NELSON MANDELA UNIVERSITY

CREATIVE CONSTRUCTION CONFERENCE 2019

BUDAPEST, HUNGARY, 29 JUNE – 2 JULY

KEYNOTE ADDRESS

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

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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 (98.1% of the sites) 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)
- Fatality rate per 100 000 workers: 25.5 (cidb, 2009)
- Australia: 3.3 in 2016 (Safe Work Australia, 2017) and UK: 1.94 in 2015 / 2016 (HSE, 2016)

Introduction (2)

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

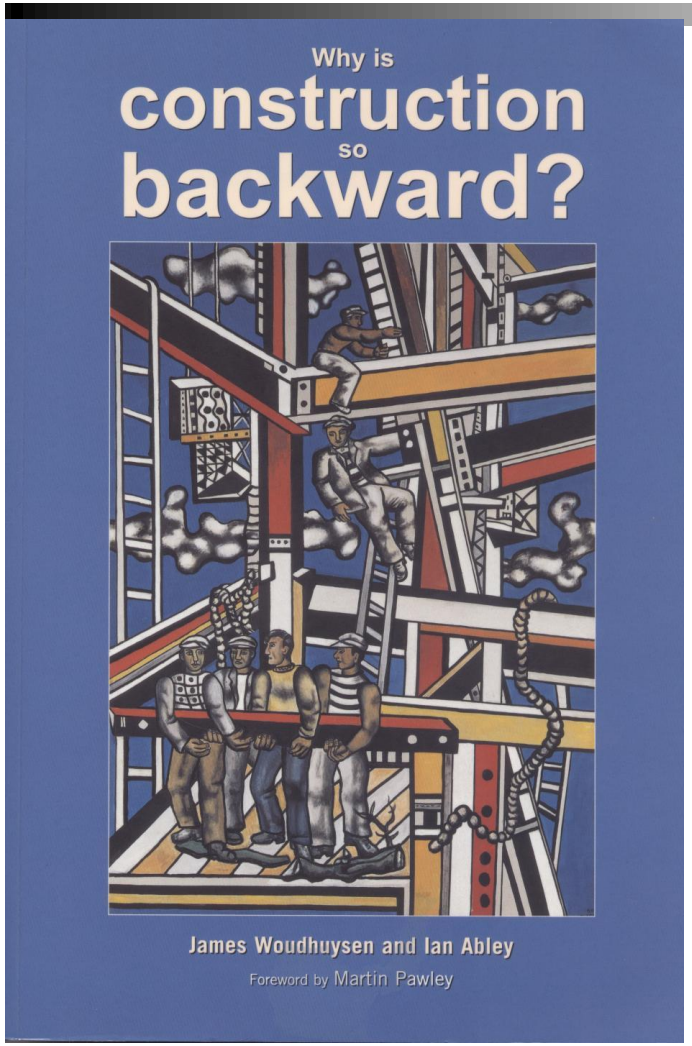
- **The following articles reflect the experience of collapses:**
  - **Constructing reinforced concrete frames without injury and fatality: The relationship between health and safety and quality, *The Civil Engineering and Building Contractor*, March 1997**
  - **Large-scale construction accidents Is 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**
  - **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**

Introduction (3)

- Accidents will continue to occur in construction until ….. , *Specifier*, August 2004

- 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 post-Tongaat Mall collapse, 19 November 2013)

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 Ableу, 2004)

Pretoria North Shopping Centre slab collapse (October, 1996)

(Davis, 1996)

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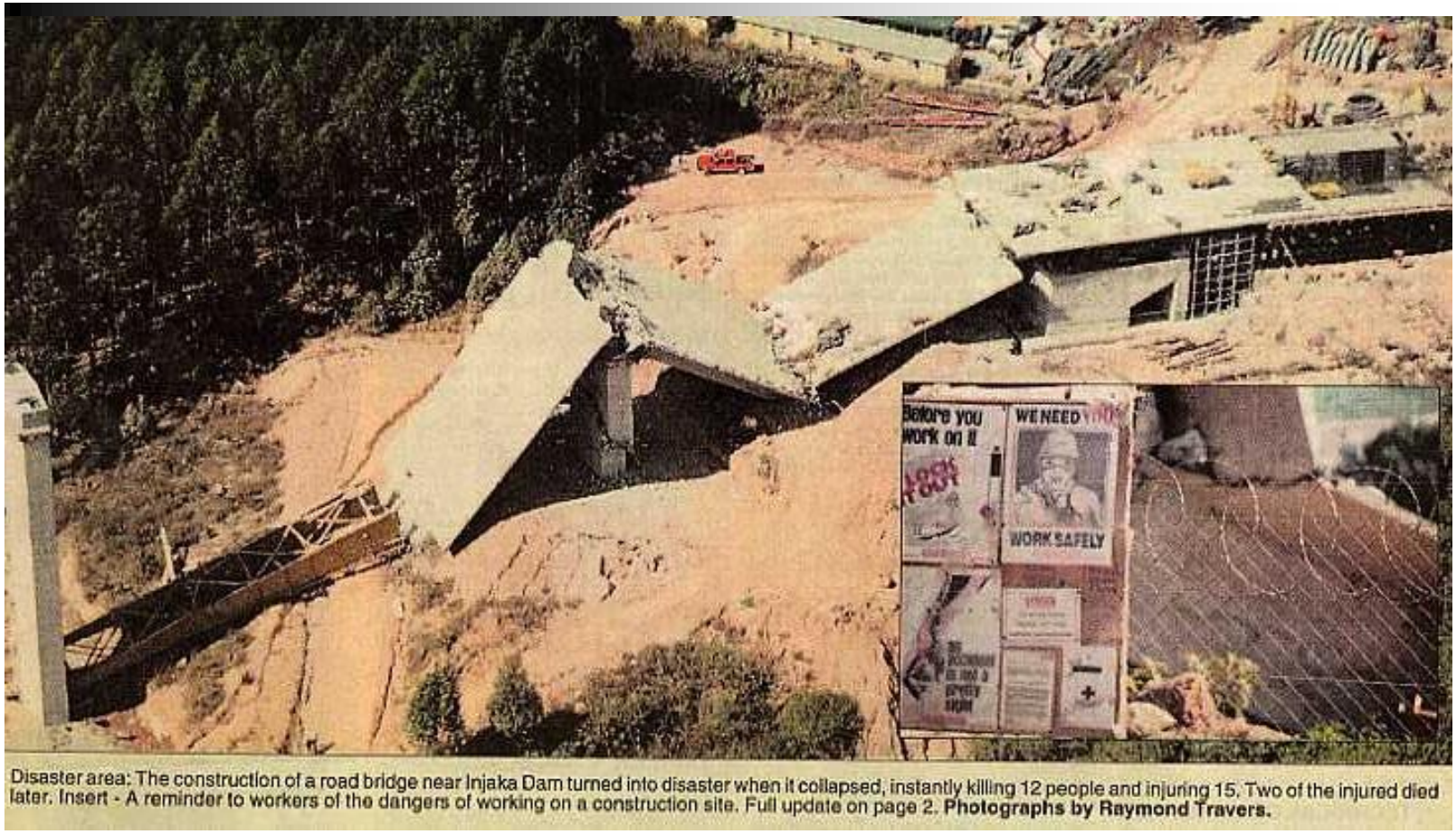
Injaka Bridge collapse, Mpumalanga (July 1998)



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.**

(Travers, 1998)

Coega Bridge collapse, Port Elizabeth (November, 2003) (1)

(Markman, 2003)

Coega Bridge collapse, Port Elizabeth (November, 2003) (2)

(Markman, 2003)

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

(Tertius, 2004)

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

(Tertius, 2004)

Umhlanga Ridge collapse (1)

(Anonymous)

Umhlanga Ridge collapse (2)

(Anonymous)

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Tongaat Mall Collapse (19 November 2013) (1)

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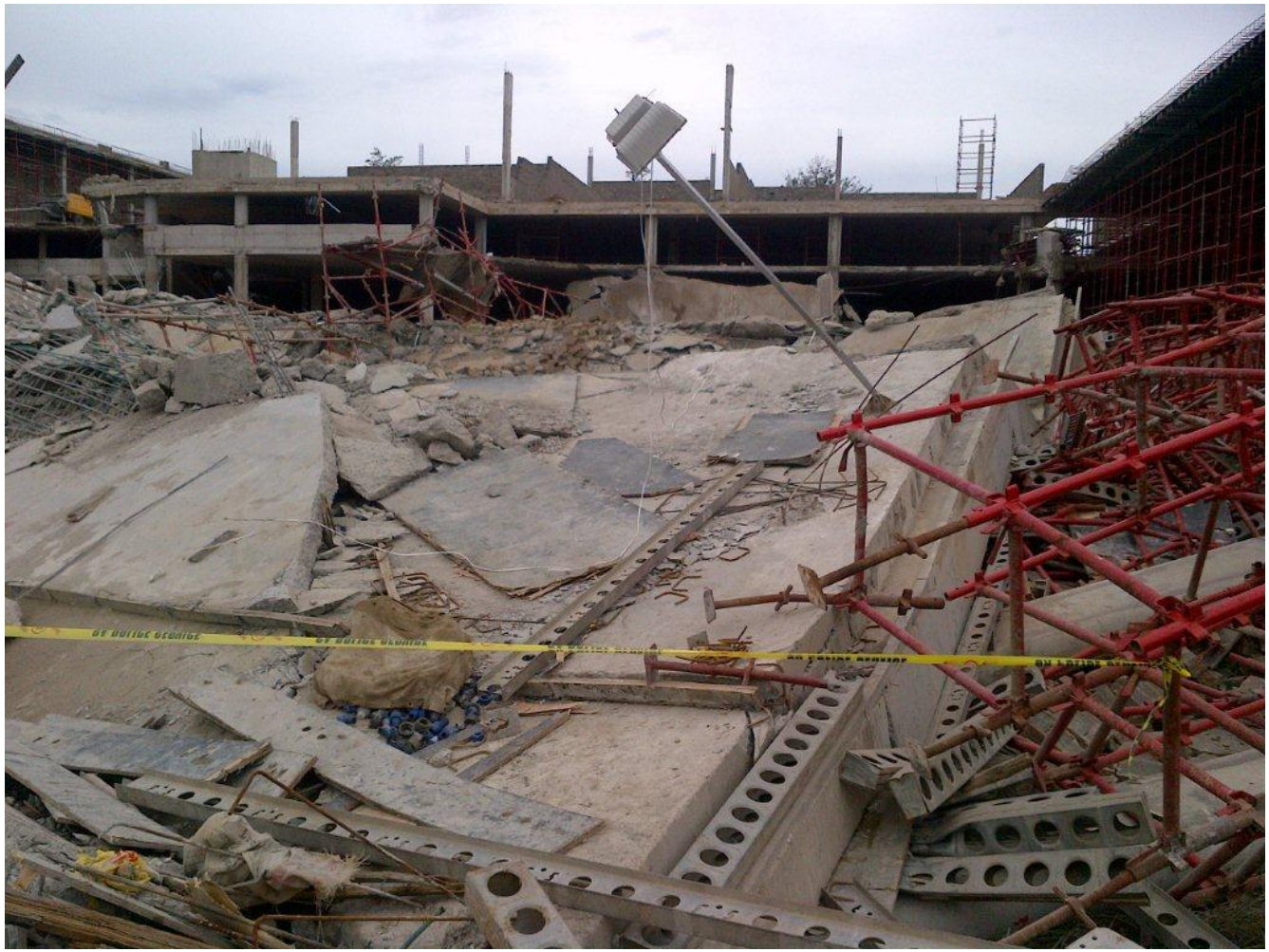
Tongaat Mall Collapse (19 November 2013) (2)



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Beacon Bay Hotel collapse (July 2015)

(DispatchLIVE, 2015)

M1 Highway Temporary Bridge collapse, Johannesburg (14 October 2015)

(Reuters)

Worcester Reservoir Collapse (14 October 2019) (1)

(Anonymous)

Worcester Reservoir Collapse (14 October 2019) (2)

(Anonymous)

Brazil bridge collapse, Belo Horizonte (3 July 2014) (1)

(Sweet, 2019)

Brazil bridge collapse, Belo Horizonte (3 July 2014) (2)

(Sweet, 2019)

Morandi Bridge, Genoa (14 August 2018) (1)

(Controlled explosion, 28 June 2019: Global Construction Review, 2019)

Morandi Bridge, Genoa (14 August 2018) (2)

(Smallwood, 2018)

Morandi Bridge, Genoa (14 August 2018) (3)

(Smallwood, 2018)

Morandi Bridge, Genoa (14 August 2018) (4)

(Smallwood, 2018)

Morandi Bridge, Genoa (14 August 2018) (5)

(Smallwood, 2018)

Morandi Bridge, Genoa (14 August 2018) (6)

(Smallwood, 2018)

Morandi Bridge, Genoa (14 August 2018) (7)

(Smallwood, 2018)

Building collapse, Sihanoukville, Cambodia (22 June 2019)

(Associated Press, 2019)

Issues (1)

- 'Failure of management' versus 'Accident'
- Construction is not inherently dangerous
- Risk management
- Respect for people
- 'People are our most important resource'
- Optimum H&S culture
- Optimum status for H&S – H&S is a value not a priority
- Planning
- Construction is a Science, Art, and a Profession
- Sound Construction Management
- Tertiary Built Environment education that addresses construction H&S
- Sound core and surface competencies
- Integration of design and construction

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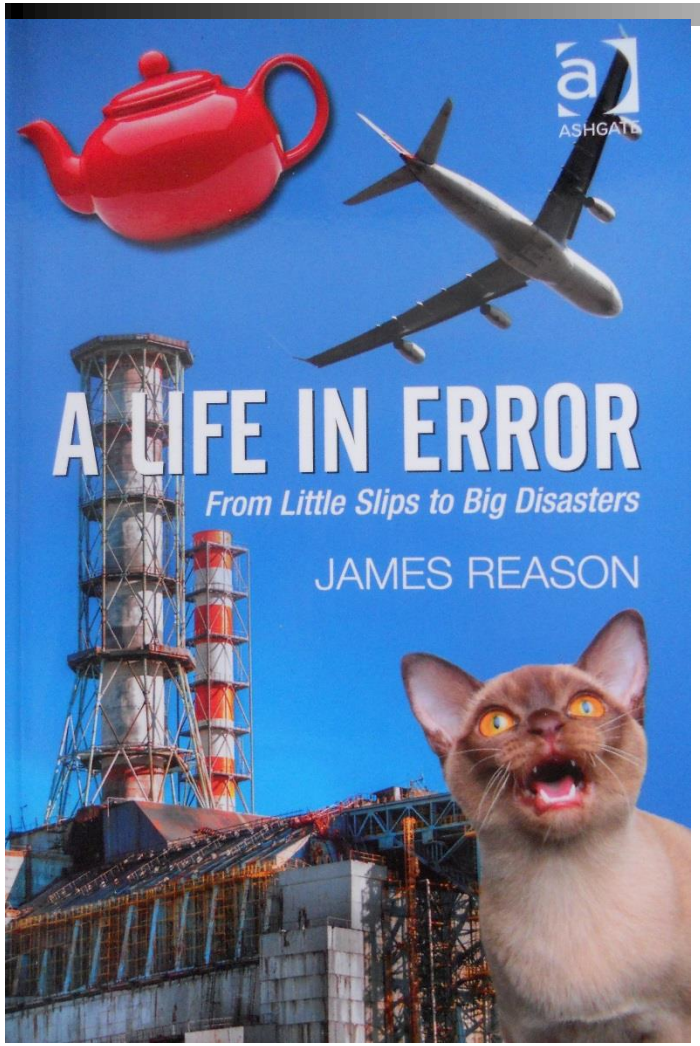
Issues (2)

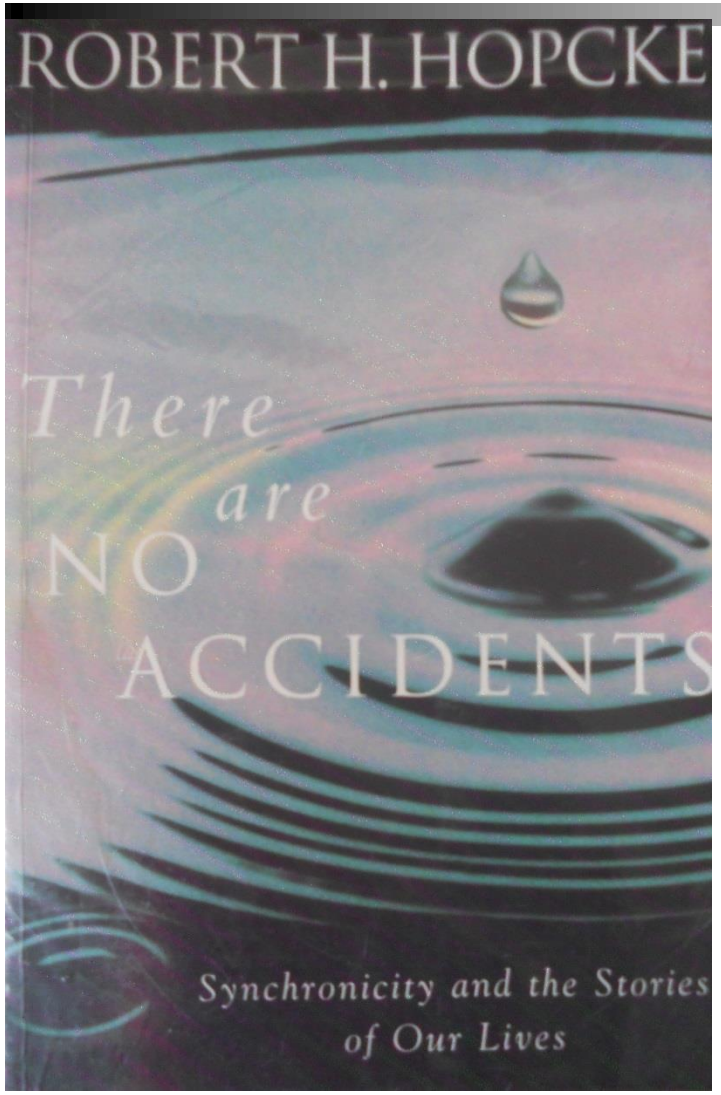
- Quality and Quality Management Systems
- Health and Safety Management Systems
- H&S is a ‘profit centre’
- Elimination / Mitigation of ‘excusitis’
- Consciousness and mindfulness

‘Failure of management’ versus ‘Accident’(1)



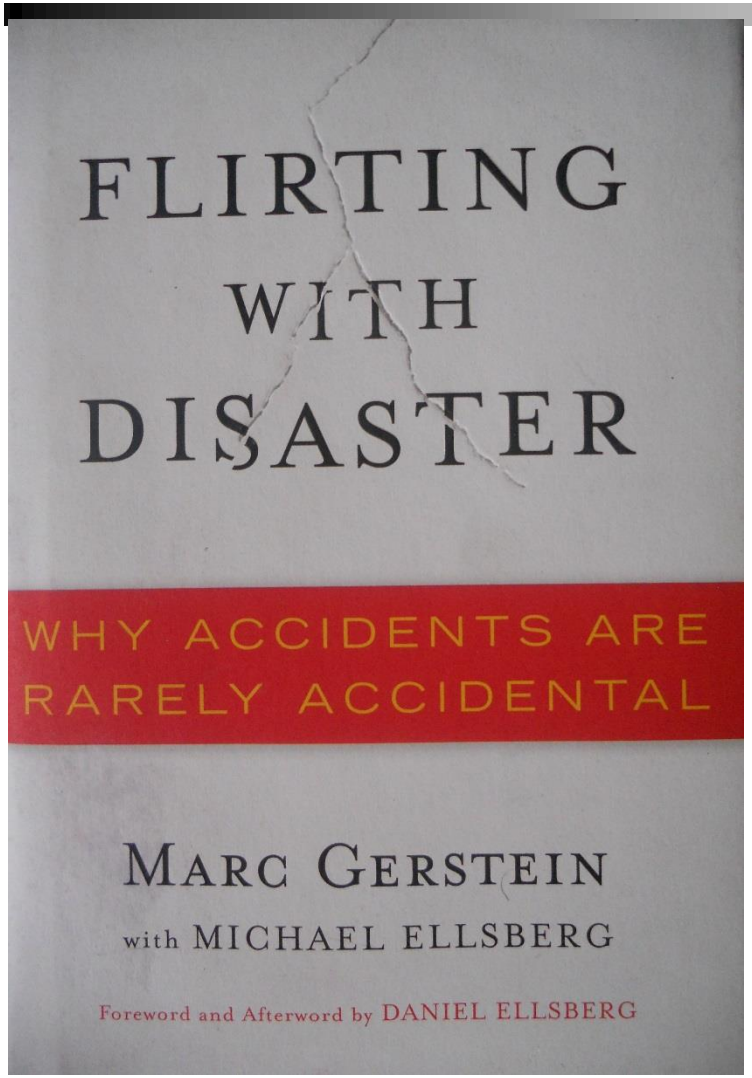
Chapter 8: Planning Failures

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



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)

‘Failure of management’ versus ‘Accident’(3)



‘Failure of management’ versus ‘Accident’(4)

Stellenbosch Collapse (Anonymous, June 2008)

‘Failure of management’ versus ‘Accident’(5)

Stellenbosch Collapse (Anonymous, June 2008)

‘Failure of management’ versus ‘Accident’ (6)

Stellenbosch Collapse (Anonymous, June 2008)

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.

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This is not the result of consciousness and mindfulness

Stellenbosch Collapse (Anonymous, June 2008)

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

Scaffolding, Bradford on Avon (Smallwood, August 2014)

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

Scaffolding, Bradford on Avon (Smallwood, August 2014)

The Golden Rule (1)

Eckhardt (2001) says the 'golden rule', which establishes a moral level of care for others that we are responsible to provide, is a common theme in most, if not all, of the world's major religions:

- Buddhist: hurt not others in ways that you would find hurtful
- Christian: all things whatsoever he would that men should do to you, do ye even so to them;
- Confucian: do not unto others what you would not have them do unto you
- Hindu: this is the sum of the duty; do naught unto others which if done to thee would cause thee pain
- Islamic: no one of you is a believer until he desires for his brother that which he desires for himself

The Golden Rule (2)

- Jain: in happiness and suffering, in joy and grief, we should regard all creatures as we regard our own self
- Sikh: as thou deemest thyself, so deem others
- Taoist: regard your neighbours gain as your own gain, and your neighbour's loss as your own loss
- Zoroastrian: that nature alone is good which refrains from doing unto another whatsoever is not good for itself

The Golden Rule (3)

Statement	MS		
	2002	2018	Var.
A price cannot be put on a person's life	4.94	4.94	0.00
Values influence a person's concern for another person's well-being	4.53	4.89	0.36
People have a body, mind, and a soul	4.82	4.83	0.01
People are an organisation's most important resource	4.88	4.82	(0.06)
Values are important for H&S	4.82	4.82	0.00
Non-compliance with legislation is unethical	4.35	4.78	0.43
Exclusive / Primary focus on cost compromises H&S	4.00	4.72	0.72
We as people are 'our brother's (sister's) keeper'	4.12	4.67	0.55
Workers should be assigned work which suits their abilities	4.13	4.67	0.54
People and the environment (nature) are inter-connected	4.41	4.65	0.24
H&S should be a value and not a priority	4.50	4.56	0.06
A healthy and safe work place results in justice and equity (fairness)	3.94	4.56	0.62
A healthy and safe work place results in dignity of labour	3.82	4.56	0.74
Accidents result in hardship to the injured	4.59	4.56	(0.03)
Optimum H&S engenders sustainability of the organisation	4.24	4.56	0.32
Management is responsible for workers' well-being	3.88	4.44	0.56
Belief in and practice of a religion influences a person's values	3.94	4.35	0.41
A healthy and safe work place results in avoidance / removal of hardship	3.76	4.35	0.59
Optimum H&S engenders sustainability of the earth	4.06	4.24	0.18
Optimum H&S reduces waste	4.59	4.17	(0.42)
Work is a deed of spiritual value	3.65	3.44	(0.21)

Table 1: Comparison of the 2018 versus the 2002 degree of concurrence with 'morality' related statements (MS = 1.00 – 5.00).

Research method (1)

- Exploratory study to determine:
  - Importance of project parameters to respondents' organisations
  - Importance of 55 factors relative to preventing the collapse of RC structures during construction
  - Importance of 30 factors relative to optimum support work and formwork and the integrity of structures under construction
- 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 at the time, NMMU
- A total of fourty-three (43) responses were included in the analysis of the data

Research method (2)

- Descriptive statistics:
  - Frequencies (percentages)
  - Measure of central tendency (mean score) between 1.00 and 5.00
- Factor analysis was conducted to identify whether a number of variables of interest, are linearly related to a smaller number of unobservable factors

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)

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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

Table 3: Top 10 / 55 factors in terms of the 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 (3)

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
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
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 4: Top 15 / 30 factors in terms of the 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 (4)

Factor	Loading per factor					
	1	2	3	4	5	6
Registration of:						
• Project managers	-0.063	0.335	0.591	0.119	0.000	0.067
• Architectural designers	-0.157	0.262	0.686	0.262	0.225	0.049
• Engineering designers	0.415	-0.029	0.646	0.027	-0.248	0.040
• Quantity surveyors	-0.174	0.192	0.609	0.253	0.096	0.211
• Construction managers	0.398	0.018	0.712	-0.109	-0.335	0.138
• H&S Agents (Client appointed)	-0.232	0.578	0.272	0.182	0.172	0.130
• H&S Managers	-0.189	0.800	0.258	-0.090	0.045	0.145
• H&S Officers	0.071	0.833	0.099	0.088	-0.046	0.069
Municipal approval of plans (prior to construction)	0.080	0.011	0.246	0.370	-0.064	0.668
Construction Work Permit (DoL)	0.071	0.202	0.004	0.074	-0.055	0.706
Project risk management (overall)	0.311	0.272	0.096	-0.225	0.412	0.569
Project H&S management (overall)	0.224	0.257	0.116	0.445	0.143	0.366
Project quality management (overall)	0.538	0.097	0.437	-0.051	-0.141	0.458
Design of the permanent structure	0.536	0.098	0.548	0.105	0.092	-0.115
Design hazard identification and risk assessments (HIRAs)	0.560	0.165	-0.279	0.170	0.307	0.020
3rd party review of the design of the permanent structure	0.147	0.163	0.179	0.733	0.049	0.022
Temporary works design (scientific)	0.605	0.040	-0.119	0.143	0.019	0.123
Integration of design and construction	0.630	-0.023	-0.052	0.167	0.216	0.112
H&S Specification (issued to the designers)	0.076	0.411	0.097	0.716	0.277	0.214
Designer report submitted to the client ito a response to the H&S Specification	0.193	0.509	-0.026	0.632	0.130	0.079

Table 5A: Pattern matrix for the importance of factors relative to preventing the collapse of RC structures during construction (Smallwood, 2016)

Research findings (5)

Factor	Loading per factor					
	1	2	3	4	5	6
Project risk schedule (overall)	0.250	0.235	0.011	0.370	0.618	0.260
H&S Specification (issued to the Principal Contractor)	0.223	0.680	-0.027	0.253	0.190	0.314
H&S Plan (Principal Contractor)	0.252	0.740	-0.075	0.238	0.107	0.341
H&S Plan (Contractors) e.g. support work contractor	0.295	0.739	-0.205	0.292	0.063	0.098
H&S Agents' (Client appointed):						
• Project management competencies	0.073	0.394	0.465	0.496	0.349	-0.008
• Construction management competencies	0.106	0.497	0.469	0.482	0.319	-0.032
• Structural competencies	0.403	0.422	0.470	-0.114	0.481	-0.032
• Temporary works design competencies	0.557	0.344	0.360	0.055	0.343	-0.151
• H&S competencies	0.244	0.621	0.023	0.562	0.106	0.131
Construction Management's:						
• Construction management competencies	0.693	0.335	0.027	-0.013	0.217	0.197
• Structural competencies	0.549	0.392	0.063	-0.220	0.455	0.203
• Temporary works design competencies	0.592	0.328	0.033	-0.190	0.359	0.245
• H&S competencies	0.212	0.579	0.048	0.341	0.360	0.209
Temporary Works Designers':						
• Project management competencies	0.211	-0.005	0.104	0.276	0.657	-0.081
• Construction management competencies	0.423	0.043	0.035	0.148	0.666	-0.055
• Structural competencies	0.624	0.056	-0.080	0.279	0.397	-0.230
• Temporary works design competencies	0.639	0.026	-0.172	0.331	0.227	-0.176
• H&S competencies	0.315	0.572	-0.085	0.323	0.359	-0.044

Table 5B: Pattern matrix for the importance of factors relative to preventing the collapse of RC structures during construction (Smallwood, 2016)

Research findings (6)

Factor	Loading per factor					
	1	2	3	4	5	6
H&S Officers':						
• Construction management competencies	0.219	0.639	0.169	0.116	0.160	0.051
• Structural competencies	0.277	0.706	0.255	-0.080	0.135	-0.092
• Temporary works design competencies	0.262	0.719	0.231	0.020	0.086	-0.157
• H&S competencies	0.362	0.592	0.116	0.525	0.089	-0.001
Contractor risk management system	0.671	0.542	0.113	0.109	0.115	0.161
Contractor H&S management system	0.665	0.540	0.136	0.198	0.162	0.100
Contractor quality management system	0.829	0.067	0.309	0.092	-0.051	0.063
Contractor project risk management plan	0.816	0.195	0.218	0.033	0.154	0.073
Contractor project quality plan	0.727	-0.023	0.372	0.257	0.105	0.177
Contractor planning	0.700	0.092	0.109	0.051	0.026	0.105
Construction hazard identification and risk assessments (HIRAs)	0.709	0.460	0.006	0.376	0.006	-0.158
Construction method statements (generic)	0.320	0.102	0.424	-0.101	0.150	0.213
H&S method statements	0.181	0.771	0.284	0.241	-0.182	0.171
Safe work procedures (SWPs)	0.151	0.723	0.294	0.345	-0.307	0.012
Dedicated contractor supervision of the structure during construction	0.828	0.230	0.151	0.037	-0.041	0.145
Close contractor supervision of the structure during construction	0.770	0.201	0.164	-0.008	0.193	-0.056
Close engineering designer supervision of the structure during construction	0.380	0.096	0.441	-0.010	0.177	-0.108

Table 5C: Pattern matrix for the importance of factors relative to preventing the collapse of RC structures during construction (Smallwood, 2016)

Research findings (7)

Factor	Loading per factor				
	1	2	3	4	5
Sound structural design	0.328	0.081	-0.076	0.273	0.002
H&S Management System (Principal Contractor)	0.026	0.729	-0.029	0.089	-0.005
Quality Management System (QMS) during:					
• Design (Structure)	0.670	0.067	0.122	0.131	0.088
• Construction	0.688	0.192	0.176	0.315	0.105
• Design (Support work)	0.772	0.161	0.111	0.336	0.126
Scientific support work design	0.320	0.094	0.394	0.292	0.138
Competencies of temporary works designer	0.564	0.319	0.188	0.392	0.321
H&S Plan (Principal Contractor)	0.381	0.846	0.107	0.078	0.235
H&S Plan (Contractors) e.g. support work contractor	0.223	0.706	0.258	0.123	0.298
Construction method statements (generic)	0.326	0.269	0.529	0.294	-0.002
H&S method statements	0.068	0.835	0.313	0.223	0.092
Safe work procedures (SWPs)	0.140	0.811	0.183	0.148	0.140
Dedicated support work supervision	0.519	0.089	0.075	0.347	0.456
Condition of components	0.478	0.272	0.249	0.340	0.303

Table 6A: Pattern matrix for the importance of factors relative to optimum support work and formwork and the integrity of structures under construction (Smallwood, 2016)

Research findings (8)

Factor	Loading per factor				
	1	2	3	4	5
Testing of components	0.153	0.026	0.642	0.347	-0.198
Maintenance of components	0.454	0.063	0.218	0.597	0.068
Founding of support work	0.649	0.102	0.231	0.345	0.326
Reconciliation of erected with design	0.364	0.029	0.157	0.535	0.139
Pre-pour designer inspection:					
• Reinforcing steel	0.328	0.125	0.086	0.469	0.230
• Support work and formwork	0.674	0.133	0.090	0.421	0.200
Concrete strength as per specified	0.178	0.198	0.242	0.829	0.154
Compaction of concrete	0.265	0.266	0.324	0.551	0.083
Concrete strength upon striking of support work	0.141	0.183	0.181	0.712	0.446
Back propping layouts	0.317	0.269	0.147	0.246	0.734
Back propping as per requirements	0.313	0.251	0.139	0.305	0.841
Periodic inspections during erection	0.273	0.270	0.738	0.074	0.414
Periodic inspections during pouring	0.582	0.503	0.368	0.082	0.129
Periodic inspections during striking	0.021	0.240	0.818	0.159	0.258
Periodic inspections during the back-propping period	0.537	0.372	0.484	0.033	0.242
Circumspect loading of slabs and other elements during the back-propping period	0.604	0.127	0.313	0.013	0.225

Table 6B: Pattern matrix for the importance of factors relative to optimum support work and formwork and the integrity of structures under construction (Smallwood, 2016)

Research findings (9)

- 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 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

Research findings (10)

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

Research findings (11)

- 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

Research findings (12)

- 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;

Research findings (13)

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 (14)

- 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

Conclusions (1)

- Importance of project parameters:
  - The industry collectively is perpetuating the paradigm of 'cost, quality, and time' to the detriment of H&S
- Importance of factors in terms of preventing the collapse of RC structures during construction:
  - Identification of six 'groups' of factors
  - 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, integration of design and construction, and the construction work permit, are all important as clusters or individually

Conclusions (2)

- The importance of factors relative to optimum support work and formwork and the integrity of structures under construction:
  - Identification of five ‘groups’ of factors
  - 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 important as clusters or individually

Recommendations (1)

- Ultimately, conformance to requirements is the key, which includes, among other, municipal approval of building plans, and the construction work permit (South Africa)
- 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

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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