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Preventing the Collapse of Reinforced Concrete (RC) Structures, and Support Work During Construction: A Support Work Manufacturer's Perceptions

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Abstract

In recent years, there have been a spate of collapses in South Africa, in terms of buildings, slabs, and support work. Given the current reality, a study was initiated to determine, inter alia, the importance of fifty-five factors relative to preventing the collapse of RC structures during construction, and the importance of thirty factors relative to optimum support work and formwork and the integrity of structures under construction.

The study reported on is based upon findings resulting from a self-administered survey of a temporary works designer and suppliers' staff that attended a workshop presented by the author.

The salient findings are as follows. 83.3% of the 55 factors are between near major to major / major importance, and 16.7% are between important to near major / near major importance relative to preventing the collapse of RC structures during construction. 83.3% of the 30 factors are between near major to major / major importance, and 16.7% are between important to near major / near major importance relative to optimum support work and formwork and the integrity of structures under construction.

Recommendations include that conformance to requirements is the key, that such requirements 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.

Keywords: Collapses; Construction; Structures; Support work; Zero

1. Introduction

The report 'Construction Health & Safety Status & Recommendations' highlighted the considerable number of accidents, fatalities, and other injuries that occur in the South African construction industry [1]. The report cited the high-level of non-compliance with H&S legislative requirements, which is indicative of a deficiency of effective management and supervision of H&S on construction sites as well as planning from the inception / conception of projects within the context of project management. The report also cited a lack of sufficiently skilled, experienced, and knowledgeable persons to manage H&S on construction sites.

The spate of collapses in South Africa include the Pretoria North slab collapse, 1996, a notable collapse, which was 'flagged' in the 'Construction Health & Safety Status & Recommendations' report [1]. Then, more recently the Tongaat mall collapse in November 2013 [2] while under construction, highlighted the nature and extent of collapses involving reinforced concrete structures and support work. Furthermore, there have been a plethora of collapses between these two collapses, including the Injaka bridge collapse in July 1998 [3].

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Given the aforementioned, and the need to adopt a ‘preventative’ approach with respect to the problem, a study was conducted, the objectives being to, *inter alia*, determine the:

- 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. Review of the literature

2.1. Health and safety legislation and standards

The South African Construction Regulations constitute the primary regulations in terms of managing H&S in the construction industry [4].

Clients are required to, inter alia, prepare an H&S specification based on their baseline risk assessment (BRA), which is then provided to designers. They must then ensure that the designer takes the H&S specification into account during design, and that the designers carry out their duties in terms of Regulation 6 ‘Duties of designers’. Thereafter, clients must include the H&S specification in the tender documentation, which in theory should have been revised to include any relevant H&S information included in the designer report as discussed below.

Designers in turn are required to, inter alia: consider the H&S specification; submit a report to the client before tender stage that includes all the relevant H&S information about the design that may affect the pricing of the work, the geotechnical-science aspects, and the loading that the structure is designed to withstand; inform the client of any known or anticipated dangers or hazards relating to the construction work, and make available all relevant information required for the safe execution of the work upon being designed or when the design is changed; modify the design or make use of substitute materials where the design necessitates the use of dangerous procedures or materials hazardous to H&S, and consider hazards relating to subsequent maintenance of the structure and make provision in the design for that work to be performed to minimize the risk. To mitigate design originated hazards, requires hazard identification and risk assessment (HIRA) and appropriate responses, which process should be structured and documented. Furthermore, the designer report submitted to the client should schedule the residual hazards on projects, which in turn should be included in the ‘revised’ H&S specification included in the tender documentation.

Furthermore, the International Labour Office (ILO) [5] as early as 1992 recommended that designers should, inter alia: receive training in H&S; integrate the H&S of construction workers into the design and planning process, and not include anything in a design which would necessitate the use of dangerous structural or other procedures or hazardous materials which could be avoided by design modifications or by substitute materials.

The Construction Regulations [4] make provision for the appointment of Construction H&S Agents (CHSAs), and require the appointment of either part-time or full-time construction H&S Officers. However, the cidb industry report ‘Construction Health & Safety Status & Recommendations’ highlighted the need for professional registration of construction H&S practitioners due to, among other, the finding that there was a lack of competencies, and no formal registration process. The Council for the Built Environment (CBE) then mandated the South African Council for the Project and Construction Management Professions (SACPCMP) in terms of Act No.48 to register construction H&S professionals. This in turn led to the identification of three such categories of registration, namely Professional Construction Health and Safety Agent (Pr CHSA), Construction Health and Safety Manager (CHSM), and Construction Health and Safety Officer (CHSO).

The definition of temporary works includes any falsework, formwork, support work, scaffold, shoring, or any other temporary structure designed to provide support or means of access during construction work.

In terms of ‘Duties of designer’ Regulation 6(2), the designer of temporary works must ensure, inter alia, that: temporary works are designed such that they will support all anticipated vertical and lateral loads applied; the designs are done with close reference to the structural drawings, and the loads caused by the temporary works and any imposed loads are clearly indicated in the design.

In terms of ‘Temporary works’ Regulation 12, a contractor must: appoint a temporary works designer in writing to design, inspect, and approve temporary works before use; ensure that all temporary works are carried out under the supervision of a competent person appointed in writing; ensure that all temporary works are adequately erected, supported, braced, and maintained by a competent person so that they are capable of supporting all anticipated vertical and lateral loads, and that no additional loads are imposed on the structure; ensure that detailed activity specific drawings pertaining to the design of temporary works structures are kept on site; ensure that all persons required to

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erect, move, or dismantle temporary structures are trained and instructed to perform these operations safely; ensure that all equipment used for temporary structures are examined and checked for suitability before use by a competent person; ensure that all temporary works structures are inspected before, during, and after placement of concrete, after inclement weather, or any other imposed load and at least on a daily basis until the structure has been removed; ensure that no concrete may be cast till written authorisation has been given by the competent person, the temporary works structure is left in place until the concrete has acquired sufficient strength to support its own weight and any imposed load after casting the concrete, and the removal has been authorised by the competent person, the foundation conditions are capable of withstanding the loads of the temporary works structure and any imposed loads, temporary works drawings and any related document includes construction sequences and method statements, and temporary works drawings are approved by the temporary works designer before the erection of any temporary works.

The regulations referred to above can be summarised as follows in terms of issues: scientific design; coordination and integration of temporary with permanent works; consideration of the range of loads; foundation conditions; planning including method statements; competency; training; control, including inspections, and dismantling (striking).

2.2. Support work and formwork failures

The causes of support work and formwork failures are classified as enabling, triggering, and procedural [6]. Enabling causes are defined as events that contribute to the deficiencies in the design and construction of the support work, and include inadequate: design; soil foundation; cross-bracing, and design / construction of permanent structure. Triggering causes are events that initiate support work collapses, which are mostly and essentially the result of excessive loads exerted during construction. The loads are usually not expected, or underestimated at the design stage, and hence they trigger a local failure, which propagates a major collapse. Examples include: fierce winds; impact loads during concreting; vibration from equipment, and improper / premature removal of support work components. Procedural causes are procedural in nature and do not directly cause the support work to fail. However, the procedural errors are often hidden events that produce the enabling and trigger events. Furthermore, they are not easily extracted from failure reports due to a variety of reasons: inadequate review of support work design / construction; lack of inspection of support work during concreting, and inadequate communication between parties involved.

An investigation of falsework in the United Kingdom [7] concluded, inter alia: at all levels there is a lack of understanding of the fundamentals of stability of falsework and the basic principles involved; wind loading is rarely considered; contractors and specialist contractors predominately believe that the drawings and schemes prepared by proprietary suppliers are ‘designed’ and that they have incorporated in the ‘design’ all the correct assumptions necessary; there is a lack of checking of falsework designs prior to use, whether by suppliers, contractors or specialists, is seen to be an industry-wide problem, and there is a lack of falsework design experience in contracting, as the ‘design’ process has moved to suppliers.

A study conducted in Nigeria [8] determined the predominant reasons for building collapse include structural failure, poor supervision and workmanship, the use of sub-standard materials, lack of competency in construction techniques and supervision skills, faulty design, excessive loading, and adaptation and disdain for approved drawings.

The inquiry into the Coega bridge collapse in November 2003, determined, inter alia, that the scaffolding (sic) was unsafely designed, though there was a degree of safety [9].

2.3. The Tongaat mall collapse

A section of the Tongaat mall in South Africa, collapsed in November 2013 while under construction. A study conducted by Emuze, van Eeden, and Geminiani [10] summarised regulatory failures based upon a document analysis. Selected failures include: plans were not submitted to the local municipality’s development, applications, and approvals department; the principal contractor was unable to indicate the qualifications of responsible staff on site, and no consent was given by the construction H&S agent to remove formwork, props, or scaffolding on the day of the accident. Summarised causal factors include: plans rejected / failed four times; false work and formwork removed too soon; inadequate concrete strength; lapses in construction work and supervision; inadequate structural design, and inadequate steel reinforcing.

3. Research

3.1. Research method and sample stratum

A survey was conducted at the inception of one of two workshops presented by the author to a regional entity of a major international temporary works designer and supplier using a self-administered questionnaire. The questionnaire consisted of eleven (11) questions, ten (10) of which were close-ended, and one (1) of which was open-ended. Three (3) of the close-ended questions were five-point Likert scale type questions, which also included an 'unsure' response option. The other close-ended questions were demographic data related. Twenty-three (23) Responses were received from the delegates and included in the analysis of the data.

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.

3.1. Research findings

Table 1 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 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 23 / 55 (41.8%) of all the MSs are > 4.20 ≤ 5.00, which indicates that the importance of the factors is between near major to major / major.

Of the 23 factors in the MSs range > 4.20 ≤ 5.00, the number per category are as follows: competency (8 No.); registration (3 No.); supervision (3 No.); design (3 No.); hazard and risk management (3 No.); quality management (2 No.), and project management (1 No.). Given the sample, it is notable that Temporary Works Designers' Temporary works design competencies is ranked first.

The remaining 32 / 55 (58.2%) factors' MSs are > 3.40 ≤ 4.20 - between important to near major / near major importance.

Table 1. Importance of factors relative to preventing the collapse of RC structures during construction.

Factor	Response (%)						MS	Rank
	Un-sure	Limited……………………				…Major		
		1	2	3	4	5		
Temporary Works Designers' Temporary works design competencies	0.0	0.0	0.0	0.0	25.9	74.1	4.74	1
Registration of Engineering designers	0.0	0.0	0.0	3.7	22.2	74.1	4.70	2
Dedicated contractor supervision of the structure during construction	0.0	0.0	0.0	3.7	33.3	63.0	4.59	3
Close contractor supervision of the structure during construction	0.0	0.0	0.0	3.7	33.3	63.0	4.59	4
Temporary Works Designers' Structural competencies	0.0	0.0	3.7	3.7	22.2	70.4	4.59	5
Design of the permanent structure	0.0	0.0	3.8	11.5	7.7	76.9	4.58	6
Construction Management's Temporary works design competencies	0.0	0.0	0.0	11.1	25.9	63.0	4.52	7
H&S Agents' Temporary works design competencies	0.0	0.0	0.0	11.1	25.9	63.0	4.52	8
Construction Management's Structural competencies	0.0	0.0	0.0	7.4	33.3	59.3	4.52	9
Temporary works design	0.0	0.0	0.0	14.8	18.5	66.7	4.52	10
Integration of design and construction	0.0	0.0	0.0	11.1	25.9	63.0	4.52	11
Safe work procedures	0.0	0.0	0.0	8.3	33.3	58.3	4.50	12
Registration of Construction managers	0.0	0.0	3.7	7.4	25.9	63.0	4.48	13
Close engineering supervision of the structure during construction	3.7	0.0	0.0	11.1	29.6	55.6	4.46	14

Construction Management's Construction management competencies	0.0	0.0	0.0	11.1	33.3	55.6	4.44	15
Construction hazard identification and risk assessment	0.0	0.0	0.0	18.5	22.2	59.3	4.41	16
Project quality management	0.0	0.0	0.0	18.5	22.2	59.3	4.41	17
H&S Agents' Construction management competencies	0.0	0.0	11.1	0.0	25.9	63.0	4.41	18
H&S Agents' Structural competencies	0.0	0.0	11.1	0.0	29.6	59.3	4.37	19
Project H&S management	0.0	0.0	3.7	14.8	22.2	59.3	4.37	20
Design hazard identification and risk assessments	0.0	0.0	11.1	3.7	29.6	55.6	4.30	21
Registration of Project managers	0.0	0.0	0.0	22.2	25.9	51.9	4.30	22
Contractor quality management system	14.8	0.0	0.0	14.8	37.0	33.3	4.22	23
Contractor H&S management system	11.1	0.0	3.7	18.5	25.9	40.7	4.17	24
Contractor risk management system	7.4	0.0	0.0	18.5	40.7	33.3	4.16	25
H&S Specification	3.7	0.0	3.7	22.2	25.9	44.4	4.15	26
Project risk management	0.0	0.0	11.1	7.4	37.0	44.4	4.15	27
Temporary Works Designers' Construction management competencies	0.0	7.4	0.0	7.4	40.7	44.4	4.15	28
Contractor planning	11.1	0.0	0.0	14.8	48.1	25.9	4.13	29
Contractor project risk management plan	7.4	0.0	0.0	29.6	22.2	40.7	4.12	30
Construction Management's H&S competencies	0.0	3.7	0.0	25.9	22.2	48.1	4.11	31
H&S Agents' Project management competencies	0.0	0.0	14.8	7.4	29.6	48.1	4.11	32
Temporary Works Designers' Project management competencies	0.0	7.4	0.0	7.4	44.4	40.7	4.11	33
Design report submitted to the client in response to the H&S Specification	7.4	0.0	0.0	29.6	25.9	37.0	4.08	34
H&S Officers' H&S competencies	3.7	3.7	3.7	18.5	25.9	44.4	4.08	35
H&S Agents' H&S competencies	0.0	3.7	11.1	11.1	25.9	48.1	4.04	36
Temporary Works Designers' H&S competencies	0.0	11.1	0.0	11.1	33.3	44.4	4.00	37
H&S method statements	0.0	3.8	3.8	26.9	23.1	42.3	3.96	38
Contractor project quality plan	14.8	0.0	0.0	33.3	22.2	29.6	3.96	39
Project risk schedule	7.4	3.7	0.0	25.9	33.3	29.6	3.92	40
H&S Plan (contractors)	4.0	0.0	4.0	32.0	28.0	32.0	3.92	41
Construction method statements	4.2	4.2	4.2	29.2	16.7	41.7	3.91	42
H&S Officers' Temporary works design competencies	0.0	3.7	3.7	25.9	33.3	33.3	3.89	43
H&S Officers' Construction management competencies	0.0	7.4	0.0	25.9	29.6	37.0	3.89	44
H&S Officers' Structural competencies	3.7	3.7	7.4	22.2	33.3	29.6	3.81	45
H&S specification	7.7	3.8	0.0	34.6	26.9	26.9	3.79	46
3rd party review of the design of the permanent structure	0.0	0.0	25.9	11.1	22.2	40.7	3.78	47
H&S Plan (principal contractor)	8.0	4.0	4.0	32.0	24.0	28.0	3.74	48
Registration of H&S Officers	0.0	7.4	11.1	22.2	25.9	33.3	3.67	49
Construction Work Permit	11.1	14.8	7.4	11.1	18.5	37.0	3.63	50
Registration of Quantity surveyors	3.8	3.8	19.2	23.1	15.4	34.6	3.60	51
Registration of H&S Managers	0.0	14.8	7.4	18.5	25.9	33.3	3.56	52
Registration of H&S Agents	0.0	18.5	0.0	18.5	33.3	29.6	3.56	53
Municipal approval of plans	3.7	18.5	7.4	18.5	11.1	40.7	3.50	54
Registration of Architectural designers	0.0	14.8	7.4	25.9	22.2	29.6	3.44	55

Table 2 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 25 / 30 (83.3%) of the MSs are > 4.20 ≤ 5.00, which indicates that the importance of the factors is between near major to major / major. Of the 9 factors in the upper part of the MS range > 4.20 ≤ 5.00 (> 4.60), the number per category are as follows: supervision (2 No.), competency (1 No.), and quality management (6 No.).

The remaining 5 / 30 (16.7%) factors' MSs are > 3.40 ≤ 4.20 - between important to near major / near major importance.

Table 2. Importance of factors relative to optimum support work and formwork and the integrity of structures under construction.

Factor	**Response (%)**						**MS**	**Rank**
	Un-sure	**Limited……………..…………Major**						
		1	**2**	**3**	**4**	**5**		
Pre-pour designer inspection (Support work and formwork)	0.0	0.0	0.0	3.8	7.7	88.5	4.85	1
Competencies of temporary works designer	0.0	0.0	0.0	3.7	14.8	81.5	4.78	2
Reconciliation of erected with design	0.0	0.0	0.0	0.0	30.8	69.2	4.69	3
Founding support work	0.0	0.0	0.0	0.0	34.6	65.4	4.65	4
Concrete strength upon striking of support work	0.0	0.0	0.0	0.0	34.6	65.4	4.65	5
Periodic inspections during erection	3.8	0.0	0.0	0.0	34.6	61.5	4.64	6
Concrete strength as per specified	3.8	0.0	0.0	3.8	26.9	65.4	4.64	7
QMS during design (Support work)	0.0	0.0	0.0	14.8	7.4	77.8	4.63	8
Back propping as per requirements	0.0	0.0	0.0	7.7	23.1	69.2	4.62	9
Dedicated support work supervision	3.8	0.0	0.0	3.8	30.8	61.5	4.60	10
Periodic inspections during pouring	3.8	0.0	0.0	3.8	30.8	61.5	4.60	11
Pre-pour designer inspection (Reinforcing steel)	7.7	0.0	0.0	7.7	23.1	61.5	4.58	12
Scientific support work design	3.7	0.0	0.0	3.7	33.3	59.3	4.58	13
Back propping layouts	0.0	0.0	0.0	7.7	26.9	65.4	4.58	14
Maintenance of components	0.0	0.0	0.0	7.7	30.8	61.5	4.54	15
Testing of components	3.8	0.0	0.0	7.7	30.8	57.7	4.52	16
Condition of components	3.8	0.0	0.0	7.7	30.8	57.7	4.52	17
QMS during construction	0.0	0.0	0.0	18.5	11.1	70.4	4.52	18
QMS during design (structure)	0.0	0.0	0.0	18.5	11.1	70.4	4.52	19
Circumspect loading of slabs and other elements during the back-propping period	0.0	0.0	0.0	12.0	28.0	60.0	4.48	20
Compaction of concrete	3.8	0.0	0.0	3.8	42.3	50.0	4.48	21
Sound structural design	11.5	0.0	7.7	7.7	7.7	65.4	4.48	22
Safe work procedures	4.0	0.0	0.0	8.0	40.0	48.0	4.42	23
Periodic inspections during striking	3.8	0.0	0.0	11.5	34.6	50.0	4.40	24
Periodic inspections during the back-propping period	3.8	0.0	0.0	11.5	34.6	50.0	4.40	25
Construction method statements	3.7	3.7	3.7	25.9	25.9	37.0	3.92	26
H&S Plan (Contractors)	7.4	3.7	3.7	40.7	7.4	37.0	3.76	27
H&S Management System	11.5	3.8	11.5	19.2	26.9	26.9	3.70	28
H&S Plan (Principal Contractor)	7.4	3.7	3.7	40.7	18.5	25.9	3.64	29
H&S method statements	11.5	3.8	7.7	34.6	15.4	26.9	3.61	30

4. Conclusions

Given the importance of factors in terms of preventing the collapse of RC structures during construction, 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, 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 to enable such evolution. 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.

References

[1] Construction Industry Development Board (cidb), Construction Health & Safety in South Africa Status & Recommendations, Pretoria: cidb, 2009.

[2] F.A. Emuze, L. van Eeden, F. Geminiani, F., Causes and Effects of Building Collapse: A Case Study in South Africa, In M. Behm, & C. McAleenan (eds.), Proceedings of CIB W099 Benefitting Workers and Society through Inherently Safe(r) Construction Belfast, Northern Ireland, 10-11 September, pp. 407-416, 2015.

[3] Department of Labour (DoL), Section 32 Investigation Report into the Injaka Bridge Collapse of 6 July 1998, DoL, Pretoria (2002).

[4] Republic of South Africa, No. R. 84 Occupational Health and Safety Act, 1993 Construction Regulations 2014. Government Gazette No. 37305. Pretoria, 2014.#

[5] International Labour Office (ILO), Safety and health in construction, ILO, Geneva., 1992.

[6] S.W. Poon, A.D.F. Price, Falsework and Bridge Failures, Asia Pacific Building and Construction Management Journal. 2(1) (1996) 20-24.

[7] P.F. Pallett, M.P.N. Burrow, L.A. Clark, and R.T. Ward, Investigation into aspects of falsework. Contract Research Report 394/2001, Health & Safety Executive (HSE), Norwich, 2001.

[8] C. Ayedun, O. Durodola, & O. Akinjare, O. An Empirical Ascertainment of the Causes of Building Failure and Collapse in Nigeria, Mediterranean Journal of Social Sciences. (2012) 2039-2117.

[9] H. Mphande, Bridge deaths: two charged, The Herald. 29 June (2011) 8.

[10] F.A. Emuze, L. van Eeden, F. Geminiani, F. Regulatory Factors Contributing to Building Collapse in South Africa: A Case Study. In M. Prins, H. Wamelink, B. Giddings, K. Ku, & M. Feenstra (eds.), Proceedings of CIB World Building Congress 2016 (Volume 2 - Environmental Opportunies and Challenges. Constructing Commitment and Acknowledging Human Experiences, Tampere, Finland: Tampere University of Technology. Department of Civil Engineering. Construction Management and Economics. Report; Vol. 18. Tampere University of Technology. Department of Civil Engineering pp. 236-246, 2016.