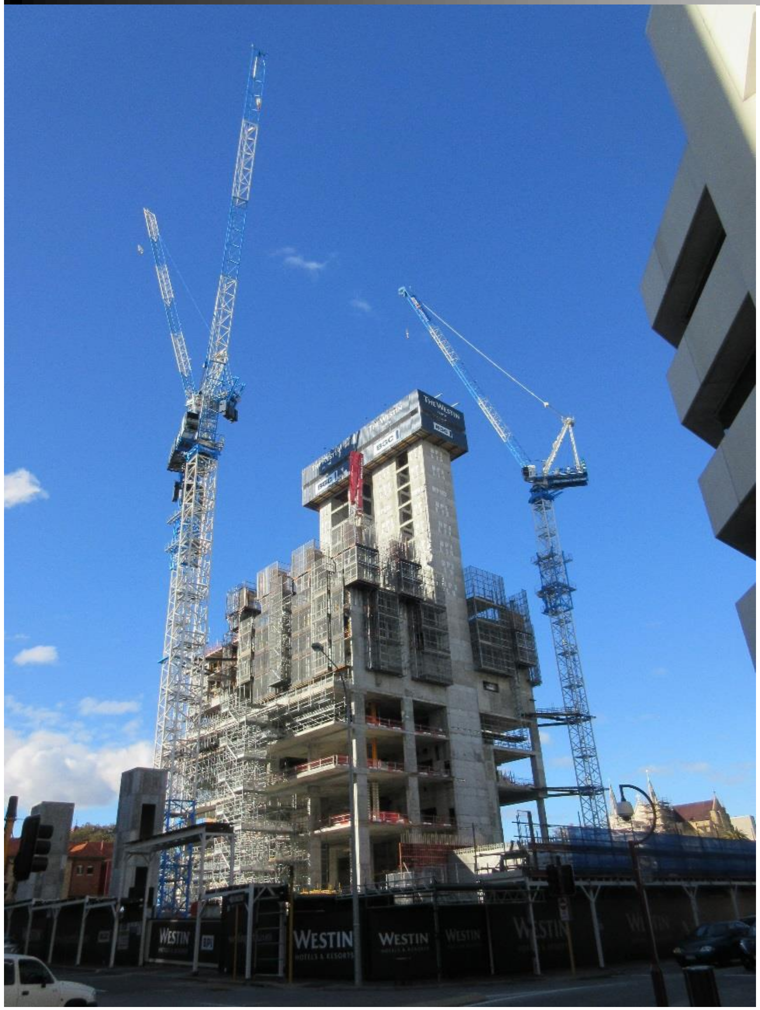
Australian support work and construction (1)



Perth, Australia (Smallwood, July 2016)

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Australian support work and construction (2)

Perth, Australia (Smallwood, July 2016)

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Australian support work and construction (3)

Perth, Australia (Smallwood, July 2016)

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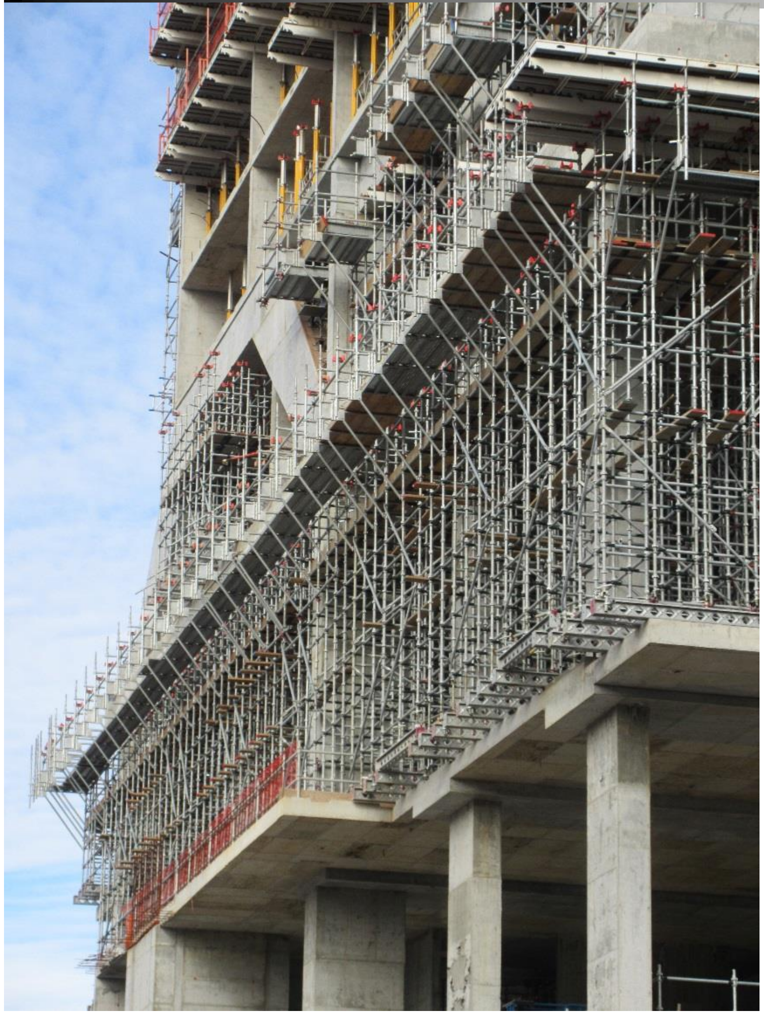
Australian support work and construction (4)



Perth, Australia (Smallwood, July 2016)

Australian support work and construction (5)

Perth, Australia (Smallwood, July 2016)

Australian construction fatality rates

Sector	Number of fatalities		Fatality rate / 100 000		
	2003-07	2009-13	2003-07	2009-13	Change (%)
Construction services:	**138**	**119**	**4.69**	**3.38**	**-28%**
Building installation services	44	43	4.75	3.42	-28%
Land development & site preparation services	34	28	15.32	9.94	-35%
Building completion services	13	22	1.43	2.20	54%
Building structure services	30	13	6.67	2.73	-59%
Other construction services	17	13	3.96	2.59	-35%
Building construction	**20**	**21**	**1.89**	**1.76**	**-7%**
Heavy & civil engineering construction	**38**	**27**	**13.76**	**7.35**	**-47%**
Total	**196**	**167**	**4.59**	**3.29**	**-28%**

Table 1: Worker fatalities in the construction industry (Safe Work Australia, 2015)

Pretoria North Shopping Centre slab collapse (October, 1996)

(Davis, 1996)

Cleveland Bridge (M2) (July, 2004) (1)

(Tertius, 2004)

Cleveland Bridge (M2) (July, 2004) (2)

(Tertius, 2004)

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Umhlanga Ridge (1)

(Anonymous)

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Umhlanga Ridge (2)

(Anonymous)

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Meyersdal Collapse, 18 August 2014 (1)

(TimesLIVE Mobile, 2014)

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Meyersdal Collapse, 18 August 2014 (2)

(The New Age, 2015)

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Tongaat Mall Collapse, 19 November 2013

Tongaat Mall Collapse, 19 November 2013

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Beacon Bay Hotel, July 2015

(DispatchLIVE, 2015)

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Construction H&S – the macro environment

Construction H&S occurs in a macro environment:

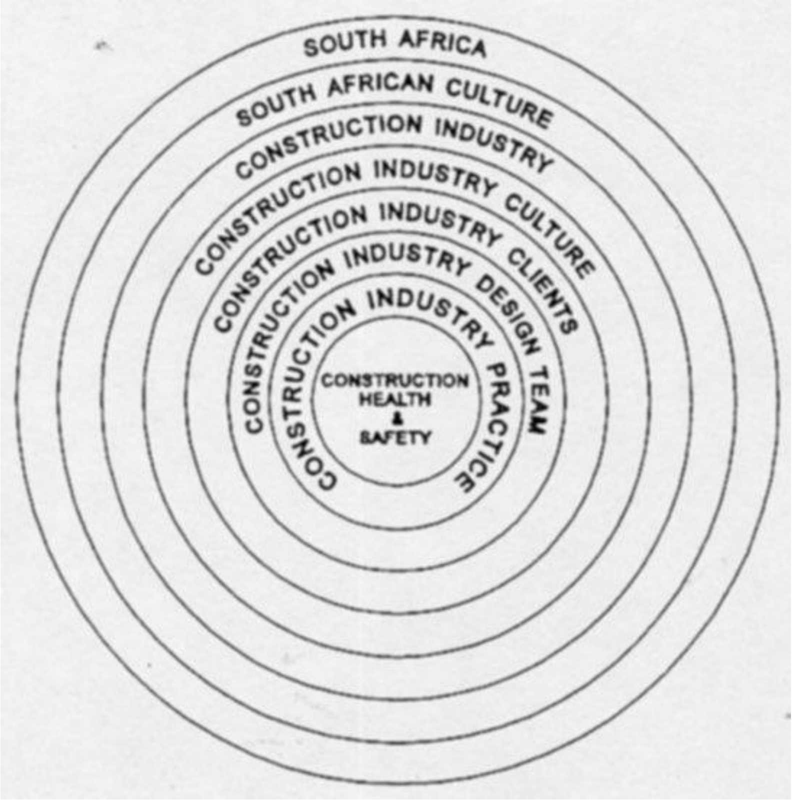

Figure 1: Construction H&S – the macro environment (Smallwood, 1995)

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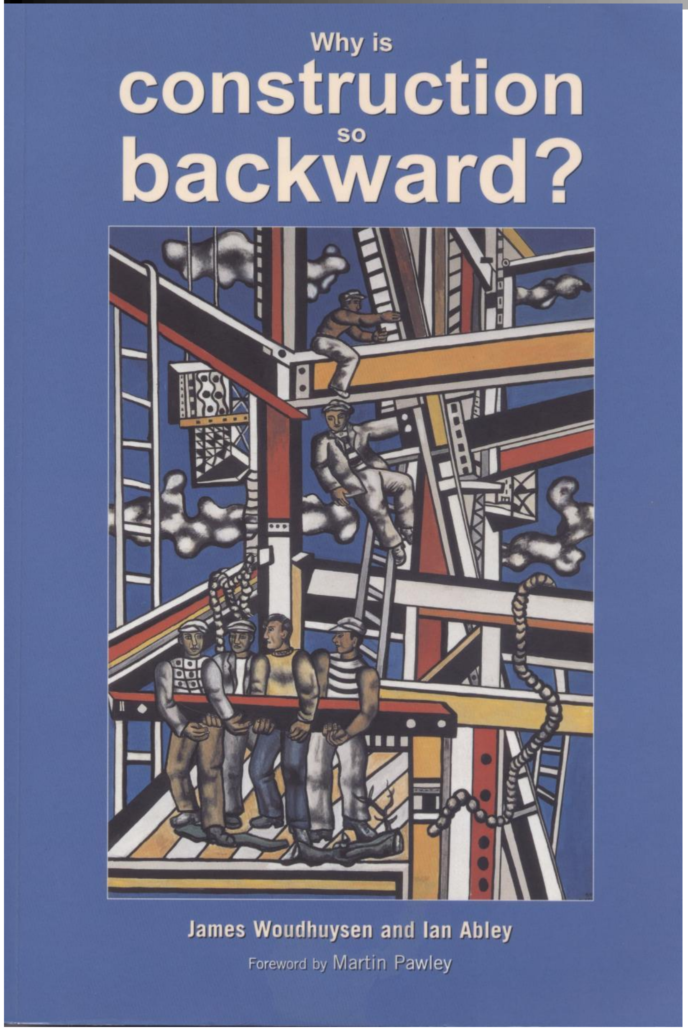
Why is construction so backward?



"So long as construction remains a backward industry, safety within it will be backward. So long as off-site manufacturing remains a footnight to general building, a lot of accidents are bound to happen in the hurly-burly rush to get on-site work completed on time ." (p. 43)

(Woudhysen and Abley, 2004)

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'Failure of management' versus 'Accident'(1)

- There is no such thing as an 'accident' (Myth)!
- Traditional definitions include, among other: 'An unplanned event'
- Are 'accidents' unplanned?
  - Absolutely not!
  - Any review will indicate that they are meticulously planned by default i.e. through actions and or omissions
- Consequently, given that the five functions of management work are planning, organising, leading, controlling, and coordinating, then unplanned events such as 'accidents' = 'failure of management' (Reality)
- Philosophy and constitutes a state of mind

‘Failure of management’ versus ‘Accident’(2)

- Management of all built environment stakeholder organisations, including client, project manager, designer, and quantity surveyor, not just contractors

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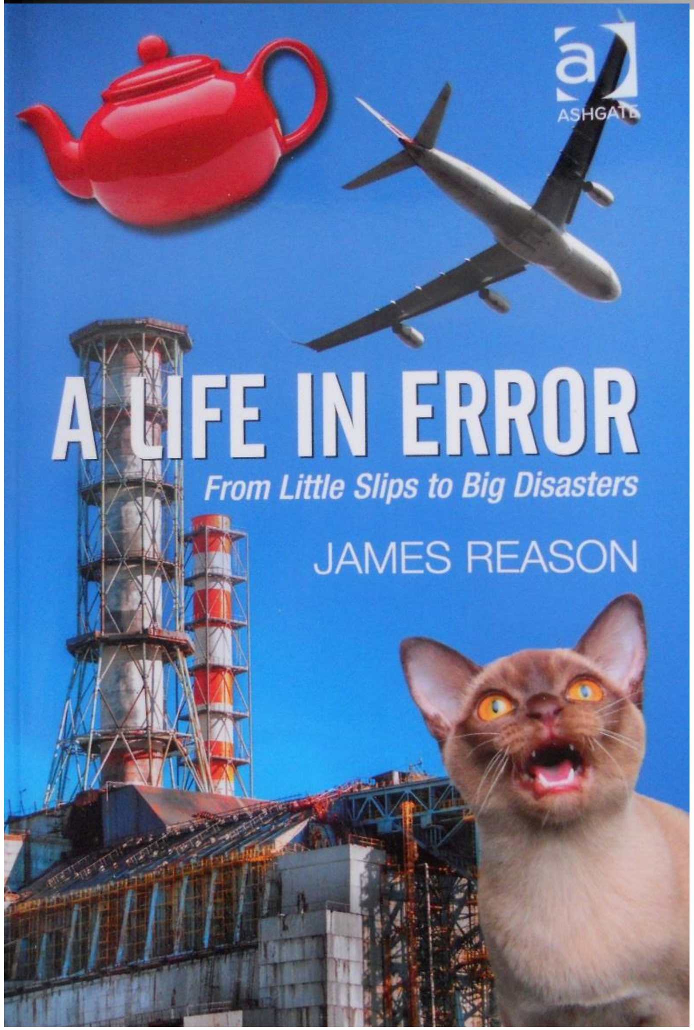
'Failure of management' versus 'Accident'(3)



Chapter 8: Planning Failures

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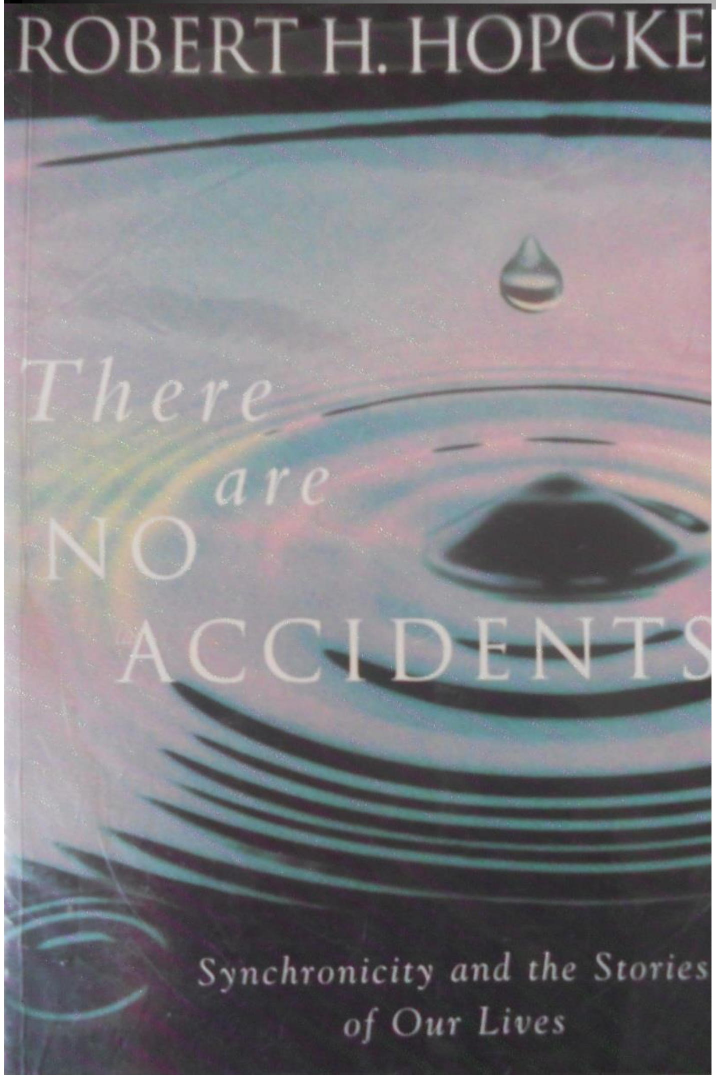
'Failure of management' versus 'Accident'(4)



A different kind of coincidence, a confluence of events that shakes us up. Can see and feel a significance in the randomness. Like pure chance, or just a coincidence. However, Jung refers to it as synchronicity. (p. 3)

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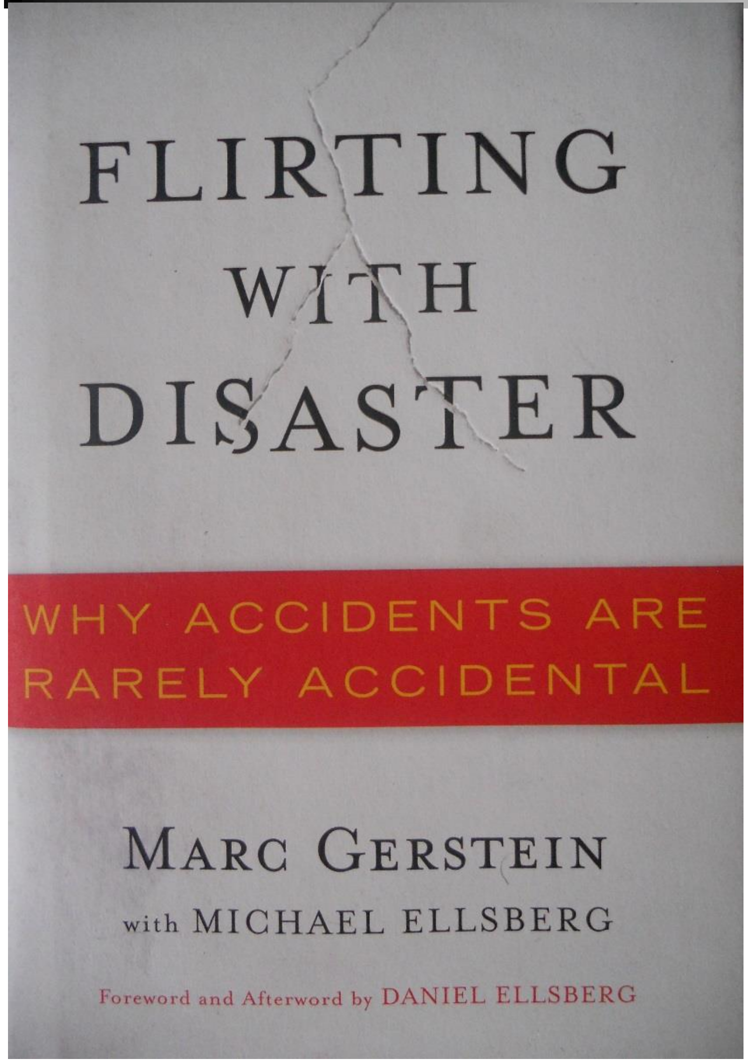
'Failure of management' versus 'Accident'(5)



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Construction is not inherently dangerous

- The myth that 'construction is inherently dangerous' or 'accidents are part of the job' implies that there is nothing that can be done to mitigate hazards and risk
- Strategies, systems, procedures, and protocol can mitigate or even eliminate hazards and risk

Risk management (1)

- Risk introduces potential variability in outcomes
- Risk is not complementary to the business of construction and projects
- Project risk management is 1 / 9 project management knowledge areas
- There are numerous risks in construction, H&S included
- Built environment is not renowned for risk management
- The lack of aversion to risk does not complement construction H&S
- Clients, project managers, principal agents, and construction managers especially should adopt a formal risk management process
- Quantify the risks, rank, and evolve appropriate responses where required

Risk management (2)

- **Beware of 'low probability / high impact' risks e.g. Injaka Bridge**

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Risk management (3)

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, July, 1998 (Travers, 1998)

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Risk management (4)

Department of Labour (2002):

- Causes:
  - 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

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Risk management (5)

- The use of design and construction personnel, at decision-making level, without appropriate qualification and experience in incremental launched bridges
- No independent design reviews were conducted of either the temporary or permanent works

- Contributory causes:
  - 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

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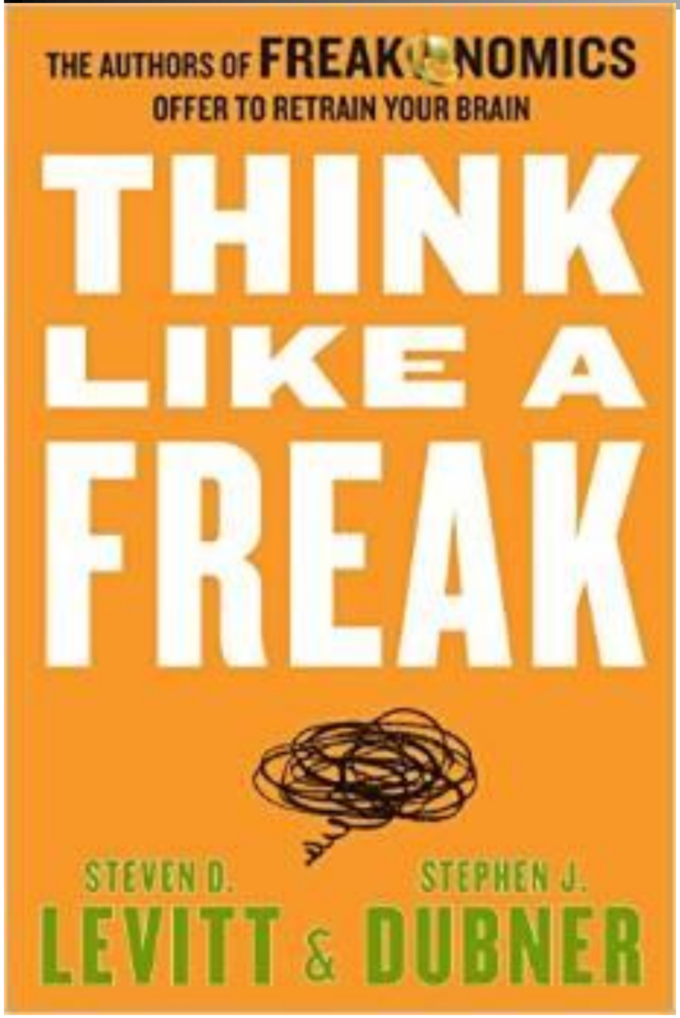
Risk management (6)



Risk management (7)

Chapter 9, *Think like a freak* addresses the Challenger space shuttle (1986):

- **Cold weather might damage the rubber O-rings that kept hot gases from escaping the shuttle boosters**
- **Morton Thiokol's senior engineer and others recommended the launch be postponed – over ruled by NASA**
- **Knowledgeable people forecast the exact cause of failure**
- **Levitt and Dubner advocate 'premortems' as opposed to 'postmortems' i.e. learn how you might fail without failing**
- **Premortem: Gather those involved and imagine that the project or an activity failed and require them to record the exact reasons for failure**

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Respect for people and 'People are our most important resource' (1)

- Respect for people is the catalyst for the value 'people are our most important resource'
- However, poor welfare facilities on site, among other, are not a manifestation of respect for people
- This value is critical as it is the catalyst for H&S culture
- Supervisors and workers that are exposed to hazards and risk are people that have a body, mind, and a soul. They invariably have a partner, a family and are derived from a community
- Such a value is the foundation for H&S and sustainability of an organisation

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Respect for people and 'People are our most important resource' (2)

Workers change room, shower, and lockers, Max 4 project, Lund, Sweden (Smallwood, August 2012)

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Respect for people and ‘People are our most important resource’ (3)

Workers’ mess area, Max 4 project, Lund, Sweden (Smallwood, August 2012)

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Respect for people and 'People are our most important resource' (4)

Mess facility, Sancti Spiritus, Cuba (Smallwood, 2007)

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Respect for people and 'People are our most important resource' (5)

'Outdoor dining', Sishen Expansion Project (SEP) (Smallwood, 2007)

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Respect for people and 'People are our most important resource' (6)

Lockers, SEP (Smallwood, 2007)

Optimum H&S culture

- The catalyst for H&S culture is the value ‘people are our most important resource’
- Such a value will engender a vision of a ‘fatality, injury, and disease-free work place’
- Such a vision requires a complementary goal of ‘zero deviations’
- To realise a goal of ‘zero deviations’, requires ‘continual improvement’ – the mission
- A higher-level purpose is necessary for an optimum H&S culture:
  - ‘Sustainability of the organisation’
  - ‘Sustainability of the industry’
  - Needs to be a rationale for H&S endeavours when fatalities, injuries, and disease are no longer occurring
  - H&S is a means to the end, not an end in itself.

Optimum status for H&S – H&S is a value not a priority

- The passé paradigm of cost, quality, and time is a critical mind set yet to be dispensed with:
  - Using these as the set of criteria by which projects' success is measured marginalises H&S
  - Confirms ignorance with respect to the synergistic role H&S plays in overall project performance
  - Also marginalises H&S culture
  - Reflects a lack of respect for people
- H&S is often referred to as a priority:
  - Priorities may change on a daily basis
  - Therefore, H&S should be a value
  - H&S must always be the first consideration and all activities must be 'structured around it'

Planning (1)

- A hallmark (should be) of the built environment and relevant to all built environment disciplines
- 'Construction is 80% planning and 20% execution'
- 'H&S does not happen by chance, it must be planned'
- However, many facets to 'planning for construction H&S':
  - Completeness of design facilitates construction planning for H&S
  - Client 'baseline risk assessments' [CR 5 (1) (a)]:
    - Prerequisite for preparing H&S Specifications [5 (1) (b)]
  - Design hazard identification and risk assessments (HIRAs):
    - Required to mitigate the use of hazardous materials and undertaking of hazardous processes
    - HIRAs are a prerequisite for preparing H&S Specifications and 'designer reports for clients' [CR 6(1) (c, d, & e), which should include residual hazards and risks i.e. those remaining after conducting HIRAs
  - Designers may also need to prepare 'design and construction' method statements - refer to temporary works and related interventions

Planning (2)

  - Clients' requirements, a form of planning, should also be included in such H&S specification
- Contractors' H&S Plans should respond to such H&S Specifications:
  - Response should reflect in the tender documentation i.e. in the form of budgeting
  - Adequate financial and other resource budgeting is not facilitated by the competitive tendering system
  - Obvious solution being the inclusion of comprehensive 'H&S' preliminaries as opposed to provisional sums
- Construction planning for H&S commences during the pre-tender stage:
  - Followed by the pre-contract stage
  - Which provides the foundation for construction stage planning

Planning (3)

- Pre-tender and pre-contract HIRAs, programmes, site layouts, generic method statements, and temporary works designs are obvious focus areas in terms of integrating construction H&S into the future construction process
- Following adjustments during the pre-contract phase the aforementioned need to translate into daily actions such as HIRAs, focused planning of construction activities, and coordination

Construction is a Science, Art, and a Profession / Sound Construction Management (1)

- Management skills and the application thereof are a pre-requisite for optimum H&S
- The five functions of management work, namely planning, organising, leading, controlling, and coordinating are necessary to realise among other the development of objectives, strategies, systems, procedures, and protocol
- Management and integration of project resources (Smallwood, 2006) are also a pre-requisite for H&S
- One of the many challenges in terms of construction H&S is the limited 'barriers to entry' to the construction industry
- Construction Management programmes established at traditional universities in the 60's and 70's:
  - Result of an identified need therefore
  - The existing management with origins in other built environment disciplines and 'people from the tools' unable to effectively manage the business of construction and projects

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Construction is a Science, Art, and a Profession / Sound Construction Management (2)

- Such programmes focus on three streams, namely economics, management, and science and technology - required to manage the business of construction and projects, construction H&S included
- Every profession, including Construction Management, makes use of a common vocabulary:
  - Not as per the slide ‘Scaffolding Safe For Use’ (two slides from this slide)
  - It was allegedly support work not scaffolding

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Construction is a Science, Art, and a Profession / Sound Construction Management (3)

Coega Bridge collapse, Port Elizabeth, November, 2003 (Markman, 2003)

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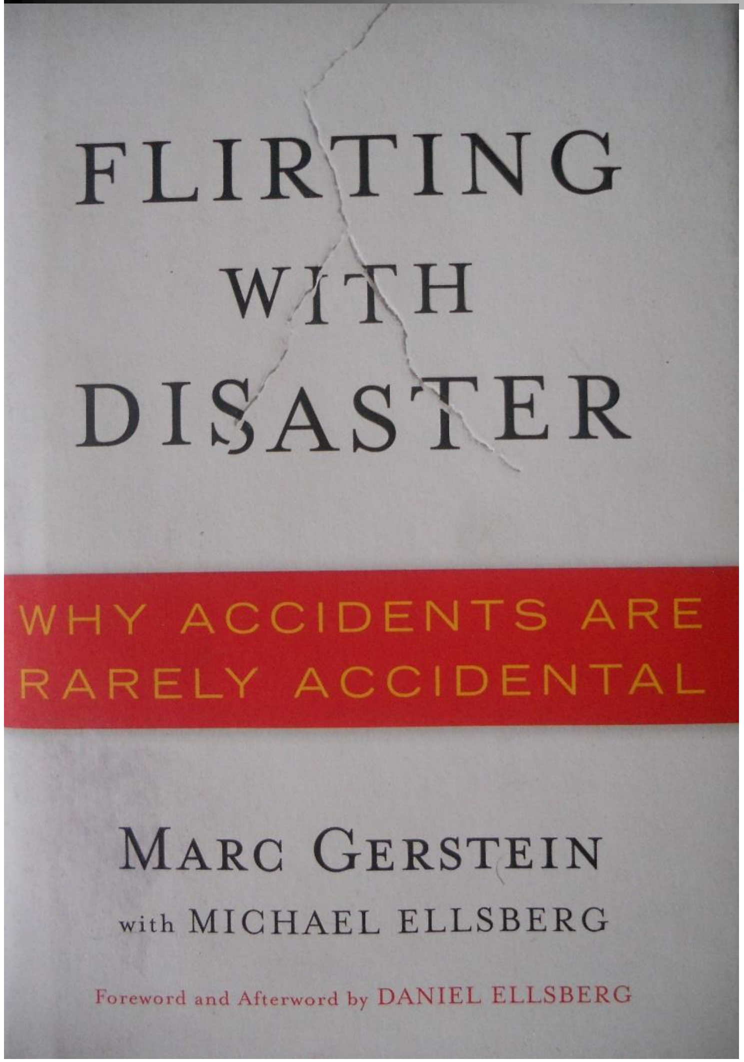
Construction is a Science, Art, and a Profession / Sound Construction Management (4)

Coega Bridge collapse, Port Elizabeth, November, 2003 (Markman, 2003)

Construction is a Science, Art, and a Profession / Sound Construction Management (5)



Construction is a Science, Art, and a Profession / Sound Construction Management (6)

Stellenbosch Collapse (Anonymous, June 2008)

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Construction is a Science, Art, and a Profession / Sound Construction Management (7)

Stellenbosch Collapse (Anonymous, June 2008)

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Construction is a Science, Art, and a Profession / Sound Construction Management (8)

Stellenbosch Collapse (Anonymous, June 2008)

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Construction is a Science, Art, and a Profession / Sound Construction Management (9)

Scaffolding, Bradford on Avon (Smallwood, August 2014)

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Construction is a Science, Art, and a Profession / Sound Construction Management (10)

Scaffolding, Bradford on Avon (Smallwood, August 2014)

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Tertiary Built Environment education that addresses construction H&S

- A pre-requisite for optimum H&S / appropriate status, is the inclusion of H&S in the tertiary education of all built environment disciplines
- Education is a pre-requisite for awareness, sensitisation, commitment, and the development of an optimum H&S culture, and the required competencies to contribute to construction H&S
- With the exception of construction management programmes, which address construction H&S to varying degrees, tertiary built environment education addresses construction H&S to a limited extent, if at all

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Sound core and surface competencies

- Competencies are divided into two categories (Sanghi, 2004):
  - Surface - required to be at least effective
  - Core - distinguishes superior performance from average performance
- The surface competencies are:
  - Knowledge - information regarding content, and
  - Skills - ability to perform a task
- The core competencies are:
  - Self-concept: values; aptitude; attitude, and self-image
  - Traits: self-confidence; team player, and handles ambiguity
  - Motives: focus on client success, and preserves organisation / personal integrity
- Surface competencies are important, but core competencies are critical in a dynamic environment - values, aptitude, ability to handle ambiguity, and preservation of integrity
- The DoL focus is on surface competencies

Integration of design and construction (1)

- Two issues - influence of design on construction H&S, and the type of procurement system
- Design influences construction directly and indirectly:
  - Directly, through design, choice of structural frame, details, method of fixing, constructability, and specification of materials and finishes
  - Indirectly, through choice of procurement system and conditions of contract, procurement, decision regarding project duration, and reference to H&S on various occasions
- Certain procurement systems such as design-build promote the integration of design and construction
- Optimum integration engenders and enhances H&S as it facilitates contractor contributions to the design process
- Designing for H&S is one of sixteen design for constructability principles – contractors can contribute

Integration of design and construction (2)

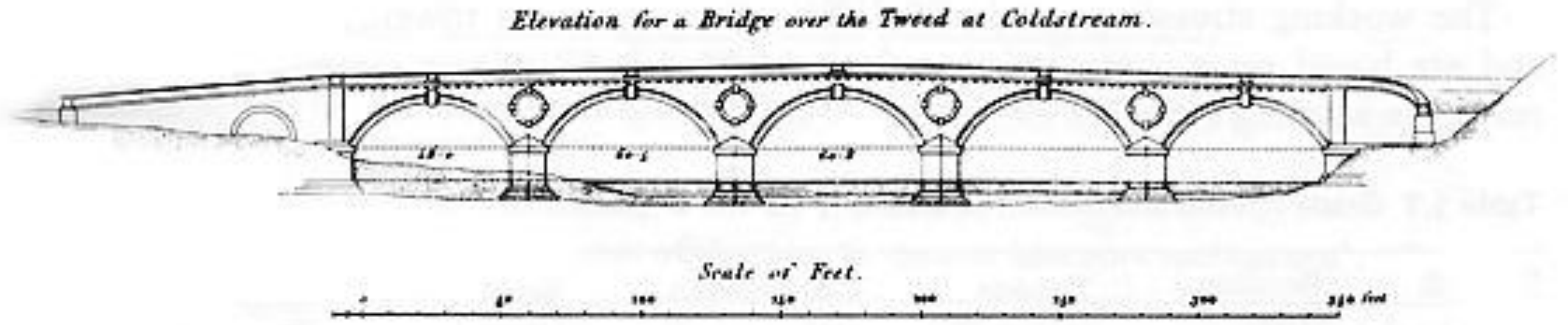

Figure 2: Elevation of masonry Bridge over the Tweed at Coldstream, 1866 (Irwin and Sibbald, 1983)

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Integration of design and construction (3)

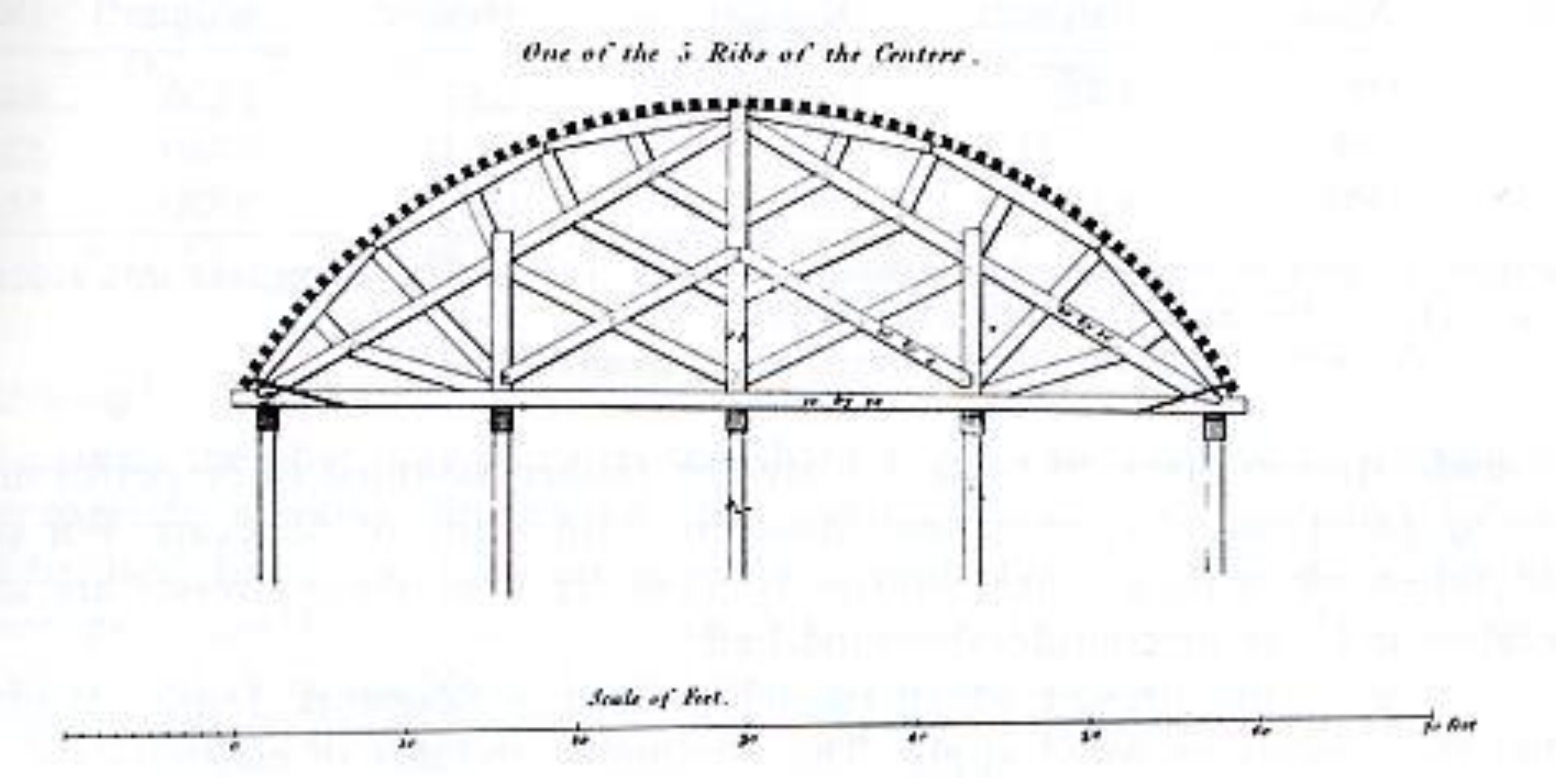

Figure 3: Centering for masonry Bridge over the Tweed at Coldstream, 1866 (Irwin and Sibbald, 1983)

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Integration of design and construction (4)

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

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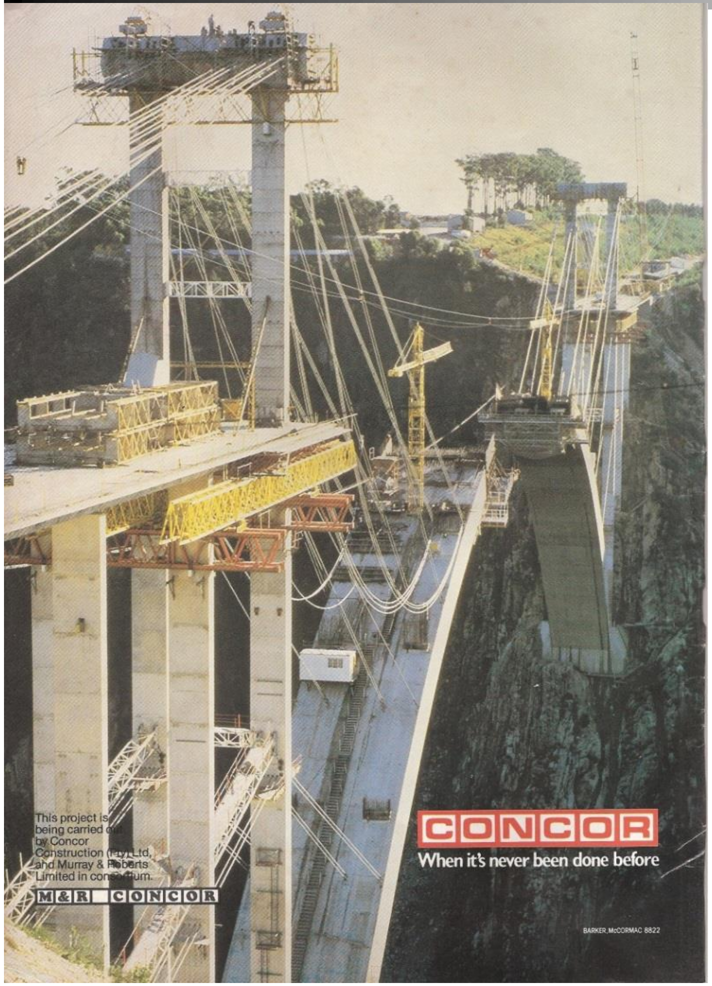
Integration of design and construction (5)



Bloukrans Bridge (Inside Front, Concrete Beton, 1983)

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Integration of design and construction (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…"

Quality and Quality Management Systems (1)

- Four absolutes of quality (Crosby, 1979):
  - Definition – conformance to requirements
  - Performance standard – zero defects
  - System – prevention
  - Measurement – price of non-conformance
- Apply unequivocally to H&S:
  - Numerous H&S requirements contained in, among other, legislation, standards, and H&S Specifications
  - Obvious performance standard relative to H&S is zero accidents – however, deviations create the opportunity for incidents and accidents
  - System is certainly prevention as opposed to appraisal or inspection
  - Cost of accidents (COA) is an ideal form of measurement:
    - All stakeholders can relate thereto
    - Can be expressed as a percentage of the cost or value of a project or the value of completed construction on a macro scale

Quality and Quality Management Systems (QMSs) (2)

- Documented QMS complements H&S as it, among other, documents the systems, procedures, and protocol required relative to the design, procurement, and construction processes

Health and Safety Management Systems (H&SMSs)

- The elements of an H&SMS provide the framework for the management of H&S, namely policy, planning, implementation and operation, checking and corrective action, and management review
- However, given the relationship between quality and H&S, the use of a documented QMS or an integrated management system, will complement H&S

'H&S is a profit centre'

- Given that the COA is estimated to be between 4.3% and 5.4% of the value of completed construction (Smallwood, 2004; cidb, 2009) whereas the cost of implementing H&S is estimated to be:
  - Between 0.5% and 3% of project costs (Smallwood, 2004)
  - 1.6% of tender cost estimate and 1% of project cost (Smallwood, 2011)
- However, the synergy between construction H&S and the other eleven project parameters (Smallwood, 2006) results in further financial benefits: environment; cost; developmental criteria; environment; productivity; public H&S; quality; time; client satisfaction; design team satisfaction, and worker satisfaction

Elimination / Mitigation of ‘excusitis’

- Schwartz (1995) maintains unsuccessful people suffer from a mind deadening thought disease called ‘excusitis’
- Every failure has the disease in its advanced form
- The more successful the individual, the less inclined he / she is to make excuses
- Schwartz also 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
- Consciousness and mindfulness will avert the development of ‘excusitis’ due to the lack of necessity

Consciousness and mindfulness (1)

- Consciousness (Payutto, 1999):
  - "The perception and awareness of sensations, which will be related to particular intentions."
  - "The awareness of sensations, namely seeing, hearing, smelling, tasting, touching and cognising; the basic climate of the mind from moment to moment."
  - Fashioned into specific qualities by intention
- Through self-observation a person can see, be aware, and in control of his / her own body or mind-mindfulness:
  - This includes awareness of mind movement – thoughts
  - Awareness of the constant changes of all mental phenomena resulting in intuitive wisdom, which in turn averts clinging to conditioned phenomena that would lead to suffering (Tanphaichitr, 2001).

Consciousness and mindfulness (2)

- **Support work can be used to explain the role of optimum consciousness and mindfulness. The intention to realise optimum H&S will engender optimum observation and cognising relative to inadequate support work - consciousness. Mindfulness will result in, among other, intuitive wisdom, which will prevent clinging to the conditioned phenomenon of cost i.e. reducing the centres of standards or omitting bracing to reduce cost, which could result in a collapse and suffering of workers.**

This is not the result of consciousness and mindfulness

Stellenbosch Collapse (Anonymous, June 2008)

Research method

- Exploratory study
- Thirty (30) Responses were received from a convenience sample of six general contractors (GCs) and one construction project management practice. A further thirteen (13) responses were received from the Construction Management alumni of the then University of Port Elizabeth (UPE) and now NMMU
- A total of fourty-three (43) responses were included in the analysis of the data

Research report

http://forum.safebuild.co.za/index.php?threads/report-on-preventing-the-collapse-of-reinforced-concrete-rc-structures-support-work-formwork.1082/

Research findings (1)

Parameter	Response (%)						MS	Rank
	U	Limited. ……………………Major						
		1	2	3	4	5		
Project quality	0.0	0.0	0.0	2.4	9.8	87.8	4.85	1
Project cost	0.0	0.0	0.0	0.0	17.1	82.9	4.83	2
Project time	0.0	0.0	0.0	2.4	19.5	78.0	4.76	3
Project H&S	0.0	0.0	0.0	7.3	9.8	82.9	4.76	4
Environment	0.0	0.0	4.9	7.3	26.8	61.0	4.44	5

Table 2: Importance of project parameters to respondents' organisations (MS = 1.00 – 5.00) (Smallwood, 2016)

Research findings (2)

Factor	Response (%)						MS	Rank
	U	Limited. ....Major						
		1	2	3	4	5		
Construction Management's construction management competencies	0.0	0.0	0.0	4.7	7.0	88.4	4.84	1
Design of the permanent structure	2.3	0.0	0.0	2.3	11.6	83.7	4.83	2
Registration of Engineering Designers	0.0	2.4	0.0	2.4	7.1	88.1	4.79	3
Construction Management's structural competencies	0.0	0.0	0.0	9.3	4.7	86.0	4.77	4
Construction hazard identification and risk assessments (HIRAs)	0.0	2.4	0.0	4.9	4.9	87.8	4.76	5
Design HIRAs	0.0	0.0	0.0	2.3	20.9	76.7	4.74	6
Construction Management's temporary works design competencies	0.0	0.0	0.0	9.3	7.0	83.7	4.74	7
Registration of Construction Managers	0.0	2.4	0.0	2.4	14.3	81.0	4.71	8
Temporary Works Designers' temporary works design competencies	0.0	0.0	2.3	2.3	18.6	76.7	4.70	9
Dedicated contractor supervision of the structure during construction	0.0	0.0	2.4	2.4	19.0	76.2	4.69	10
Safe work procedures (SWPs)	0.0	2.4	0.0	2.4	17.1	78.0	4.68	11
Temporary Works Designers' structural competencies	0.0	0.0	2.3	2.3	20.9	74.4	4.67	12
Project quality management (overall)	0.0	0.0	2.3	4.7	20.9	72.1	4.63	13
H&S Plan (Contractors) e.g. support work contractor	0.0	2.3	2.3	2.3	18.6	74.4	4.60	14
Contractor H&S management system	0.0	2.4	0.0	4.8	21.4	71.4	4.60	15
Close contractor supervision of the structure during construction	2.4	0.0	2.4	4.8	23.8	66.7	4.59	16
Temporary works design (scientific)	0.0	0.0	2.3	7.0	20.9	69.8	4.58	17
Project risk management (overall)	0.0	0.0	2.3	9.3	16.3	72.1	4.58	18

Table 3A : Importance of factors relative to preventing the collapse of RC structures during construction (MS = 1.00 – 5.00) (Smallwood, 2016)

Research findings (3)

Factor	Response (%)						MS	Rank
	U	Limited. …………………………Major						
		1	2	3	4	5		
Integration of design and construction	2.3	0.0	2.3	4.7	25.6	65.1	4.57	19
Contractor project risk management plan	0.0	2.4	2.4	2.4	21.4	71.4	4.57	20
H&S method statements	0.0	2.4	0.0	9.5	16.7	71.4	4.55	21
Close engineering designer supervision of the structure during construction	0.0	0.0	2.4	9.5	21.4	66.7	4.52	22
Contractor risk management system	0.0	2.4	0.0	9.5	19.0	69.0	4.52	23
Project H&S management (overall)	0.0	2.3	0.0	9.3	20.9	67.4	4.51	24
H&S Plan (Principal Contractor)	0.0	2.3	2.3	7.0	18.6	69.8	4.51	25
H&S Agents' (Client appointed) Structural competencies	0.0	0.0	7.0	7.0	16.3	69.8	4.49	26
H&S Agents' (Client appointed) H&S competencies	0.0	2.3	7.0	4.7	16.3	69.8	4.44	27
Temporary Works Designers' construction management competencies	0.0	0.0	2.3	16.3	18.6	62.8	4.42	28
H&S Agents' (Client appointed) temporary works design competencies	0.0	2.3	7.0	4.7	18.6	67.4	4.42	29
Construction Management's H&S competencies	0.0	0.0	2.3	23.3	7.0	67.4	4.40	30
Project risk schedule (overall)	2.3	0.0	4.7	9.3	27.9	55.8	4.38	31
H&S Officers' H&S competencies	0.0	4.8	2.4	11.9	11.9	69.0	4.38	32
H&S Agents' (Client appointed) H&S competencies	0.0	2.4	0.0	19.0	16.7	61.9	4.36	33
Registration of H&S Managers	0.0	2.4	0.0	16.7	23.8	57.1	4.33	34
Contractor quality management system	0.0	7.1	0.0	4.8	28.6	59.5	4.33	35
Construction method statements (generic)	0.0	0.0	0.0	19.0	31.0	50.0	4.31	36
Contractor planning	0.0	4.8	4.8	9.5	16.7	64.3	4.31	37

Table 3B : Importance of factors relative to preventing the collapse of RC structures during construction (MS = 1.00 – 5.00) (Smallwood, 2016)

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Research findings (4)

Factor	Response (%)						MS	Rank
	U	Limited. ....Major						
		1	2	3	4	5		
H&S Specification (issued to the Principal Contractor)	0.0	2.3	4.7	14.0	18.6	60.5	4.30	39
Contractor project quality plan	0.0	4.8	2.4	9.5	26.2	57.1	4.29	40
Designer report submitted to the client ito a response to the H&S Specification	2.3	2.3	2.3	11.6	32.6	48.8	4.26	41
Registration of H&S Officers	0.0	2.4	2.4	14.3	28.6	52.4	4.26	42
Construction Work Permit (DoL)	2.4	7.3	7.3	7.3	12.2	63.4	4.20	43
H&S Specification (issued to the designers)	2.4	4.9	7.3	2.4	34.1	48.8	4.18	44
Registration of H&S Agents (Client appointed)	0.0	4.8	4.8	9.5	31.0	50.0	4.17	45
H&S Officers' temporary works design competencies	0.0	2.4	11.9	9.5	23.8	52.4	4.12	46
3rd party review of the design of the permanent structure	2.3	2.3	7.0	18.6	27.9	41.9	4.02	47
Registration of Project Managers	0.0	7.1	4.8	11.9	31.0	45.2	4.02	48
Temporary Works Designers' project management competencies	0.0	2.3	2.3	23.3	34.9	37.2	4.02	49
H&S Agents' (Client appointed) project management competencies	0.0	2.3	9.3	14.0	37.2	37.2	3.98	50
H&S Officers' construction management competencies	0.0	2.4	7.1	23.8	28.6	38.1	3.93	51
H&S Officers' structural competencies	0.0	2.4	9.5	21.4	26.2	40.5	3.93	52
Municipal approval of plans (prior to construction)	2.4	11.9	4.8	11.9	26.2	42.9	3.85	53
Registration of Architectural Designers	0.0	11.9	9.5	14.3	33.3	31.0	3.62	54
Registration of Quantity Surveyors	2.4	16.7	14.3	33.3	19.0	14.3	3.00	55

Table 3C : Importance of factors relative to preventing the collapse of RC structures during construction (MS = 1.00 – 5.00) (Smallwood, 2016)

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Research findings (5)

Factor	Response (%)						MS	Rank
	U	Limited. ……………………Major						
		1	2	3	4	5		
Pre-pour designer inspection: Support work and formwork	0.0	0.0	0.0	2.4	4.8	92.9	4.90	1
Founding of support work	0.0	0.0	0.0	2.4	12.2	85.4	4.83	2
Pre-pour designer inspection: Reinforcing steel	0.0	0.0	0.0	0.0	19.0	81.0	4.81	3
Quality Management System (QMS) during construction	2.3	0.0	2.3	0.0	11.6	83.7	4.81	4
Sound structural design	0.0	0.0	0.0	7.1	4.8	88.1	4.81	5
Reconciliation of erected with design	2.4	0.0	0.0	4.8	11.9	81.0	4.78	6
Quality Management System (QMS) during design (Support work)	2.3	0.0	2.3	0.0	16.3	79.1	4.76	7
Back propping as per requirements	2.4	0.0	0.0	4.8	14.3	78.6	4.76	8
Concrete strength upon striking of support work	2.4	0.0	0.0	7.1	9.5	81.0	4.76	9
Competencies of temporary works designer	0.0	0.0	2.3	0.0	18.6	79.1	4.74	10
Condition of components	0.0	0.0	0.0	2.4	23.8	73.8	4.71	11
Periodic inspections during pouring	2.4	0.0	0.0	2.4	23.8	71.4	4.71	12
Concrete strength as per specified	2.4	0.0	0.0	4.8	19.0	73.8	4.71	13
Back propping layouts	2.4	0.0	0.0	4.8	19.0	73.8	4.71	13
Dedicated support work supervision	0.0	0.0	0.0	7.1	19.0	73.8	4.67	15

Table 4A : Importance of factors relative to optimum support work and formwork and the integrity of structures under construction (MS = 1.00 – 5.00) (Smallwood, 2016)

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Research findings (6)

Factor	Response (%)						MS	Rank
	U	Limited. ……………………Major						
		1	2	3	4	5		
Maintenance of components	0.0	0.0	0.0	2.4	33.3	64.3	4.62	16
Periodic inspections during the back propping period	2.4	0.0	0.0	4.8	28.6	64.3	4.61	17
Circumspect loading of slabs and other elements during the back propping period	2.4	0.0	0.0	7.1	23.8	66.7	4.61	18
Periodic inspections during erection	2.4	0.0	0.0	7.1	26.2	64.3	4.59	19
Compaction of concrete	2.4	0.0	0.0	9.5	21.4	66.7	4.59	20
Scientific support work design	2.4	0.0	4.9	2.4	26.8	63.4	4.53	21
Quality Management System (QMS) during: Design (Structure)	2.3	0.0	2.3	4.7	30.2	60.5	4.52	22
Periodic inspections during striking	2.4	2.4	0.0	4.8	28.6	61.9	4.51	23
Testing of components	0.0	0.0	2.4	4.8	35.7	57.1	4.48	24
H&S Plan (Contractors) e.g. support work contractor	0.0	2.3	2.3	7.0	25.6	62.8	4.44	25
H&S Management System (Principal Contractor)	0.0	2.4	0.0	14.6	17.1	65.9	4.44	26
H&S Plan (Principal Contractor)	0.0	2.3	2.3	7.0	27.9	60.5	4.42	27
Safe work procedures (SWPs)	0.0	2.4	0.0	11.9	26.2	59.5	4.40	28
H&S method statements	0.0	2.4	0.0	16.7	21.4	59.5	4.36	29
Construction method statements (generic)	0.0	0.0	2.4	19.0	23.8	54.8	4.31	30

Table 4B : Importance of factors relative to optimum support work and formwork and the integrity of structures under construction (MS = 1.00 – 5.00) (Smallwood, 2016)

Research findings (7)

- Factor analysis is a method for investigating whether a number of variables of interest, are linearly related to a smaller number of unobservable factors
- Six factors were identified in terms of the 'importance of factors relative to preventing the collapse of RC structures during construction', the factors with loadings > 0.400 being:
  - Factor 1 includes: registration of engineering designers; project quality management (overall); design of the permanent structure; design hazard identification and risk assessments (HIRAs); temporary works design (scientific); integration of design and construction; structural, and temporary works design competencies of H&S Agents; construction management competencies, structural competencies, and temporary works design competencies of both Construction Management and Temporary Works Designers; contractor risk management system; contractor H&S management system; contractor

Research findings (8)

quality management system; contractor project risk management plan; contractor project quality plan; contractor planning; construction HIRAs; dedicated contractor supervision of the structure during construction, and close contractor supervision of the structure during construction

- Factor 2 includes: registration of H&S Agents (Client appointed), H&S Managers, and H&S Officers; H&S Specification (issued to the designers); designer report submitted to the client ito a response to the H&S Specification; H&S Specification (issued to the Principal Contractor); H&S Plan (Principal Contractor); H&S Plan (Contractors); H&S Agents' construction management competencies, structural competencies, and H&S competencies; Construction Management's H&S competencies; Temporary Works Designers' H&S competencies; H&S Officers' construction management competencies, structural competencies, temporary works design competencies, and H&S competencies; contractor risk management system; contractor H&S

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Research findings (9)

management system; construction HIRAs, and H&S method statements, and SWPs

- Factor 3 includes: registration of Project managers, Architectural designers, Engineering designers, Quantity surveyors, and Construction managers; project quality management (overall); design of the permanent structure; H&S Agents' (Client appointed) project management competencies, construction management competencies, and structural competencies; construction method statements (generic), and close engineering designer supervision of the structure during construction
- Factor 4 includes: project H&S management (overall); 3rd party review of the design of the permanent structure; H&S Specification (issued to the designers); designer report submitted to the client ito a response to the H&S Specification; H&S Agents' (Client appointed) project management competencies, construction management competencies, and H&S competencies, and H&S Officers' H&S competencies

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Research findings (10)

- Factor 5 includes: project risk management (overall); project risk schedule (overall); H&S Agents' (Client appointed) structural competencies; Construction Management's structural competencies; Temporary Works Designers' project management competencies, and construction management competencies
- Factor 6 includes: municipal approval of plans (prior to construction); construction work permit (DoL); project risk management (overall), and project quality management (overall)

- Five factors were identified in terms of the importance of factors relative to optimum support work and formwork and the integrity of structures under construction, the factors with loadings > 0.400 being:
  - Factor 1 includes: Quality Management System (QMS) during design (structure), construction, and design (support work); competencies of temporary works designer; dedicated support work supervision;

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Research findings (11)

condition of components; maintenance of components; founding of support work; pre-pour designer inspection (support work and formwork); periodic inspections during pouring; periodic inspections during the back propping period, and circumspect loading of slabs and other elements during the back propping period

- Factor 2 includes: H&S Management System (Principal Contractor); H&S Plan (Principal Contractor); H&S Plan (Contractors); H&S method statements; SWPs, and periodic inspections during pouring
- Factor 3 includes: construction method statements (generic); testing of components; periodic inspections during erection; periodic inspections during striking, and periodic inspections during the back propping
- Factor 4 includes: maintenance of components; reconciliation of erected with design; pre-pour designer inspection (reinforcing steel) and (support work and formwork); concrete strength as per specified; compaction of concrete, and concrete strength upon striking of support work

Research findings (12)

- **Factor 5 includes: dedicated support work supervision; concrete strength upon striking of support work; back propping layouts; back propping as per requirements, and periodic inspections during erection**

Research summary

- Importance of factors in terms of preventing the collapse of RC structures during construction:
  - 42 / 55 (76.4%) factors are of near major to major / major importance
  - 12 / 55 (21.8%) factors are of importance to near major / near major importance
  - 1 / 55 (1.8%) factor is of near minor importance to importance / importance
- Importance of factors relative to optimum support work and formwork and the integrity of structures under construction:
  - 30 / 30 (100.0%) factors are of near major to major / major importance

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Conclusions (1)

- Given that the traditional three project parameters, namely quality, cost, and time are perceived to be more important than H&S to respondents' organisations, it can be concluded that the industry collectively is perpetuating the paradigm to the detriment of H&S
- Given the importance of factors in terms of preventing the collapse of RC structures during construction, and more importantly the identification of six 'groups' of factors, it can be concluded that the requisite 'cocktail' of factors must be in place and to an optimum extent. Competencies, design, registration of built environment professionals, HIRAs, supervision, quality management, H&S management, risk management, planning and H&S planning in various forms,

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Conclusions (2)

integration of design and construction, and the construction work permit, are all important as clusters or individually relative to preventing the collapse of RC structures during construction

- Similarly, given the importance of factors relative to optimum support work and formwork and the integrity of structures under construction, and more importantly the identification of five 'groups' of factors, it can be concluded that the requisite 'cocktail' of factors must be in place and to an optimum extent. Quality management, competencies, supervision; a range of support work aspects, inspections, circumspect loading, H&S management, planning and H&S planning in various forms, and conformance to requirements, are all

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Conclusions (3)

important as clusters or individually relative to optimum support work and formwork and the integrity of structures under construction

Recommendations (1)

- Ultimately, conformance to requirements is the key, which includes, among other, municipal approval of building plans, and the construction work permit
- However, a pre-requisite for conformance to requirements is that many of the requirements should be scientifically evolved and communicated
- However, in parallel, the required competencies must exist else the aforementioned cannot be achieved. Competencies in turn can only be assured through a formal registration process such as that required by the six South African built environment councils
- Registration of contractors should interrogate H&S, quality, and risk management systems and practices

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Recommendations (2)

- Clearly, contractors should also be also be pre-qualified in terms of H&S, quality, and risk management systems and practices
- Ideally, multi-stakeholder project H&S, quality, and risk plans should be evolved
- Design and construction must be integrated and the ‘grey areas’ relative to achieving same must be addressed
- General construction management and H&S planning must be a hallmark of all projects
- Management and supervision are critical, as both planning and execution are important

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