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FEEDBACK REPORT ON AN EXPLORATORY STUDY ‘PREVENTING THE COLLAPSE OF REINFORCED CONCRETE (RC) STRUCTURES, SUPPORT WORK AND FORMWORK DURING CONSTRUCTION’

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DEDICATION

The report is dedicated to the improvement of health and safety (H&S) performance in South African construction, and more specifically, preventing the collapse of reinforced concrete (RC) structures, and support work and formwork.

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A research report, regardless of magnitude, requires acknowledgements and thanks to:

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ORIGIN OF THE REPORT

The continuing occurrence of 'collapses', both in terms of structure, and support work and formwork, underscore the need for a proactive approach to the addressing of the phenomena. Furthermore, there are 'better practice' construction firms in South Africa that subscribe to the concept of continuous improvement and 'better practice', and hence their willingness to participate in the study reported on.

SCOPE OF THE REPORT

This report has been compiled primarily to provide feedback to the respondents, but also the South African construction industry.

EXECUTIVE SUMMARY

The traditional three project parameters, namely quality, cost, and time are perceived to be more important than H&S to respondents' organisations.

42 / 55 (76.4%) Factors are of near major to major / major importance in terms of preventing the collapse of RC structures during construction. A further 12 / 55 (21.8%) factors are between important to more than important / more than important, and only 1 is between less than important to important / important.

A further 30 factors are of near major to major / major importance in terms of realising optimum support work and formwork, and the integrity of structures under construction.

Factor analysis identified six groups of factors relative to the 'importance of factors relative to preventing the collapse of RC structures during construction' and five groups of factors relative to the 'importance of factors relative to optimum support work and formwork, and the integrity of structures under construction'.

Conclusions include that competencies, design, registration of built environment professionals, hazard identification and risk assessments (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 of factors, or individually, relative to preventing the collapse of RC structures during construction.

Recommendations include that conformance to requirements is the key, that such recommendations be scientifically evolved and communicated, a pre-requisite being that the required competencies exist, which can only be assured through a formal registration process, including that of contractors. Ideally, multi-stakeholder project H&S, quality, and risk plans should be evolved, and design and construction must be integrated. Then, general construction management and H&S planning must be a hallmark of all projects, and then optimum management and supervision to ensure execution of such planning.

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1. OBJECTIVES OF THE STUDY

The objectives of the study were to determine the:

- Perceived importance of five project parameters;
- Importance of fifty-five factors relative to preventing the collapse of RC structures during construction, and
- Importance of thirty factors relative to optimum support work and formwork and the integrity of structures under construction.

2. RESEARCH METHOD AND SAMPLE STRATUM

Thirty (30) Responses were received from a convenience sample of six (6) general contractors (GCs) and one (1) 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.

3. RESEARCH FINDINGS

3.1 Analysis

The analysis of the data consisted of the calculation of descriptive statistics to depict the frequency distribution and central tendency of responses to fixed response questions to determine the degree of importance.

Close ended questions with five-point Likert scales, which also included an 'unsure' response option were used. Therefore, to rank fixed response items according to the central tendency of responses, mean scores (MSs) were calculated as follows:

$$MS = \frac{1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5}{(n_o + n_1 + n_2 + n_3 + n_4 + n_5) - n_0}$$

The variables are referenced in Table 1.

Table 1: Definition of Likert scale points and related variables

Likert scale point		Variable
Unsure	Unsure	n_o
Not	Limited	n_1
Less than important	More than limited	n_2
Important	Importance	n_3
More than important	Near major	n_4
Very important	Major	n_5

3.2 Findings

Table 2 indicates that 45.3% of respondents have worked for their current employer '> 1 ≤ 5' years, followed by 19% '> 5 ≤ 10' years, and 11.9% relative to each of '≤ 1', '> 10 ≤ 20', and '> 20' years. In summary, 88.1% of respondents have worked for their current employer > 1 year, 42.8% for > 5 years, and 23.8% > 10 years. The mean length of time respondents have worked for their current employer is 7.9 years. Therefore, the respondents can be deemed to have had exposure to their oragnisations, which contributes to the reliability of the findings.

Table 2: Length of time respondents have worked for their current employer

Period (Years)	Response (%)
≤ 1	11.9
> 1 ≤ 5	45.3
> 5 ≤ 10	19.0
> 10 ≤ 20	11.9
> 20	11.9

34.2% of respondents have worked in construction '> 10 ≤ 20' years, followed by 26.8% '> 5 ≤ 10' years, 22% '> 20' years, 14.6% '> 1 ≤ 5' years, and 2.4% '≤ 1' year (Table 3). In summary, 97.6% of respondents have worked in construction > 1 year, 83% for > 5 years, and 56.2% > 10 years. The mean length of time respondents have worked in construction is 14.5 years. This implies that the respondents can be deemed experienced, which contributes to the reliability of the findings.

Table 3: Length of time respondents have worked in construction

Period (Years)	Response (%)
≤ 1	2.4
> 1 ≤ 5	14.6
> 5 ≤ 10	26.8
> 10 ≤ 20	34.2
> 20	22.0

Table 4 indicates that 42.9% of respondents were '> 30 ≤ 40' years of age, followed by 23.8% '≤ 30', 14.3% for each of '> 40 ≤ 50' and '> 50 ≤ 60', and only 4.8% '> 60'. In summary, 66.8% were '≤ 40' years of age, and 33.2% were > 40 years. Per definition relative to workers, people > 40 years of age are 'older workers'. The mean age was 37.9 years.

Table 4: Respondents' age

Period (Years)	Response (%)
≤ 30	23.9
> 30 ≤ 40	42.9
> 40 ≤ 50	14.3
> 50 ≤ 60	14.3
> 60	4.8

7% of respondents were female and 90.7% were male. 2.3% did not select a gender.

Table 5 indicates the importance of five parameters to respondents' organisations on a scale of 1 (not important) to 5 (very important), and a mean score (MS) ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general the respondents can be deemed to perceive the parameters as important. However, given that the MSs are all > 4.20 ≤ 5.00, the respondents can be deemed to perceive them to be between more than important to very important / very important.

Furthermore, it is notable that the traditional three project parameters, namely quality, cost, and time are perceived to be more important than H&S. However, quality management is critical in terms of assuring the structural integrity of permanent and temporary structures.

Table 5: Importance of project parameters to respondents' organisations

Parameter	Response (%)						MS	Rank
	Unsure	Not ………………………………………… Very						
		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 6 indicates the importance of 55 factors relative to preventing the collapse of RC structures during construction on a scale of 1 (limited) to 5 (major), and a mean score (MS) ranging between 1.00 and 5.00. It is notable that except for one, all the MSs are above the midpoint score of 3.00, which indicates that in general the respondents perceive the factors as being of major as opposed to limited importance relative to preventing the collapse of RC structures during construction.

It is also notable that 42 / 55 (76.4%) of all the MSs are > 4.20 ≤ 5.00, which indicates that the importance of the factors is between near major to major / major. A further 12 / 55 (21.8%) factors' MSs are > 3.40 ≤ 4.20 - between important to more than important / more than important. Only 1 factor has a MS > 2.60 ≤ 3.40 - between less than important to important / important.

With respect to the upper half of the MS range > 4.20 ≤ 5.00, thirteen factors have MSs > 4.60. 'Construction Management's construction management competencies' (1st), 'Construction Management's structural competencies' (4th), and 'Construction Management's temporary works design competencies' (7th) amplify the reality, namely that construction management is an all-encompassing discipline. Firstly, it must manage the construction process and its activities (also the business of construction at a macro level), and secondly it must be empowered to do so. Hence, Construction Management programmes include three main streams, namely economics, management, and science and technology. However, their ability to do so must be assured, hence 'Registration of Construction Managers' eighth ranking. Then, Design of the permanent structure' ranked second and 'Registration of Engineering designers' ranked third as the former is a pre-requisite for the prevention of collapses, and the latter assures that the designers are competent. 'Construction hazard identification and risk assessments (HIRAs)' and 'Design HIRAs' ranked fifth and sixth respectively amplify the importance of planning in general and 'prevention through design'. 'Safe work procedures (SWPs)' ranked eleventh further amplifies the importance of planning and assurance relative to H&S and quality. 'Dedicated contractor supervision of the structure during construction' ranked tenth, reflects the importance of supervision. 'Temporary Works Designers' temporary works design competencies' and 'Temporary Works Designers' structural competencies' ranked ninth and twelfth reflect the importance of temporary works in preventing the collapse of RC structures during construction. Thirteenth ranked 'Project quality management (overall)' highlights the importance of quality management across all stakeholder groups involved with a construction project, and the linkage between H&S and quality.

With respect to the lower half of the MS range > 4.20 ≤ 5.00, twenty-nine factors have MSs > 4.20. It is notable that 'H&S Plan (Contractors) e.g., support work contractor' is ranked fourteenth, and 'Contractor project risk management plan' is ranked twentieth, whereas 'H&S Plan (Principal Contractor)' is ranked twenty-fifth. Related 'H&S method statements' is ranked twenty first. In terms of management and management systems, 'Contractor H&S management system' is ranked fifteenth, 'Project risk management (overall)' eighteenth, 'Contractor risk management system' twenty-third, and 'Project H&S management (overall)' twenty-fourth. Supervision features in the form of 'Close contractor supervision of the structure during construction' ranked sixteenth, and 'Close engineering designer supervision of the structure during construction' ranked twenty-second. It is notable that 'Temporary works design (scientific)' is ranked seventeenth, whereas 'Design of the permanent structure' was ranked second. Furthermore, 'Integration of design and construction' which links the aforementioned, is ranked nineteenth. A range of competency related factors are ranked between twenty-sixth and fourty-fourth. It is notable that 'H&S Agents' (Client appointed) structural competencies' (26th) and 'H&S Agents' (Client appointed) H&S competencies' (27th) are ranked higher than 'Temporary Works Designers' construction management competencies' (28th), followed by 'H&S Agents' (Client appointed) temporary works design competencies' (29th). The aforementioned highlights the importance of H&S Agents (Client appointed). 'Construction Management's H&S competencies' is ranked thirtieth, followed by 'H&S Officers' H&S competencies' (32nd), 'H&S Agents' (Client appointed) H&S competencies' (33rd), and 'Temporary Works Designers' H&S competencies' (38th). Registration first features in the form of 'Registration of H&S Managers' (34th), followed by 'Registration of H&S Officers' (42nd). The relationship between H&S and risk management and quality management features in the form of 'Project risk schedule (overall)' (31st), 'Contractor quality management system' (35th), and 'Contractor project quality plan' (40th). The importance of planning relative to H&S is reflected in 'Construction method statements (generic)' (36th), and 'Contractor planning' (37th). It is notable that although 'H&S Plan (Principal Contractor)' was ranked twenty-fifth, it was followed distantly by two factors with which it is directly related, namely 'H&S Specification (issued to the Principal Contractor)' (39th), and 'Designer report submitted to the client ito a response to the H&S Specification' (41st).

12 / 55 (21.8%) of the MSs are > 3.40 ≤ 4.20, which indicates that the importance of the factors is between important to near major important / near major important. 'Construction Work Permit (DoL)' (45th) is courtesy of the 2014 Construction Regulations and is intended to act as a filter in terms of ensuring that clients' baseline risk assessments (BRAs) and the 'H&S Specification (issued to the designers)' (46th) have been provided. 'Registration of H&S Agents (Client appointed)' (47th) follows higher ranked 'Registration of Engineering designers' (3rd), 'Registration of: Construction Managers' (8th), 'Registration of H&S Managers' (34th), and 'Registration of H&S Officers' (42nd). In turn it is followed by 'Registration of Project managers' (52nd), 'Registration of Architectural designers' (59th), and 'Registration of Quantity surveyors' (60th). A cluster of competency related factors include: 'H&S Officers' temporary works design competencies' (49th); 'Temporary Works Designers' project management competencies' (53rd); 'H&S Agents' (Client appointed) project management competencies' (54th); 'H&S Officers' construction management competencies' (55th), and 'H&S Officers' structural competencies' (56th). What is significant relative to the aforementioned is the importance of non-H&S competencies to H&S Agents, and H&S Officers. Municipal approval of plans (prior to construction) (51st) and '3rd party review of the design of the permanent structure' (58th) are ranked within the aforementioned cluster. The former is notable as the non-approval of plans has been linked to buildings and structures that have collapsed.

The MS of 'Registration of Quantity Surveyors' is > 2.60 ≤ 3.40, which indicates the importance is between near limited to important / important.

Table 6: Importance of factors relative to preventing the collapse of RC structures during construction

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
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
Temporary Works Designers H&S competencies	0.0	0.0	4.7	16.3	23.3	55.8	4.30	38
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

Factor	Response (%)						MS	Rank
	U	Limited ……………………………………Major						
		1	2	3	4	5		
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 7 indicates the importance of 30 factors relative to optimum support work and formwork and the integrity of structures under construction on a scale of 1 (limited) to 5 (major), and a MS ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general the respondents perceive the factors as being of major as opposed to limited importance relative to optimum support work and formwork and the integrity of structures under construction. It is also notable that all the MSs are > 4.20 ≤ 5.00, which indicates that the importance of the factors is between near major to major / major.

With respect to the upper half of the MS range > 4.20 ≤ 5.00, eighteen (60%) factors have MSs > 4.60. Two 'pre-pour designer inspection' feature, namely 'support work and formwork' ranked first and 'reinforcing steel' ranked third. Founding of support work is ranked third. Two 'Quality Management System (QMS) during' feature, namely 'construction' ranked fourth, and 'design (support work)' ranked seventh. 'Sound structural design' and 'reconciliation of erected with design' ranked fifth and sixth respectively reflect the importance of linking the processes relative to support work and formwork. 'Back-propping as per requirements' (8th) and 'Concrete strength upon striking of support work' (9th) are related. It is notable that the highest ranked competencies factor is 'Competencies of temporary works designer' (10th). 'Condition of components' (11th) is important as corrosion, pitting, and buckled components compromise the 'temporary structure'. 'Maintenance of components' (16th) assures the 'Condition of components'. 'Periodic inspections during pouring' (12th) and 'Periodic inspections during the back-propping period' (17th) highlight the importance of active management and supervision. This is reinforced or underscored by 'Dedicated support work supervision' (15th). 'Concrete strength as per specified' (13th) may be deemed obvious, however the challenge is to ensure that the designed strength concrete is poured in the respective elements – this requires, among other, quality management. 'Back-propping layouts' (14th), and 'Circumspect loading of slabs and other elements during the back-propping period' (18th) are related, and critical in terms of assuring the integrity of the permanent structure and the preventing of collapses.

With respect to the lower half of the MS range > 4.20 ≤ 5.00, twelve factors have MSs > 4.20. Further inspection related factors include 'Periodic inspections during erection' (19th) and 'Periodic inspections during striking' (23rd), which again highlight the importance of active management and supervision. 'Compaction of concrete' (20th) is important in terms of realising structural integrity. 'Scientific support work design' ranked twenty-first is notable as it is the 'point of departure' in terms of support work. 'Quality Management System (QMS) during design (Structure)' (22nd) again amplifies the importance of quality management and the link with H&S management. 'Testing of components' (24th) is necessary to ensure that the structural support capacity of components has not been compromised through use. H&S plans feature twice in the form of 'H&S Plan (Contractors) e.g. support work contractor' (25th) and 'H&S Plan (Principal Contractor)' (27th). The former is applicable should the support work and formwork activity be subcontracted. However, regardless of the form of the provision thereof, it should be addressed in the overarching H&S plan. 'H&S Management System (Principal Contractor)' (26th) constitutes better practice as such a system is similar to a QMS as it provides the framework within which H&S is managed in an organisation. 'Safe work procedures (SWPs)' (28th), 'H&S method statements' (29th), and 'Construction method statements (generic) (30th).

Table 7: Importance of factors relative to optimum support work and formwork and the integrity of structures under construction

Factor	U	Limited ……………………………………Major					MS	Rank
		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
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

Factor analysis was then conducted relative to the ‘importance of factors relative to preventing the collapse of RC structures during construction’ and the ‘importance of factors relative to optimum support work and formwork and the integrity of structures under construction’. Factor analysis is a method for investigating whether several variables of interest, such as the factors discussed in Tables 6 and 7, are linearly related to a smaller number of unobservable factors.

Table 8 presents the pattern matrix for the importance of factors relative to preventing the collapse of RC structures during construction. Six factors were identified and the loadings > 0.400 have been identified in the form of red font.

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.

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.

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.

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).

Table 8: Pattern matrix for the importance of factors relative to preventing the collapse of RC structures during construction

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
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

Factor	Loading per factor					
	1	2	3	4	5	6
• 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
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 9 presents the pattern matrix for the importance of factors relative to optimum support work and formwork and the integrity of structures under construction. Five factors were identified and the loadings > 0.400 have been identified in the form of red font.

Factor 1 includes: Quality Management System (QMS) during design (structure), construction, and design (support work); competencies of temporary works designer; dedicated support work supervision; 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.

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.

Table 9: Pattern matrix for the importance of factors relative to optimum support work and formwork and the integrity of structures under construction

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
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

A total of 77 comments were received, which equates to a mean of 1.8 comments per respondent. The highest number of comments received from a respondent was seven. The aforementioned is notable and correlates with the response to similar topical issues, which elicit emphatic comments, particularly from knowledgeable and / or committed practitioners. Table 8 presents a summary of the number of comments per respondent and the frequency thereof. 81.4% of respondents made a comment or more. The comments will be recorded in the final report.

Table 8: Number of comments in general regarding preventing collapses of structures during construction

No.	Response (%)
0	18.6
1	32.6
2	23.3
3	14.0
4	4.7
5	4.7
6	0.0
7	2.3

4. CONCLUSIONS

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

5. RECOMMENDATIONS

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. Clearly, contractors should 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. Then, 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.