INCREASING THE UTILISATION OF HYBRID CONCRETE CONSTRUCTION IN SOUTH AFRICA

by

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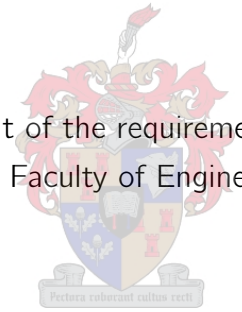

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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Synopsis

Hybrid concrete construction (HCC) is a construction technique that makes use of both in-situ and pre-fabricated concrete products by making optimum use of the advantages of both these methods in the same project. Although the advantages of this building method is well recognised throughout the world and a feasibility study illustrated that HCC is a suitable building method in South Africa, it remains under-utilised in the country.

HCC encourages early involvement from the project team and provides clients with the best value projects and a "win-win" situation for the project team during the project development. The objective of this study is to identify barriers that prohibit an increased utilisation of HCC for the South African construction industry. Additionally, it provides possible solutions to overcome these barriers. These proposed solutions are similar to the programmes and methods that are implemented in other countries to improve their HCC utilisation. Furthermore, drivers are identified in this study to implement these solutions in the industry and a proposed "change model" is developed for private companies to assist with the change process.

This study is unique because current South African conditions are used to establish the barriers and solutions. Furthermore, it takes into account that not all countries have such progressive construction industries as the European markets and therefore it considers solutions and drivers that are suitable for less advanced industries such as South Africa. The model that is proposed is applicable to any industry regardless of its nature or country.

Although the United Kingdom is not the widest user of pre-fabricated concrete products, their HCC research is extensive, making it a suitable comparative country for the South African construction industry.

During the investigation, the procurement methods in South Africa were found to be traditional and do not allow for early involvement or partnering in the project team. To obtain early involvement, it is critical to initiate methods such as design-and-build, contract management or public-private-partnerships during the procurement phase.

Decision and design assistance from the whole project team and software tools are essential when HCC is considered. Because the South African construction industry does not provide such support it is advised here to incorporate contractors from an early stage and to develop software tools that can assist during the decision making and design process of HCC structures. The industry does not provide the project team with sufficient training programmes that increase knowledge of HCC. Training programmes that are cognitive stimulating must be developed for the industry. Furthermore, a database is required to illustrate the utilisation of different pre-fabricated products and in different projects within South Africa.

Labour-intensive construction regulations and green building techniques (not compulsory) are promoted in South Africa. Labour-intensive programmes should consider the negative impact it has on the labourers and consider HCC as a building technique because the pre-fabricated elements are manufactured in a controlled and safe environment. It is advised that the toolkits that are used for green building accreditation, must be revised to accommodate the additional benefits such as less waste generation, that HCC offers to a project.

Regardless of the country in which HCC is utilised, the environment must be acceptable for the innovation. By analysing the criteria that influences the use of HCC in a country and adding weighting functions to these criteria, the acceptability towards the innovation can be obtained.

Furthermore, public clients and companies are recognised here as drivers of change. While public clients can commit to HCC for the cost, labour-intensive factories, green building methods, improved health and safety, training for labourers, private companies can utilise HCC to provide best value to a project. A model is proposed here for innovative companies that will allow them to change not only the company, but the industry towards a HCC "mindset".

Opsomming

Hibriede beton konstruksie (HBK) is 'n tegniek waarby beide voorafvervaardigde betonelemente en in-situ beton in dieselfde projek gebruik word ten einde voordeel uit beide metodes te trek. Alhoewel die voordele van die konstruksietegniek wel bekend is in talle lande van die wêreld en 'n uitvoerbaarheidsanalise getoon het dat HBK 'n voordelige konstruksiemetode vir Suid-Afrika is, is dit tans onderbenut in die plaaslike sektor.

HBK bied vir kliënte projekte van goeie waarde en omdat dit vroeë betrokkenheid verg vanaf die projekspan, resulteer dit 'n "wen-wen" situasie tydens die projekontwikkeling. Die doel van hierdie studie is om die hindernisse te ondersoek wat veroorsaak dat HBK nie meer gereeld in Suid-Afrika gebruik word nie. Ten einde die effekte hiervan te verminder, word moontlike oplossings vir hierdie hindernisse voorgestel. Die oplossings is gebaseer op tegnieke en metodes wat geïmplimenteer word in ander lande waar HBK gebruik word. Rolspelers wat hierdie verandering na HBK kan dryf word geïdentifiseer en 'n model om verandering binne 'n maatskappy te lei word voorgestel om die rolspelers te ondersteun tydens die proses.

Hierdie studie is uniek omdat dit inligting gebruik van die huidige situasie van die Suid-Afrikaanse konstruksie-industrie om die hindernisse en oplossings te identifiseer. Omdat nie alle konstruksie-industrieë so vooruitstrewend is soos in Europese lande nie, is die oplossings en rolspelers relevant vir enige land wat 'n industrie het wat soortgelyk is aan Suid-Afrika. Die model wat voorgestel word is ook relevant tot enige industrie afgesien van die land waar nuwe tegnieke geïmplimenteer word.

Alhoewel dit bevind is dat die Verenigde Koningkryk nie die grootste gebruikers van HBK is nie, is hulle navorsing in die veld omvattend. Daarom word die Verenigde Koningkryk beskou as 'n voorbeeld om Suid-Afrika se konstruksie-industrie mee te vergelyk, asook om inligting van HBK te verkry.

Tydens die studie is bevind dat die projekaanstellingsmetodes van projekte in Suid-Afrika tradisioneel is, aangesien dit nie toelaat vir vroeë betrokkenheid of vennootskappe binne die projekspan nie. Om vroeë betrokkenheid te verkry, is dit noodsaaklik om van ontwerp-en-bou, kontrakbestuur of publiek-privaat-vernootskappe gebruik te maak.

Tans is daar geen hulp wat aan ontwerpers verleen word ten opsigte van besluitnemingsmodelle en ontwerpsagteware wanneer HBK oorweeg word in Suid-Afrika nie. Die behoefte aan sulke bystand dui daarop dat sagtewarepakkette ontwerp moet word wat toepaslik is vir Suid-Afrika se konstruksie-industrie. Die industrie bied nie doelgerigte en genoegsame opleidingsprogramme aan om die industrie se kennis van HBK te verbreed nie. Addisionele opleiding wat kognitiewe stimulasie sal bied vir die hele projekspan word aanbeveel. 'n Databasis wat HBK projekte insluit, moet geskep word om die industrie bloot te stel aan die verskillende moonlikhede.

Arbeid-intensiewe konstruksie-regulasies asook groen konstruksietegnieke (nie wetgedrewe nie) word sterk bevorder in Suid-Afrika. Dit word hier aanbeveel, dat voorafvervaardiging se addisionele voordele in ag geneem word wanneer hierdie regulasies en tegnieke relevant is. Hierdie voordele sluit onder meer in: die veiligheid wat aan werkers gebied word in arbeid-intensiewe fabrieke en die vermindering van afval in HBK projekte.

Afgesien van die land waarin HBK gebruik word, moet die omgewing ontvanklik vir die tegniek wees. Deur verskillende kriteria te analiseer wat die gebruik van HBK beïnvloed binne 'n land en geweegde faktore daaraan te koppel, kan die ontvanklikheid van die innovasie bepaal word.

Laastens word publieke kliënte en maatskappye as die drywers (of katalisators) wat verandering kan meebring, beskou. HKB bied onder andere die volgende voordele aan publieke kliënte: koste-effektiwiteit, arbeid-intensiewe werk, groen konstruksie, beter gesondheid, veiligheid en opleiding vir werkers. Maatskappye kan gebruik maak van HBK om waarde tot hul projekte toe te voeg. 'n Model word hier voorgestel om innoverende maatskappye in staat te stel om nie net hulself nie, maar ook die industrie as 'n geheel te help om 'n gesindheidsverandering jeens HBK te skep.

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Glossary

Employer's agents

The agents are either the architect or engineer or 3^{rd} party that are responsible for ensuring that the project is according to the project specifications.

Best value engineering

Providing the client with a product that is procured according to best value instead of lowest cost

Contract

Refer to the lawful documentation that are signed after tender adjudication

Contractor

For the purpose of this document it refers to the main contractor responsible for the construction of a project

Cost

The financial value of a specific item or project

Client

Either the building owner, employer or person/group financially responsible for the building project

Engineers

For the purpose of this document it refers to structural engineers except where reference is made to other design engineers

Innovation champion

The drivers of innovation change within an industry

ISO standards

For the purpose of this document it refers to the ISO 9000 quality series that includes the ISO 9001 standards

Just-in-time

Philosophy of providing the right product, at the right time and the right quantity and quality

Labour-intensive construction

The use of labour to replace equipment on construction projects as a method of improving unemployment in a country

SABS standards

For the purpose of this document it refers to the SABS 1200 quality standards or the new SANS 2001 standards

Specialist contractor

Manufacturers or suppliers of pre-fabricated elements

Procurement

The process of appointing a contractor to construct a specific facility. The process includes the preparation of contract documentation, a tender process and the appointment of the contractor.

Project

The structure that are required

Project team

Refer to all participants of the project including clients, quantity surveyors, architects, engineers, contractors and suppliers

Value

Refer to a combination of cost, quality, service, professionalism etc.

Workability

The ease at which elements are handled on site

Abbreviations

BIFSA	Building Industries Federations of South Africa
BREEAM	Building Research Establishment Environmental Assessment Method
CIDB	Construction Industry Development Board
C&CI	Cement and Concrete Institute
CO_2	Carbon dioxide
COID	Compensation for Occupational Injuries and Diseases
CMA	Concrete Manufacturers Association
ECSA	Engineering Council of South Africa
EIA	Environmental Impact Assessment
EN	European Standard
EPWP	Expanded Public Works Programme
FEMA	Federated Employers' Mutual Assurance
FIDIC	International Federation of Consulting Engineers
GBCSA	Green Building Council of South Africa
GCC	General Conditions of Contract 2004
HCC	Hybrid concrete construction
ISO	International Organisation of Standardisation
JBCC	Joint Building Contracts Committee 2000
LEED	Leadership in Energy and Environmental Design
LFC	Lead-frame contractor
NEC	New Engineering Contract 3
NOSA	National Occupational Safety Association
PFI	Private-finance-initiative
PPP	Public-private-partnership
SABS	South African Bureau of Standards
SAICE	South African Institute of Civil Engineering
TCQ	Time, cost and quality

Chapter 1

Introduction

1.1 Background

Hybrid concrete construction (HCC) is the technique in which different in-situ products are used in combination with pre-fabricated concrete products to achieve the advantages of all of these products simultaneously in the same project (Goodchild 1995, Soetanto et al. 2004*a*). From the definition, HCC appears to be an excellent building method, however it appears to be under-utilised in South Africa even though literature is of the opinion that:

> "hybrid concrete construction is about providing (the client with) best value in structural frames" (Goodchild & Glass 2004)

If the purpose of HCC is to provide improved value to a project, why is it under-utilised in South Africa? Is HCC a feasible construction method for South Africa? What caused for other countries to have increased their utilisation of HCC? What strategies are required in South Africa to improve the use of HCC? Whom must be the catalyst of change for construction industry? These are frequent questions that are directed to the South African construction industry. Before these questions can be answered, the background of HCC needs to be investigated.

Precast concrete construction has always been a fast, cost effective and efficient method of construction in European countries. For this reason, modular and other pre-fabricated construction techniques were the method of choice when mass housing projects were constructed during the 1940's throughout Europe. The lack of specific codes of practice or "best practice" guidance for hybrid structures resulted in companies resorting to their own judgement with the design and construction procedures. While many projects were successful, it remained a hazardous exercise (Goodchild 2011).

In 1968, the *Ronan Point* (a pre-fabricated, multi-storey apartment building in London) progressively collapsed after a gas explosion. The progressive collapse was partly due to the connections between the pre-fabricated elements that were not sufficiently functional for the building and caused the different precast elements to dismantle when the additional loads from the collapsing floors were added (Nair 2004). Figure 1.1 shows the corner of *Ronan Point* after the collapse.

Although there were additional problems with the design of this building such as outdated design codes, it resulted in an intense investigation into the construction industry, especially of the pre-fabricated industry. These

Figure 1.1: *Ronan Point* apartment building progressively collapsed after a gas explosion (Nair 2004)

investigations resulted in many construction industry reports and improvement programmes to be implemented in the industry.

The extensive research provided information of all the advantages of HCC resulting in different countries to realise the potential of HCC. This is illustrated by Canada that makes use of pre-fabrication due to the ductility of the elements and Italy that uses pre-fabrication because it requires less labour on sites (Fédération Internation du Béton 2003).

While the utilisation of HCC is improved in several countries, in South Africa it appears to have stagnated. Jurgens (2008) concluded in a study that HCC is a feasible construction method for the South African construction industry. Regardless of the different advantages of HCC, the utilisation of this construction method has not increased drastically.

In this thesis, the barriers that result in the under-utilisation of HCC in South Africa are investigated. Solutions and drivers to overcome these barriers are provided to assist and improve the South African pre-fabricated concrete industry. The objectives of this study are discussed in the next section.

1.2 Objectives

The ultimate objective for the industry would be to develop an industry "mindset" change towards HCC methods to provide best value to every project. Unfortunately, a "mindset" change occurs over a period of time (Jennings 2006). It is therefore critical to understand why HCC is not used more often in South Africa, how the industry can change to improve the utilisation of HCC and to initiate a "mindset" change for precast construction. For these reasons, the objectives of this study are to:

- Investigate the necessity for South Africa to make use of HCC by comparing the South African construction industry to that of the United Kingdom (before the United Kingdom identified pre-fabrication as a method

of improving their industry).

- Provide a database of HCC projects in South Africa that can be used as a reference.
- Identify the different measures that other countries applied to improve their HCC utilisation, while concentrating on the United Kingdom.
- Identify the barriers that cause the under-utilisation of HCC in South Africa.
- Provide possible achievable solutions that are suitable for the South African construction industry to overcome these barriers.
- Identify drivers that can enforce these solutions in the industry.
- Develop a model that can be used by companies to ultimately lead to an industry "mindset" change towards precast construction in the future.

1.3 Significance of this research

Numerous literature documents are available concerning international construction industries. Information is available of the current state of the South African industry, although it does not focus on construction methods or procedures of improving the industry. Even though HCC is the focus of this thesis, many solutions that are identified can assist with the improvement of the construction industry as a whole. Because the research is structured around HCC in the South African construction industry, it makes the study unique. Research that focusses on increasing the utilisation of HCC as a method of improving the construction industry has not been conducted extensively for South Africa. An "industry-change" model is developed here that can be used in any construction industry or any other industry regardless of its nature and it is not restricted to a specific country. These types of models are only available in countries with progressive industries.

1.4 Scope and limitations

To ensure that the objectives of this thesis are achieved, the scope and limitations of the thesis needs to be clarified.

This thesis focusses on management techniques and methods of improving the utilisation of HCC. It is not the purpose of this thesis to provide technical information regarding precast construction. Although design and construction issues are mentioned throughout the document, technical detail are not discussed.

This thesis is primarily concentrating on the structural building industry. Other disciplines within civil engineering that make use of pre-fabrication such as kerbs or pipes in civils construction or U-beams in bridge construction are not investigated. References to these industries are made on some occasions.

Similarly, references to project team members such as contractors, engineers and manufacturers are referring to structural building team members. Therefore these relate to building contractors, structural engineers and pre-fabricated concrete manufacturers.

Structural pre-fabricated elements are analysed in this study such as structural frames, columns, beams, floor slabs etc. Architectural pre-fabricated elements are not investigated because it does not serve a structural role in a project.

The purpose of this thesis is not to promote or demote any company and therefore no company names are mentioned. Some comments and experiences from companies are used to assist with the research.

Frequent references and comparisons are made to the United Kingdom's construction industry. Although the United Kingdom is not the international leading precast user, extensive research on HCC in the country allows it to be a suitable comparative country.

To obtain an objective opinion from the South African construction industry was extremely challenging. Questionnaires were distributed to different project team members although it provided limited feedback. Research in South Africa regarding HCC is new, resulting in a shortage of literature. An alternative method to investigate the industry is to obtain subjective opinions from project team members by means of personal interviews or e-mail correspondence.

Information regarding HCC projects in South Africa was found in engineering magazines and not from peer reviewed journals. The purpose of this information is not to provide project facts, instead the magazines are used to establish the amount of exposure the industry experiences of HCC projects in South Africa.

1.5 Research Methodology

Different methods are used to obtain the required information. Regardless of the limitations, the following methods or resources are used during the investigation:

1. Background study of the South African construction industry.
2. Engineering articles from magazines are used to obtain project examples within the country.
3. Questionnaire are developed and distributed.
4. Journal articles are used to support the interview correspondences.
5. Reports are analysed to understand the methods used to improve the United Kingdom's construction industry.
6. Interviews and e-mail correspondence are conducted to gather information from different project team members. Project team members are interviewed in both South Africa (refer to Appendix A) and the United Kingdom (refer to Appendix B).

1.6 Plan of development

This study consists of different components. Figure 1.2 illustrates these different components schematically. Each of these components or phases are structured within a chapter and the objectives and content of these chapters will briefly be discussed.

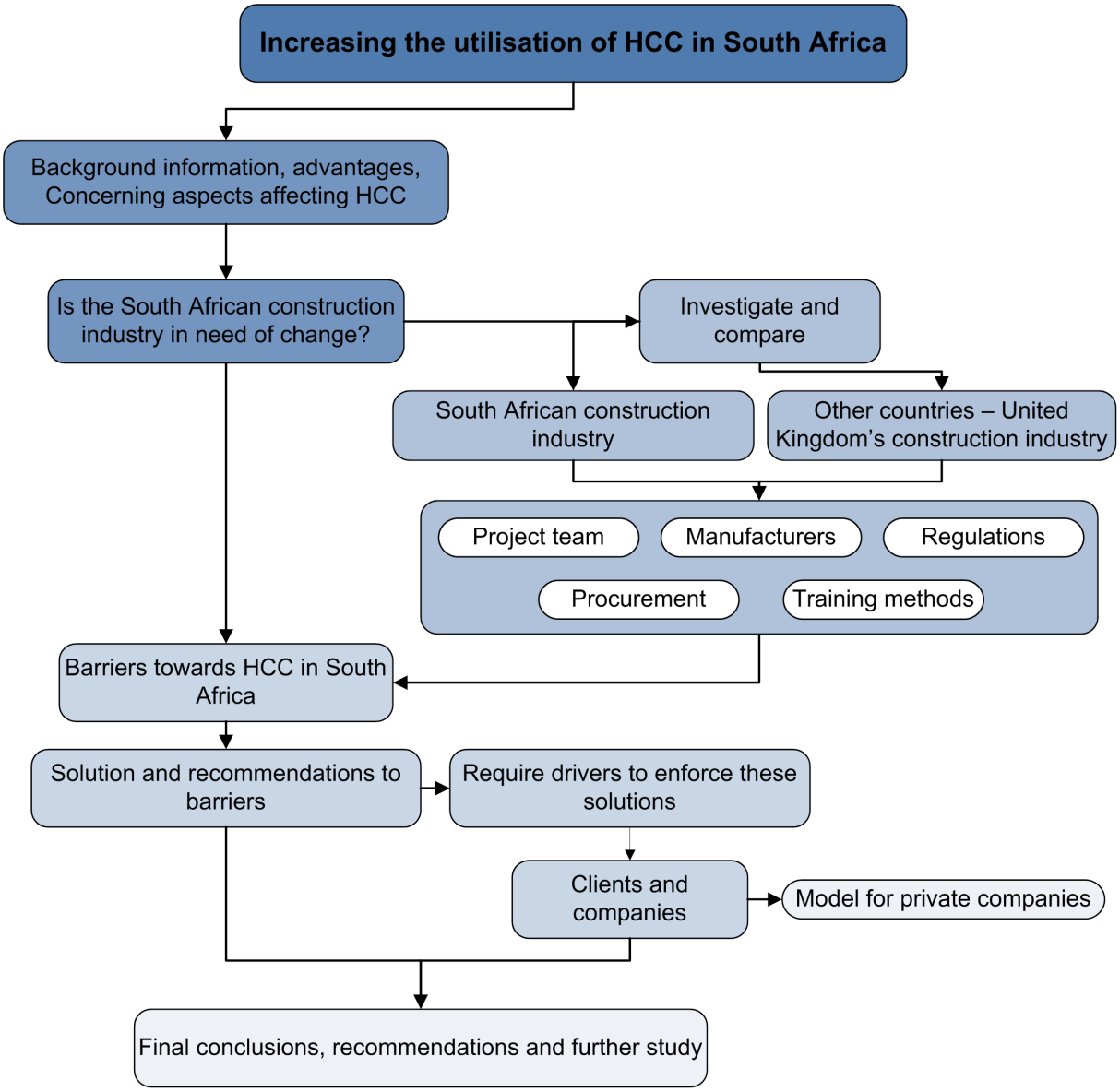

Figure 1.2: A flow diagram illustrating the breakdown of this study

Chapter 2. Background and relevant aspects of hybrid concrete construction

The background study investigates different criteria that is relevant to HCC in the construction industry. HCC is defined by means of a definition, advantages of HCC, elements and structural frame possibilities. Furthermore, procurement methods that are used in South Africa are explained. Finally, different regulations that may affect the utilisation of HCC in South Africa are investigated.

Chapter 3. South African construction industry

During this investigation, statistics are analysed regarding the South African construction industry and it is compared to the statistics of the United Kingdom's industry before they implemented their improvement techniques. The capabilities of the South African manufacturers and training institutes are investigated. Furthermore, regulations

that affect HCC are illustrated and analysed. The purpose of this chapter is to identify whether the industry is capable of accommodating HCC as a modern building method.

Chapter 4. Example projects in South Africa

This chapter serves as a database of HCC projects in South Africa. The different pre-fabricated elements that are utilised provide headings under which different example projects are briefly dicussed. The relevance of this chapter is to provide evidence of the capabilities of the South African construction industry and understand why HCC is used in South African circumstances.

Chapter 5. International hybrid concrete construction

This chapter illustrates the different procedures that are implemented by other countries to increase the HCC utilisation. Throughout this chapter, the focus of "industry-change" is on the United Kingdom, although other countries are not neglected. This chapter reviews the client's role as a driver of the industry by means of procurement methods. The capabilities of the manufacturers are investigated to evaluate the different precast possibilities. Regulations, project team assistant methods and training are discussed to understand how the industry has grown. Finally example projects are provided to illustrate projects where HCC was used for reasons other than the traditional cost and time. The techniques mentioned in this chapter are necessary when solutions for the barriers are required in Chapter 7.

Chapter 6. Barriers to hybrid concrete construction

Several barriers that decrease the utilisation of HCC in the industry are identified. These barriers relate to technical aspects such as design, production and manufacturer barriers. Furthermore, management aspects such as procurement and training barriers are also identified. Additional industry barriers such as regulations and market conditions are discussed. Many of the barriers originate from the investigation in Chapter 3.

Chapter 7. Discussion of the barriers to hybrid concrete construction

The barriers that are identified in Chapter 6 are discussed and possible solutions for these barriers are provided. Recommendations to improve the utilisation of HCC and the construction industry as a whole are identified. The objective of this chapter is to provide solutions that can be implemented in the industry to obtain a "mindset" change towards improvement and additional utilisation of HCC in South Africa.

Chapter 8. Drivers of the solutions towards industry change

Influential parties in the construction industry are identified to enforce these solutions that are discussed in Chapter 7. Two main role players are identified to start the transformation in the current state of the South African construction industry. An "industry-change" model is created to provide companies that want to change with a possible method to achieve their objectives.

Chapter 9. Conclusions, recommendations and further study

A summary of the conclusions and recommendations from the different chapters is provided. Furthermore, aspects that require additional research or investigation are provided in this chapter.

1.7 Conclusions

This chapter provides the framework of this thesis. HCC is defined as a technique that makes use of both in-situ and pre-fabricated concrete products to obtain the advantages of both products in the same project.

A brief background illustrates the concerning history of HCC and expresses the shortcomings of research in South Africa. These shortcomings are the objectives of this study with the ultimate objective to initiate a "mindset" change of the industry to improve the utilisation of HCC in South Africa.

A clear scope and limitations to the study clarifies that this document is based on structural building construction and does not consider aspects regarding other engineering disciplines. Methods that are used to obtain the information for this thesis are structured around journal articles, magazine articles, interviews and e-mail correspondence.

Finally, a brief description of the content of each chapter is provided with a plan of development diagram. The diagram shows the flow of information to finally obtain the required change of an industry "mindset" towards increased HCC utilisation.

While this chapter provides a broad visualisation framework of this study, the next chapter provides a background study of concepts that are of relevance to this study.

Chapter 2

Background and relevant aspects of hybrid concrete construction

While the previous chapter provides a broad framework of this thesis, this chapter provides a background study that is performed to attain relevant information regarding hybrid concrete construction (HCC) and the elements that affect its utilisation. The objectives of the background study are to:

1. Investigate reports that improved the pre-fabricated concrete industry.
2. Explain hybrid concrete construction as a building technique.
3. Explain the procurement methods by investigating procurement strategies, procedures and contract documents.
4. Identify regulations and programmes that affect the utilisation of HCC.

The information is obtained from journal articles, reports and internet sources. Before HCC can be discussed as a building technique, it is important to analyse the reports that initiated precast construction in the United Kingdom. This is discussed in the next section.

2.1 Reports that affected the pre-fabricated industry

The United Kingdom's construction industry experienced criticism after the *Ronan Point* building collapsed. The precast industry was criticised for the lack of standards and safety measures. Due to this criticism, project teams ignored precast concrete construction. The United Kingdom's construction industry was experiencing a low period due to problems such as poor health and safety, shortage of construction standards and guidelines, disputes and procurement problems (Latham 1994).

As a result of the criticism, studies of the construction industry were conducted for the government as a way of defining the industry problems. The first breakthrough report was "Constructing the team" by Sir Michael Latham (1994). After the application of the first report's concepts, "Rethinking Construction" by Sir John Egan (1998)

provided additional guidelines to improve the construction industry.

These reports commented on methods of improving the construction industry as a whole, although frequent references were made to improve the utilisation of pre-fabrication in the construction industry. The objective of this section is to understand the relevance of these reports to the construction industry and will now briefly be discussed.

2.1.1 Latham Report

Latham (1994) realised the potential of the construction industry. Through careful investigations he explained that drastic changes were required in the industry. He exclaimed that if change is not implemented, then 5 consequences would follow:

1. Companies will close down or reduce staff.
2. Consultant's bids will be unprofitable.
3. Contractor's tenders will be uneconomical.
4. Training and education throughout the industry will suffer.
5. Finance will be limited for research to increase the public's image of the industry.

By questioning project teams, he identified industry problems that caused concern. These problems are issues such as the role of the client, project procurement strategies and documentation, design processes and the importance of team work. Latham suggested that change was essential to improve the industry.

Latham recommended that clients must realise their involvement in the design team. Their expectations and requirements must be stressed to the project team to improve client satisfaction. The client was singled out to influence the project team to incorporate change. Furthermore, clients must evaluate tenders according to quality and cost. Training was required for the government employers (public clients) to become a "best practice" client.

Regarding procurement, Latham's main concern was for the project team to establish the design responsibility from the onset of a project. Design-and-build was recommended for projects with a limited range of standardised processes, while the construction management strategy was regarded effective with innovative construction processes. Additionally, it was advised that public and private employers must implement the *New Engineering Contract* (NEC) document due to its simplicity and flexibility.

Besides these recommendations, pre-fabrication was considered as a method of improving the efficiency on-site because less waste are generated throughout the different phases of a project. Furthermore, concern was pointed out to standardise the different elements and that pre-fabrication is only possible through close collaboration and team work.

Four years after Latham's report, Egan (1998) was instructed to report and make recommendations to improve the state of United Kingdom's construction industry.

2.1.2 Egan Report

Egan (1998) used the "Latham report" as a benchmark and built on it. Egan investigated the United Kingdom's construction industry and found similar trends as Latham. The following industry factors were mentioned:

1. Profitability rates on projects are low.
2. Crises in training cause for a lack in proper career structure to develop within the industry.
3. Clients are dissatisfied by the contractor and consultant's performance; nevertheless choose their project team based on the tender costs exclusively.
4. Fragmentation causes for flexibility in the industry, but due to excessive sub-contracting it limits continuity of teams which is required for an efficient working environment.

Although Egan was also investigating the whole construction industry, his comments and recommendations were more supportive towards the use of hybrid concrete construction.

Egan mentioned that management must believe and be totally committed to an improved and approved future agenda. Effective training throughout the project team is essential for personal and industry growth and will assist in obtaining the improved agenda.

Similar to Latham, clients were encouraged to drive the construction industry and to influence the project team. Clients were advised to replace competitive tendering methods with long term relationships to influence the project. This was especially important for the public sector. Furthermore, partnering within the project team was essential to improve fragmentation.

Pre-fabrication was again singled out as a method of improving the industry. Additionally, it was advised to standardise the off-site elements, while continually promoting and implementing pre-fabricated techniques (Egan 1998).

These two documents provided the benchmark and many reports, articles and strategies are based on these reports. Throughout this document, many references will be made to these reports.

While both reports mention several managerial aspects, both recommended the use of pre-fabricated off-site construction as a method of improving the industry. This can be achieved because pre-fabricated elements are used to ensure customer satisfaction, best value building practices and an overall satisfied project team. While different recommendations and findings are provided in these reports, it will be mentioned in more detail within the appropriate sections of this document.

Precast construction is an off-site measure that was implemented throughout the world as a method of improving the applicable construction industries (Chapter 5). Pre-fabricated concrete construction provides several benefits as discussed in the next section.

2.2 Hybrid concrete construction techniques

As mentioned before, hybrid concrete construction (HCC) is the construction process that makes use of a combination of both pre-fabricated and in-situ concrete products in the same project (Goodchild 1995, Soetanto et al. 2004*a*). For the purpose of this thesis, only the combination of in-situ concrete and precast concrete products will be investigated. Three broad categories for pre-fabricated concrete units exists (Jaillon & Poon 2009):

- Non-volumetric elements
- Volumetric elements
- Modular elements

Figure 2.1 illustrates these elements as it is used. Non-volumetric elements are typically elements such as slabs, façades and other tilt-up systems where as volumetric elements are elements such as beams, columns, stairs etc. (Canadian Precast/Prestressed Concrete Institute 2007). Modular elements are pre-assembled elements that are frequently used for school classrooms, jail blocks etc. (Oldcastle Precast 2006).

Figure 2.1: Categories of pre-fabricated units: non-volumetric wall units (left) (Canadian Precast/Prestressed Concrete Institute 2007), modular school classroom elements (right) (Oldcastle Precast 2006) and volumetric columns and beams (bottom) (Canadian Precast/Prestressed Concrete Institute 2007)

Although this technology is recognised and used in certain parts of the world, its utilisation was limited to certain elements and project types (Glass 2000). For this reason, Goodchild (1995) investigated the advantages, products, structural frame systems and project developments to improve the attractiveness of HCC. These advantages and systems will now be discussed.

2.2.1 Advantages of hybrid concrete construction

HCC is used to achieve the superior quality, flexibility and workability of several different concrete products in one project. Therefore it is required to identify what the objective of the structural frame is before the designs are completed.

While HCC is known to provide the above mentioned advantages, many additional advantages of HCC do exist (Goodchild 1995). Although additional design effort and contractual flexibility are required for HCC projects, the advantages result in a satisfied project team and a best value project (Goodchild & Glass 2004).

The advantages of HCC are as follows (Barrett 2002, *Building with the best of both worlds* 2004):

Shorter construction time
Improved quality and finish
Environmentally friendly
Increased fire protection
Improved health and safety
Buildability
Lower cost
Longer spans and therefore bigger lettable area
Flexibility in use
Service integration
Improved site conditions

Cost and construction time

Bowen (2002) found that the objectives, management and procurement strategies in South Africa are driven by the cost, time and quality that are specified by the client. Further investigations found that a bias exist towards the time constraints and project cost during the decision making processes.

The advantage of HCC is that parallel construction is possible. While normal construction continues on-site, the pre-fabricated elements can be constructed off-site, that causes for reduced construction times (Trent Concrete Limited 2001).

To quantify the cost using a HCC frame compared to a conventional frame is difficult and strenuous. Although initial cost of the HCC frames might be more expensive than for conventional frames, the shorter construction time, quality of work, limited scaffolding usage, life-cycle costs etc. must be taken into account to obtain a holistic comparison (Goodchild & Glass 2004). Goodchild (1995) emphasised that the cost of HCC must be optimised to satisfy the whole project team.

Quality and finish

Pre-fabricated units are used as permanent elements (the elements are the final product before finishing) such as columns and beams or as permanent forms (the elements provide a shell for additional in-situ construction) such as slabs and permanent precast concrete shutters. Because pre-fabricated elements are constructed in controlled environments, better quality and finishes are obtained (Chen et al. 2009). The improved quality and finishes according to the client's specification, allows for minimal additional work after installation.

Quality assurance is achieved through in-house inspections and is supervised by an independent body. These quality controls are according to national or international standards such as the SABS 1200 (or the new SANS 2001) or ISO 9001 standards respectively. Not only do these inspections provide assurance regarding the quality or the products, it allows for quality with respect to procedures such as testing, accuracy, curing, handling, storing etc. (Fédération Internation du Béton 2004).

Environment friendly

Part of the ISO 9000 series, includes standards for recycled materials used in the factories. Recycling the materials in the controlled environment such as a factory provides for a greener construction method than with traditional methods (Fédération Internation du Béton 2004). Making use of pre-fabricated concrete provides additional green advantages during construction and in the final structure such as less water usage, lower CO_2 emissions due to heating or cooling because of the concrete's thermal mass, less waste generation etc. (British Precast Concrete Federation 2008).

Spans and lettable areas

Using in-situ concrete limits the spans between columns when a floor is designed. By using pre-stressed precast beam and floor systems, longer spans can be achieved. Additionally, shallower construction depths especially with up-stand or down-stand beams can be used due to the pre-stressing of elements. The greater spans that can be obtained with slender beams and columns provides greater lettable areas (Fédération Internation du Béton 2004).

Buildability and site conditions (site safety)

Buildability is described as the extent to which the design simplifies the construction that results in less unnecessary cost that are subject to installation processes and handling (Goodchild 1995). For HCC to be a functional construction method, it must be considered as an alternative construction method from the onset of a project. By resolving construction issues by means of pre-planning simplifies the construction process and improves the buildability of the elements (Goodchild & Glass 2004).

Because these pre-fabricated elements are constructed off-site, it allows for fewer on-site activities. As a result, sites are less cluttered and less waste is produces on sites. Pre-fabricated products are installed with limited scaffolding requirements resulting in a safer working environment and a decreasing risk of slippage and falling (Goodchild & Glass 2004).

Service integration and fire protection

Manufacturers are capable of integrating services during the production of pre-fabricated concrete elements. These services include ducts, openings, conduits, insulation, sound dampers etc. By integrating the services off-site saves additional time during the installation process and on-site construction (Goodchild & Glass 2004).

Concrete is known for its fire retardant capabilities. Concrete is a non-combustible material making it useful in all areas where non-combustible construction is required. By altering the properties and ingredients of the pre-fabricated products, the elements can be fabricated with a higher fire rating. This is especially useful for

"safe-rooms" or fire-escapes in buildings (Gustaferro 2010).

The advantages of pre-fabricated concrete products especially within South African circumstances will further be discussed in Chapter 4 where different HCC example projects are provided. Goodchild (1995) illustrated not only advantages of pre-fabricated construction, he also provided structural concepts possibilities that can be implemented. These possibilities will now be discussed.

2.2.2 Structural concepts

After Latham's (1994) exclamation of the advantages of pre-fabricated construction, Goodchild (1995) illustrated different structural pre-fabricated concrete applications. Further investigations provided 5 different HCC structural concepts that were introduced to the construction industry (The Concrete Centre 2005):

1. Precast twin wall and lattice girder soffit slab with in-situ infill and topping
2. Precast columns and edge beams with cast in-situ floor slabs
3. Precast columns and floor units with cast in-situ beams
4. Cast in-situ columns and beams with precast floor units
5. Cast in-situ columns and floor topping with precast beams and floor units

These concepts are provided as guidelines and will not be explained in more detail. Different techniques and alternative applications are encouraged by *The Concrete Centre* (2005). Chapter 4 and Chapter 5 investigates the different products and systems that are used for construction in South Africa and other countries respectively.

Although this study does not investigate the technical aspects of HCC, it is important to be aware of some of these issues when HCC is considered. Some of the problem areas will now be discussed.

2.2.3 Technical aspects during project development

It is well understood that HCC requires additional design effort because of structural concepts that are different from traditional in-situ designs (Goodchild & Glass 2004). For hybrid concrete project designs, it is important to investigate the following design criteria (Fédération Internation du Béton 2004):

- Overall stability
- Structural integrity
- Connections

Stability and safety for traditional in-situ buildings are usually not an issue up to a certain height. For precast buildings the structural elements will not form an interlocking system until the connections are activated. Therefore, it is critical to consider stabilising components regardless of the building's size or height. Stability can be provided to a frame by the addition of shear cores, shear walls, bearing walls or similar bracing systems

(Fédération Internation du Béton 2004).

It is regarded as an essential design purpose of HCC structures to obtain a coherent entity from the different precast elements. While some of the elements may be load-bearing, others are stabilisers and the design must take these differences into consideration. Coherency can be obtained through a careful selection of connections that will allow the structure to behave as required (Fédération Internation du Béton 2004).

The most essential and probably most design effort is required during the connection designs. Because the structure relies on the interaction between the different elements to transfer the forces to the bearing elements, the connections will influence the overall behaviour of the structure. These connections are required to transfer compressional, tensile and shear forces between adjacent elements. Different types of connections are available and need to be considered (Fédération Internation du Béton 2004).

While other design considerations are important such as seismic analysis or standardisation, the above mentioned 3 remains the initial problem areas. Other technical aspects include the manufacturing, transportation logistics and installation procedures of precast elements.

During manufacturing processes, manufacturers are constantly seeking methods of achieving uniform distribution of concrete throughout the mould while considering handling methods or crane hooks to move the element after construction. It is therefore critical to understand the most beneficial and correct "way up" of the mould during the manufacturing process. Other considerations during the manufacturing process are the accuracy of work (tolerances), finishes, formwork type and material, labour utilisation and casting methods (Richardson 1973).

Because precast products are frequently preferred for the superior quality of the products, transportation and handling techniques are essential considerations because this is often where most damages occur. Damages to corners and especially bearing areas of beams or columns can be dangerous and therefore every care must be taken during the transportation, handling and installation of these products. Sites must be prepared for the delivery and follow the advice of the suppliers regarding hoisting methods (if the contractor is to unload the elements) (Richardson 1973).

Similar to the design specifications, many additional technical aspects can be raised regarding the handling, storage, transportation etc. It is therefore critical for the design, construction and suppliers to constantly discuss any aspects that may influence the precast elements and hence the HCC structure during the project development (Richardson 1973).

These considerations can also be discussed during the procurement phases to limit the risk of possible issues occurring later in the project. The next section concentrates on different procurement methods that are currently used throughout the world.

2.3 Procurement

The procurement of projects is of critical importance because it is the first phase of a project. To implement HCC in a project, it cannot be stressed enough to involve the project team from an early phase. The implementation of HCC requires collaboration from the whole project team including the suppliers. It is therefore required that the procurement process must allow for early involvement (Goodchild & Glass 2004).

Table 2.1 is a summary of some of the different procurement methods that are in use (Marx 2011). These different categories can be used in any order, for instance Latham (1994) mentioned that design-and-build should be procured according to the two-stage strategy or at least 3 bids must be obtained if single-stage strategy is preferred.

Table 2.1: A summary of some of the possible preferred procurement methods that can be used in projects

Procurement strategies	**Procurement procedures**	**Procurement documents**
Single-stage	Employer designs	Joint Building Contracts Committee
Two-stage	Design-and-build	General Conditions of Contract
Open tender	Contract management	New Engineering Contract
Nominations	Public-private-partnerships	International Federation of Consulting Engineers

Procurement strategies establish the method in which the project is provided to the project team (Meng 2010). While different strategies can be used with different procurement procedures, open tendering is the most widely used in South Africa (Marx 2011).

During open tenders, the employer or client invites tenders for a project (specifications of the project must be available) from the industry. Because it is an open process, any contractor is allowed to tender for the project. While single-stage tendering is similar, it relies on the client to invite or specify a group of contractors to tender for the project.

Procurement procedures develop a hierarchy or responsibility in the project (Meng 2010). Different procurement procedures are utilised throughout the world, although the most frequent procedures in South Africa are the employer designs, design-and-build, contract management and public-private-partnerships (Marx 2009, 2011).

Employer design (or employer agent design) is frequently used in combination with open or single-stage tendering. The agents may be either the architect, engineer or a 3^{rd} party that is responsible for ensuring that the project is constructed according to the project specifications. The process allows for the client to consult an architect to develop a concept of a project. An engineer is consulted to structurally design this project. This design and project specifications are then provided to a contractor that constructs the project (Ramsey 2009).

With design-and-build the client provides a contractor (or an engineer if they have the capacity to manage such a process) with the concept. The contractor takes responsibility and consults a design team to design the project and provide project specifications that align with the client's expectations. The contractor is required to construct

the project as it is designed (Hawkswell & Kilvington 2008).

Similar to a design-and-build project, the contract management procedure causes for a client to consult a consortium to manage both the design and construction processes. This consortium comprises of design and construction teams. This method is often used in the United Kingdom (Goodchild 2011).

A public-private-partnership is a long term contract between a public partner (government, municipality etc) and a private partner. The private partner is responsible for the design, construction, finance, management, maintenance and operation of the project. Public partners usually enter this procedure when infrastructure needs to be constructed without the required funds to do so (Froud 2003, Yescombe 2007). The arrangement ensures that the private partner provides initial funding and is rewarded for such investment throughout the period of the contract by either the public partner or the public that makes use of the project (Yescombe 2007).

Lastly, procurement includes the documentation that provides a lawful contract to which the project team must adhere to (Meng 2010). The *Construction Industry Development Board* (CIDB) had an objective to create an enabling environment to improve the efficiency of the construction industry of South Africa. One of the measures of achieving this objective was to develop uniform procurement documentation for construction services (Bennington 2010).

The CIDB advise the public and private sectors to make use either of 4 standard tender documents in South Africa, namely the *General Conditions of Contract* (GCC), the *Joint Building Contracts Committee* (JBCC) contract, *International Federation of Consulting Engineers* (FIDIC) contract and the *New Engineering Contract* (NEC). The CIDB encourages uniform documentation by means of the CIDB *Standard of Uniformity in Construction Procurement* regulation (Bennington 2010).

Regardless of the procurement method, certain regulations and programmes can affect the building method. These regulations and programmes are discussed in the next section.

2.4 Regulations and programmes

Regulations have the ability to affect the building methods and building procedures. In some instances the procurement method (or confined guidelines) is prescribed to public employers (Government of South Africa - Constitutional Law 1996). Within this section, regulations and programmes that may affect or influence the utilisation of HCC are introduced. These regulations are discussed in more detail where it is appropriate within this document.

One of HCC's greatest strengths is the requirement for less labour on sites that creates a safer construction environment. In South Africa, programmes enforce additional labour on sites by means of labour-intensive construction programmes. This conflicting interests are discussed below.

2.4.1 Labour-intensive construction

Unemployment in South Africa is one of the most pressing problems and it is accompanied by immense poverty. Additionally, there is also a severe shortage of houses and other infrastructure. There is a drastic requirement to implement well constructed employment-creation programmes that can eradicate the unemployment, improve infrastructure and improve national skills (McCutcheon 1995).

One method of improving the unemployment is to implement labour-intensive construction methods. Labour-intensive methods are effectively a procedure that relies on the substitution of mechanical equipment for labour as a method of decreasing unemployment, increasing labour skills and improving the poverty within a country (McCutcheon 1995).

Labour-intensive construction methods are used in many developing countries such as Ghana, Botswana and Malawi and all are initiated by governmental programmes. Labour-intensive programmes in Kenya provided favourable results although it was found to be most promising in civil infrastructure construction (McCutcheon 1995).

President *Thabo Mbeki* formally announced a labour-intensive construction programme when the *Expanded Public Works Programme* (EPWP) was initiated in his "State of the Nation Address" in February 2003. The short-to-medium term target was to alleviate and reduce the unemployment in South Africa. The improvement of skill levels through education and training was the medium-to-long term target (Department of Public Works 2004)

All public bodies involved in infrastructure development were expected to contribute to the programme. Additional conditions were issued to public provincial and municipal departments by means of the *"Guidelines for the implementation of labour-intensive infrastructure projects under the EPWP"* (Department of Public Works 2004).

Labour-intensive projects under the EPWP aim to (Department of Public Works 2004):

- provide employment opportunities to the unemployed.
- provide adequate training to equip the workers with the required skills to perform the work.
- build cost-effectively and with the required quality.

While labour-intensive construction methods are physically demanding, additional health and safety issues may arise. It is therefore necessary to investigate the health and safety regulations that are applicable in South Africa. The health and safety regulations are discussed below.

2.4.2 Health and Safety

The health and safety in the construction industry is under severe scrutiny throughout the world. In many countries the health and safety record of the construction industry make it one of the worst industries of that country (Chapter 5). In South Africa the need to provide safe working environments for the labourers are extremely important especially because labour-intensive construction methods are applicable. The *Occupational Health and*

Safety Act 85 of 1993 stipulate specific responsibilities towards members of the project team to ensure a safe working environment (Government of South Africa 1993).

The *Construction Regulations of 2003* is an additional safety regulation that is subjected to the *Occupational Health and Safety Act 85 of 1993* and is drafted specifically for the construction industry. Some of the HCC affecting regulations are crane and hoisting operations, waste removal, scaffolding etc. (Government of South Africa 2003).

An additional method that is not implemented as a regulation in South Africa, although it is becoming an international trend, is green construction. This topic will now be discussed.

2.4.3 Green Construction

The construction industry started introducing construction methods and building procedures to combat global climate changes. One such procedure is through "green building". Green buildings are energy efficient, resource efficient and environmentally responsible. The process of efficiency must be incorporated in the design, construction and operation phases of a project (Green Building Council of South Africa 2011).

In the process of creating a green building it encompasses the use of more efficient and environmentally friendly designs, materials and technology. Through the application of greener construction methods several issues such as the reduction of heat and waste, use of recycled materials, water efficiency etc. are acknowledged (Green Building Council of South Africa 2011).

The *World Green Building Council* is an international company with branches throughout the world and is one of the leading contributors to green building. Several different green building grading systems are in use throughout the world. It was found that LEED rating system are utilised in the United States of America, BREEAM in the United Kingdom and in Australia, the Australian Green Star rating system (World Green Building Council 2011).

The *Green Building Council of South Africa* (GBCSA) was established in 2007 and is the South African branch of the *World Green Building Council*. The GBCSA has adopted and amended the Australian Green Star rating system for South African conditions (Green Building Council of South Africa 2011). Although regulations do not require building owners to construct according to greener methods, some innovation leaders apply these methods to their structures (Lewin 2011).

2.5 Conclusions

The objective of this chapter is to provide information regarding the different aspects of the construction industry that affect the utilisation of HCC.

After the disintegration of the construction industry in the United Kingdom, the government requested investigations into the construction industry. The Latham and Egan reports were the most groundbreaking reports and provided insight to the whole industry and are especially important for the current South African industry.

From these reports it was established that procurement must be accompanied by partnering methods that allow for early involvement by the whole project team. Clients were addressed to realise their value to a project team especially during the procurement phases. This may be of importance when changing methods are discussed later chapters.

Furthermore, pre-fabrication was regarded as a method of improving the construction industry and to provide best value in projects due to the advantages it provides. It was also recognised that if changes were not implemented in the United Kingdom, the industry would continue to deteriorate.

Different regulations and programmes that are applicable to the South African construction industry and affect HCC development are briefly discussed. These regulations include labour-intensive construction programmes, health and safety regulations and green building methods. These regulations provide a fundamental backbone to the industry and their application must be investigated. Any solutions to the industry must comply to these regulations.

This chapter illustrates different elements that may influence the utilisation of HCC. The next chapter illustrate the current state of the South African construction industry and in some cases compare it to the United Kingdom's construction industry to evaluate the necessity to change.

Chapter 3

South African construction industry

Chapter 2 provides a background of concepts that influence the utilisation of HCC. The objectives of this chapter are to investigate whether South Africa's construction industry is in need of change and to identify possible areas that require change. Furthermore, it illustrates whether the South African construction industry is prepared for hybrid concrete construction (HCC) if it is promoted. By focussing on several different aspects that influence the utilisation of HCC, an illustration of the industry's receptiveness towards HCC can be established. The following criteria are investigated:

1. Project distribution
2. Procurement methods
3. Status of the industry concerning contractors
4. Regulations such as health and safety, labour-intensive construction and green building methods
5. Training methods and institutes
6. Comparison between the South African and United Kingdom's construction industry
7. Questionnaires for the project team

The required information was obtained from personal interviews (Appendix A), questionnaires and journal articles. This chapter provides information that illustrates the current state of the South African construction industry and will be recalled in Chapter 6 where barriers to HCC are identified. Recent industry statistics within this chapter were obtained from surveys that were conducted in South Africa. These surveys are discussed in the next section.

3.1 Survey statistics

Marx (2011) performed a survey on 2807 projects to produce statistics of the South African construction industry. A total of 2807 contractors, 2624 employers and 1520 agents (such as architects and/or engineers) under consideration for the survey while only 37.5% contractors, 16.5% employers and 29.3% agents responded. Another report that provides historical data of the South African construction industry from 2004 to 2009 illustrates how the industry has evolved (Marx 2009).

The *Construction Industry Development Board* (CIDB) published the statistics and frequently referenced public or private clients. Figure 3.1 illustrates how the CIDB divided the public clients into different departments and sectors. Additionally, the figure also illustrates that information regarding private clients are limited. Furthermore, the CIDB admitted that no information is currently available on recurring private clients (Thumbiran 2011).

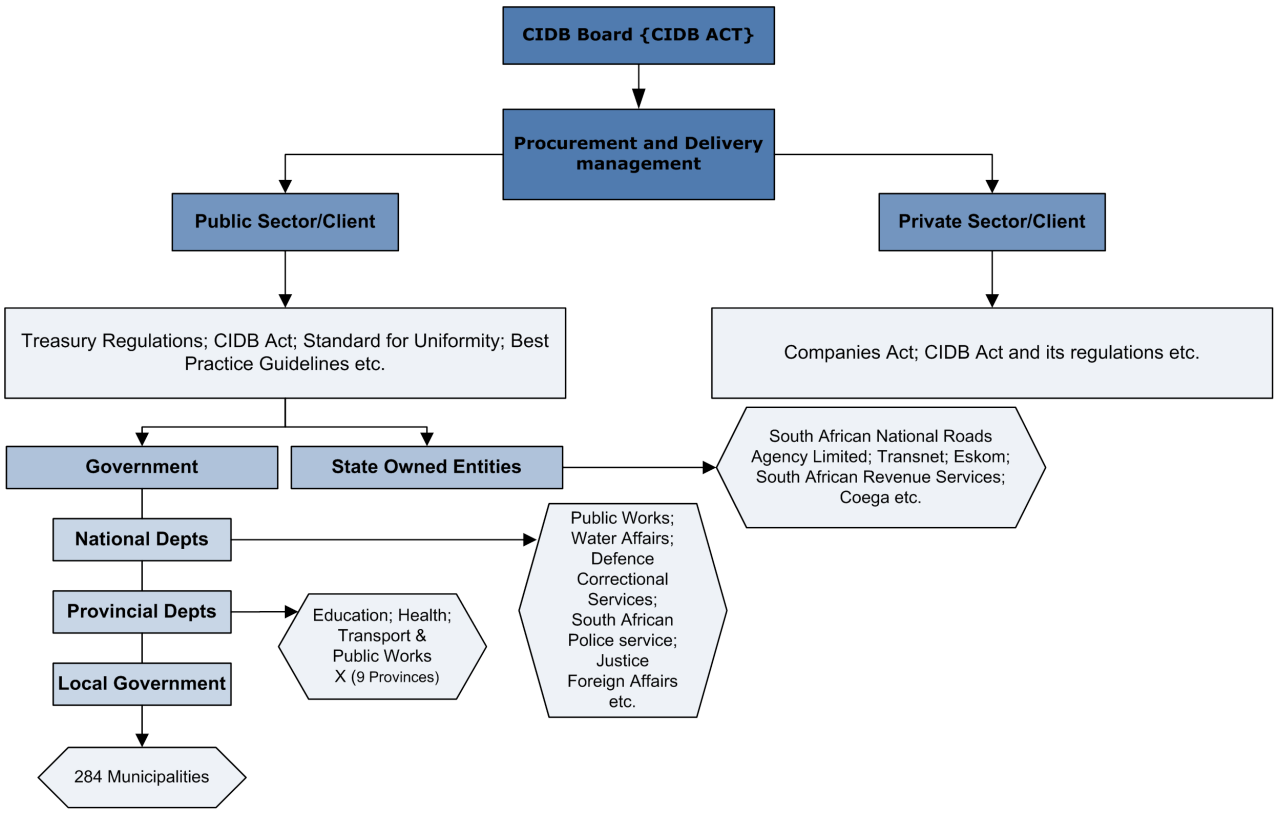

Figure 3.1: CIDB illustration of public and private clients and their different departments and sectors (Thumbiran 2011)

The statistics from these surveys mentioned above are used throughout this chapter. Statistics from Latham (1994) and Egan (1998) are used to compare the South African to the United Kingdom's construction industries. The information that was unveiled in the above mentioned reports caused for the United Kingdom to alter their construction methods. By comparing the United Kingdom and South Africa, an evaluation can be carried out to identify the need for change.

As a way of indicating the projects that are constructed in South Africa, the project distribution are discussed in the next section.

3.2 Project distribution

Table 3.1 illustrates the project distribution of each employer in 2009 in South Africa. Employers reported that a total of 432 projects were constructed of which 120 were building projects (residential or non-residential) and the remaining 312 were of other types such as mechanical, civil or electrical projects.

From the 432 projects, private employers procured 124 projects of which 47% were building projects. Similarly, the remaining 308 projects were procured by public employers of which 21% were building projects. Furthermore, it was found that public sector procured 52% of all the building projects in South Africa and the private sector procured the remaining 48% (Marx 2011).

Table 3.1: Surveyed projects illustrating the employer distribution for 2009 building projects (Marx 2011)

Project type	Private Sector	Public Corporations	National Departments	Provincial Departments	Metropolitan Council	Regional/District Council	PPP	Total Public
Residential building projects	17	4	3	2	2	0	0	11
Non-residential building projects	41	19	5	15	8	4	0	51
Total project (all project types)	124	87	23	61	108	21	8	308
% buildings of the sector's portfolio of projects	47	27	35	28	9	19	0	21
% of total surveyed buildings	48	19	7	14	8	3	0	52

According to the statistics from 2004, coincidentally private and public employers procured 48% and 52% respectively of the total building projects. The 2007 statistics illustrated that 57% and 43% of the building projects were procured by private and public employers respectively (Marx 2009).

The statistics indicate that both the public and private employers are valuable when building projects are analysed because of the even distribution of building projects. Additionally, Table 3.1 illustrated that several building projects (124) were included during the survey. Because many building projects are included in these statistics, it justifies its credibility to this study. The procurement methods that were used for these projects are discussed in the next section.

3.3 Procurement

As mentioned in Section 2.3, procurement can be subdivided into 3 parts: strategies, procedures and contracts. While private clients are allowed to be flexible on their adjudication criteria, public projects must be procured according to definite specifications.

The *Constitution of the Republic of South Africa (Act 108 of 1996)* requires that public projects must be procured according to 5 requirements. The requirements are that projects must be procured fairly, equitably, with transparency, competitively and cost effectively. These can further be explained as follow (Government of South Africa - Constitutional Law 1996):

- **Fairness**
  All participants must be offered the same information. Offers and acceptance must not be bias.
- **Equitable**
  Only "blacklisting", lack of capability or resources, legal impediments and conflicts of interest can cause for a contract not to be awarded to a tenderer who satisfies all the requirements.
- **Transparent**
  The procurement process and all decision making criteria must be publicly publicised. All decisions and reasons for the decisions regarding the contract must be open to the public.
- **Competitive**
  It allows the industry to compete for a project (through tender processes) to ensure the project is awarded to an enthusiastic tenderer.
- **Cost effective**
  The system ensures the best value regarding the quality, timing and cost of the contract while ensuring the least resources are used to effectively manage and control the procurement process.

The above criteria is valuable when the procurement is discussed. The procurement documentation will now be discussed.

3.3.1 Documentation

A project is a contract between two parties: A building contractor who agrees on constructing a building and the employer who rewards this service with payment. Contract documents are tools to manage the risks involved in contracts (Harinarain et al. 2008).

Table 3.2 shows that the building sector predominantly made use of the *Joint Building Contracts Committee* (JBCC) documentation. While the *General Conditions of Contract* (GCC) was also used on limited building projects, the use of international contract documents' (*International Federation of Consulting Engineers* (FIDIC) and *New Engineering Contract* (NEC)) are not noteworthy in South Africa. Unfortunately, Marx (2011) does not provide additional information regarding the "other" documents that were used for building projects (Marx 2011).

Table 3.2: Contract documentation (%) used for building construction 2009 (Marx 2011)

Document type	GCC	NEC	JBCC	FIDIC	Other
Residential building projects	10	0	87	0	3
Non-residential building projects	10	1	83	2	4

A trend exists towards the use of the JBCC document for building projects in South Africa, when statistics from the table are compared to older statistics. In 2006, Marx (2009) found that the JBCC was used on 56% and 69% of residential and non-residential buildings respectively. During the same period, the NEC was not used for

residential buildings and on only 2% of non-residential buildings.

The current state of the South African industry regarding procurement strategies will now be discussed.

3.3.2 Procurement strategy and procedure

The procurement strategy and procedure is a function of the following items:

1. The method how contracts are adjudicated.
2. The contractual strategy that illustrates the method the project is provided to the industry.
3. The procurement procedure that cause a hierarchy in the project team.

These functions are discussed as it appears in the list.

Contract adjudication

The contract adjudication process is important because it is influenced by the client's priorities of the project. Table 3.3 compares different adjudication processes as defined by the employer's agent. The table illustrates that in 2009, South African private employers adjudicated contracts according to cost and a combination of cost, quality and contractor preference. The public employers were more content to adjudicate contracts according to the cost and preference and the combination of cost, quality and preference (Marx 2011). Although Marx (2011) does not specify what the preference relate to; it can therefore be interpreted positively by adjudicating according to the contractor project history, or it can be negative and corruption can occur.

It is evident that while private employers adjudicate projects predominantly according to a the cost (31%) and cost, quality and preference (34%) of the tender, public clients only adjudicated according to the cost on 11.7% of projects (Marx 2011). Alternatively, public clients make more frequent use of cost and preference and cost, quality and preference (40 + 36.6 = 76.6%) processes. For public employers it appears to be contradictory to the *Constitution of the Republic of South Africa (Act 108 of 1996)* that can be interpreted that public employers would rather favour quality and cost instead of preference. If contract adjudications are based on preference (based on contractors' abilities or contractor project history), it can be possible to achieve the best value for a project instead of the lowest cost.

The adjudication preferences have changed since 2004. Comparing the 2004 and 2009 statistics, a greater preference developed for both private and public employers to adjudicate projects according to cost and preference while excluding the quality of a project (Marx 2009). It displays the trend that the industry has started to neglect the effect of quality during contract adjudication processes.

A similar scenario occurred in 1998 in the United Kingdom. Clients were undiscriminating (no contractor preference) during adjudication processes resulting in contracts being awarded almost exclusively on contract cost. The public employers were some of the worst culprits of this preference of contract cost. By changing the adjudication process, the industry wanted the clients to differentiate and understand the difference between the

Table 3.3: Tender adjudication preferences (%) for public and private employers 2009 (Marx 2011)

Adjudication Influential Factors	Private Sector	Public Corporations	National Departments	Provincial Departments	Metropolitan Council	Regional/District Council	PPP	Average Public
Cost	31	16	17	10	5	11	11	11.7
Cost and preference	14	23	53	38	54	50	22	40.0
Cost and quality	21	11	3	12	6	4	34	11.7
Cost, quality and preference	34	50	27	40	35	35	33	36.6

lowest price and best value of a project (Egan 1998).

The adjudication process usually has an affect on the contractual strategy because it is able to provide the employer with benefits such as reducing risks on projects or improved project team involvement. The contractual strategies used in South Africa will now be discussed.

Contractual strategy

The contractual strategy is the method by which the project is provided to the industry to develop. Table 3.4 shows that public and private employers in South Africa made use of a variety of strategies. Private employers awarded their contracts according to negotiations, quotations and nominations. Only 15% of private projects were awarded according to open tender procedures that usually presents the lowest cost. This is unexpected after the adjudication process found cost to be a crucial factor for private employers. Public employers remained traditional and awarded 67% of the contracts based on open tender procedures (Marx 2011).

Although the statistics implicate that the industry is involved with tendering procedures such as open strategies, the CIDB advised the industry to eliminate competitive tendering procedures to improve the health and safety on sites. It is explained that tendering will translate to less competitiveness regarding costs and will cause for the availability of additional finances for improved safety measures (Concrete Industry Development Board 2009). This implicates that the contract strategy has an important role on the health and safety of a project.

Latham (1994) suggested that contracts must move away from traditional tendering methods and must rather develop partnerships and trust between members of the project team. This was suggested because Latham found that tender processes resulted in the lowest cost of a project and not the best value.

Although the contract strategy is often related to the responsibilities within the project team, the CIDB differentiates between the contract strategy and the responsibilities. This concept is discussed below.

Table 3.4: Contracting strategy (%) for public and private employers in 2009 (Marx 2011)

Procurement Strategy	Private Sector	Public Corporations	National Departments	Provincial Departments	Metropolitan Council	Regional/District Council	PPP	Average Public
Negotiated	27	14	0	4	1	0	22	6.8
Selected/Nominated	28	18	9	16	4	4	22	12.2
Open (Traditional)	15	47	78	67	90	84	34	66.7
Quotation	24	14	13	4	2	8	22	10.5
Two Stage Tender	0	0	0	2	1	0	0	0.5
Other	6	7	0	7	2	4	0	3.3

Procurement procedure

During the procurement procedure, a hierarchy is created that influences the responsibilities within the project team (Meng 2010). Table 3.5 shows that both private and public employers preferred employer (or employer's agent) designs. This is regarded as the traditional method of design. Design-and-build and contract management procedures were not often used for both public and private projects (Marx 2011).

Table 3.5: Procurement procedure (%) for public and private employers in 2009 (Marx 2011)

Procurement procedure	Private Sector	Public Corporations	National Departments	Provincial Departments	Metropolitan Council	Regional/District Council	Average Public
Design-and-build	11	7	3	9	10	4	6.6
Develop-and-construct	10	9	6	4	7	4	6.0
Design by employer (traditional)	63	75	78	73	76	78	73.2
Management contract	10	0	6	4	0	7	8.2
Construction management	6	9	7	7	7	4	0.6
PPP	0	0	0	3	0	3	1.2

In 2002, design-and-build methods caused for mixed emotions in the project team . Clients and quantity surveyors appreciated the greater cost certainty involved with design-and-build projects in South Africa. In contrast,

engineers and architects were pessimistic of design-and-build and management orientated procurement systems. Contractors were extremely comfortable with their own capabilities and promoted the use of the design-and-build and management-orientated systems (Bowen et al. 2002).

Goodchild and Glass (2004) found that the traditional method of the design by the employer increases the difficulty to change the design after the procurement procedures. The involvement of the whole project team from an early stage of the contract is essential to initiate change to the design especially if HCC is considered as a building method.

Because contractors can have such an influential role on the project team, contractors in South Africa are discussed in the next section.

3.4 Contractors

Contractors in South Africa are required to register their company at the CIDB in order to practice in the industry. Registered contractors are rated according to a financial grading system indicating their financial capability to complete projects to certain maximum values. Ratings of 1–9 are awarded where 1 is corresponding to projects with a value less than R0.2 million and 9 is corresponding to projects with values greater than R130 million. Contractors are also categorised according to their trade, for example GB is for general building works or CE for civil engineering works (Construction Industry Development Broad 2011).

Table 3.6 shows all the registered contractors for general building works (GB). Grade 1 contractors account for 92.3% of the total contractors indicating the fragmentation within the industry. According to the CIDB, 831 contractors' registration were suspended over the last year. These contractors were suspended due to 2 main reasons: either they did not renew their registration for the annum or their tax certificate expired (Construction Industry Development Broad 2011).

Table 3.6: Contractors registered in CIDB financial grade categories (Construction Industry Development Broad 2011)

Contractor's financial grading	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
Number of contractors	58005	1940	573	863	577	560	217	82	27	62844
% of total contractors	92.3	3.09	0.91	1.37	0.92	0.89	0.35	0.13	0.04	

In the United Kingdom, Latham (1994) reported that the industry was fragmented with a large number of contractors. The construction industry comprised of 200 000 contractors, of which 48% were private individuals or one-person companies. Only 12 000 companies employed more than 7 people. Latham expressed his concern regarding this fragmentation and mentioned that it will result in companies to close down (Latham 1994).

Due to the large number of contractors, it cannot be expected of all these contractors to be profitable. The profitability of the contractors are discussed in the next section.

3.4.1 Profitability

Investigating the profitability of contractors in South Africa, Table 3.7 shows that 4.5% of building projects were completed at a loss for the contractor. Non-residential buildings tend to be less profitable than ordinary residential buildings when the profitabilities greater than 10% are compared. This may be due to the large number of parties involved with such construction projects. Furthermore, 66% (32.5 + 33.5) of building projects made profits of 0–10% (Marx 2011).

Table 3.7: Contractor's profitability according to % of projects according to the building type in 2009 (Marx 2011)

% Profitability	Residential buildings	Non-residential buildings	% of total building projects
Loss	6	3	4.5
0 – 5	29	36	32.5
6 – 10	27	40	33.5
>10	38	21	29.5

The building projects in 2009 illustrated that contractors predominantly made profits of 0–10% (Table 3.7). While some contractors achieved greater (>10%) profits, other contractors made losses from the projects (Marx 2011). Figure 3.2 illustrates how profit margins changed over the years when the 2004 profits are compared to that of 2009. In 2004 no losses were made; neither were there profits above 10% in both the residential and non-residential buildings (Marx 2009). While projects in 2009 were able to provide greater profits, it remained a risk because of the possible losses that can occur. The 2004 results appear to be less fluctuant although only profits of 0–10% were obtained.

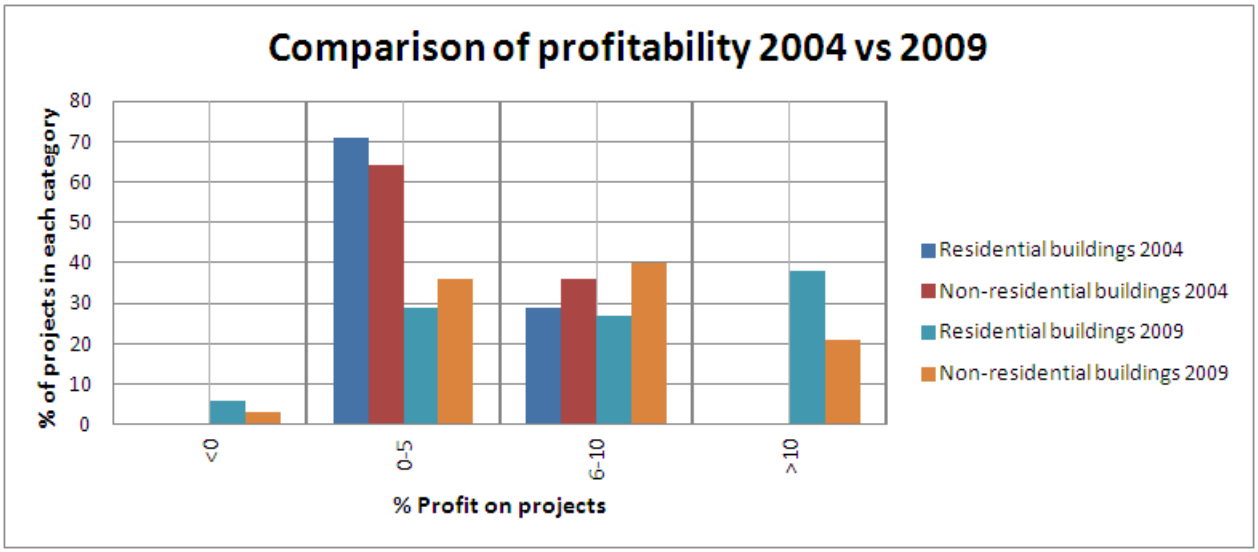

Figure 3.2: Profitability of building project for contractors (Marx 2009, 2011)

The United Kingdom realised in 1998 that the construction industry presented a low and unreliable rate of profitability. This profitability was regarded as too low to sustain a healthy industry. Change was required to

provide higher and more stable profits (Egan 1998).

Although profits for the contractors are important, client satisfaction remains a top priority during a project. Client satisfaction towards the project and contractors are discussed in the next section.

3.4.2 Client satisfaction

Client satisfaction is essential to ensure good relationships in the project team (Egan 1998). Table 3.8 illustrates the level of satisfaction that the employer experiences towards the rest of the project team and performance in South Africa. Employers experienced satisfactory work from their agents (either architect or engineer or 3^{rd} party) for both residential (81%) and non-residential building (82%) projects. Furthermore, the satisfaction towards the contractors were 84% and 82% for residential and non-residential buildings respectively. Similar satisfaction was experienced towards the project completion times and quality of the projects (Marx 2011).

Table 3.8: Employer's level of satisfaction (%) towards their project team and project performance in 2009 (Marx 2011)

Satisfaction	Residential buildings	Non-Residential buildings
Agents overall performance	81	82
Contractors overall performance	84	82
Completion time	83	81
Quality of project	84	81

Although it is unclear whether these results resemble an acceptable level of satisfaction, it can be compared to the satisfaction the clients experienced in the United Kingdom. In 1998, $^1/_3$ of clients appeared dissatisfied with the performance and products delivered by the contractors in the United Kingdom. Projects were unpredictable regarding time of delivery, costs and quality. More than $^1/_3$ of clients were dissatisfied by their contractors' performance based on time, resolving defects, cost and quality (Egan 1998).

Clients wanted to improve their satisfaction by emphasising more focus on the functional business needs. They wanted to integrate the design and construction processes with procurement methods to improve the value of the building project. Clients believed that long-term running costs (life-cycle costs) were more important than short-term costs and if the process can be integrated, greater satisfaction could be obtained (Egan 1998).

Another influential member of the project team is the manufacturers because they affect the elements that are used for construction. The manufacturers in South Africa are discussed in the next section.

3.5 Manufacturers

The *Concrete Manufacturers Association* (CMA) was established to promote pre-fabricated concrete, to write technical standards for pre-fabricated products use and to provide training and seminars. In order for the suppliers to register with the CMA, they must comply with SABS standards and hold the SABS mark on their products

or they must comply with the CMA rules. To date, only 8 precast companies are registered with the CMA to manufacture structural elements (Concrete Manufacturers Association 2008, 2011).

This investigation of the elements that the manufacturers are able to fabricate in South Africa are important to establish a clear concept of the capabilities of the manufacturers.

3.5.1 Capabilities

Table 3.9 shows some of the registered and non-registered members of the CMA that are able to manufacture structural building products. Although other precast manufacturers are operating in South Africa, their product range includes mostly architectural precast elements. The function of this table is to illustrate the low variety of structural elements that are manufactured by the South African suppliers. Furthermore, although the manufacturers in Table 3.9 do not advertise their capabilities to manufacture a wider variety of structural elements, some are willing to manufacture specific elements on request.

Manufacturers are able to produce high quality floor and wall slabs by making use of mechanical equipment and labour forces. *Special* elements such as façades or columns that require additional resources and equipment are not in high demand (September 2011). Labour-intensive procedures are used to construct moulds for beams and other odd shaped elements. Steel shuttering that will be durable are used to fabricate stair units, culverts, modular units or rib-and-block systems.

Table 3.9: Product range of South African pre-fabricated concrete manufacturers according to their websites

Company	Website	Slabs	Beams	Columns	Stairs	Culverts	Modular units	Other
Bobcrete	www.bobcrete.co.za	x			x			x
Cape Concrete	www.capeconcrete.com					x	x	
Cobute	www.cobute.co.za		x	x	x			x
Concrete Units	www.concreteunits.co.za		x			x		
Corestruc	www.corestruc.co.za	x	x	x	x			
Echo Prestress	www.echo.co.za	x						
Elematic	www.elematic.co.za	x						
Infraset	www.infraset.co.za							x
Ital Concrete Design	www.italconcrete.co.za		x					x
Rocla	www.rocla.co.za					x	x	x
Shukuma Flooring	www.shukumaflooring.co.za	x						x
Topfloor	www.topfloor.co.za	x			x			

Note: Items classed under "other" are products that are used for structural designs - typically *rib-and-block* systems or specially moulded structural members (including façades). Although many companies manufacture architectural columns or similar products, only companies that produce structural products are listed above.

When precast concrete elements are requested for the structural frame, the manufacturers request basic designs from the structural design team. The supplier is responsible for preparing the detailed design, although the design team is responsible to approve these designs. After approval of the designs, the supplier manufacture and install the elements (Concrete Manufacturers Association 2008).

South African suppliers of precast structural elements insist on installing the elements on site. In the process, they ensure that the conditions before installation is adequate and it eliminates failures due to pre-installation conditions (September 2011). Some manufacturers design elements for self installation, although it is exceptional (Angelucci 2011, Rooyen 2011).

The capabilities of the manufacturers and contractors are further illustrated in Chapter 4 where a database of HCC projects are provided.

Regulations may influence the construction method and the structural design. These regulations and practices in South Africa are discussed in the next section.

3.6 Regulations and construction practice

Regulations in South Africa differ for public and private clients especially regarding labour, methods of construction and procurement procedures. During an interview with an employer from a governmental department, the following items were identified as the 3 main criteria that are considered when projects are procured (Bouwer 2010):

1. The cost of the project.
2. The extent of labour-intensive construction methods that are used during construction.
3. The compliancy with green building regulations.

While cost is not a regulation or programme, the remaining two items are determined by regulations and will be discussed in this section.

3.6.1 Labour-intensive construction

As mentioned in Section 2.4, labour-intensive construction methods are required in the South African construction industry according to the *Expanded Public Works Programme*. Labour-intensive construction projects encourage contractors to use labourers to perform work instead of mechanical equipment especially on government funded projects. These duties include excavations, erection of formwork, concrete work, roofing, screeding, plastering etc. (Rowlinson & McDermott 1999).

Labour-intensive construction is physically demanding and expected health and safety concerns result from the constant body strain. Lifting, ergonomics, working at heights are only some of the main causes of health risks on site (Bikitsha 2010). The influence that labour-intensive construction has on the health and safety will now be discussed.

Labour-intensive construction's health and safety risks

In South Africa it was found that 90.9% of site injuries occurred at work while performing lifting operations of 20 kg or more. Exposing labourers to pushing elements, lifting operations or carrying of materials present the risk of musculo-skeletal disorders. Bikitsha (2010) performed a study of ergonomics on a labourer and indicated that bending and twisting of the body is the leading contributing factor to body strain and fatigue which can result in permanent damage. Furthermore, working in the same position for excessive periods of time presented similar consequences.

Labourers are often expected to work at different heights and through harsh environmental conditions that expose them to different health and safety problems (Bikitsha 2010). Although labour based work provide additional employment opportunities, the health and safety of the labourers becomes a significant factor and needs to be managed (Phoya & Haupt 2008, Parkikesit 2000).

The health and safety of construction sites will remain a concerning aspect. Beyond the concerns that the construction method has on the safety of a project, additional health and safety problems can be identified and discussed in the following section.

3.6.2 Health and safety

In South Africa, many construction organisations and teams have made significant efforts to improve the health and safety of the industry. However, when comparing the 2004 figures to those of 2008, the health and safety of the industry has not improved significantly. Therefore the health and safety remains a priority for the CIDB that initiates measures to provide a safer working environment (Concrete Industry Development Board 2009).

Contract documentation influencing health and safety

The contract documentation plays a significant role in the safety on sites. This is accomplished by implementing health and safety regulations in the document to which the project team must adhere. When the documentation is investigated in terms of health and safety, all documents are subject (implicit or explicit) to the laws and South African legislation regarding health and safety. More specifically however (Concrete Industry Development Board 2009):

- the GCC does not make explicit reference to health and safety. A reference is made to report accidents according to *Clause 34: Reporting of Accidents*.
- the JBCC does not make reference to health and safety either. Instead it makes explicit reference that the document is subject to comply with the laws, regulations and bylaws regarding the execution of the works.
- the FIDIC and NEC make reference to health and safety. Because these documents are of international origin, they do not always align with the South African legislative framework.

It is evident that amendments of the contract documents are required if health and safety is regarded as a high priority in a project. Documents that make reference to health and safety regulations that appear to be more beneficial (FIDIC and NEC) are not used in the building industry (Section 3.3).

Several acts and associations are responsible to improve the construction industry. These acts and associations will now be discussed.

Acts and associations regulating construction health and safety

The *Construction Industry Development Board Act no. 38 of 2000* mandates the CIDB to determine and establish best practice standards that promote positive safety, health and environmental outcomes. This Act mandates the CIDB to create a *Best Practice Project Assessment Scheme* based on the mentioned standards. According to the scheme, contractors that undertake contracts above a prescribed tender value are assessed according to their compliance with the best practice standards and guidelines (Concrete Industry Development Board 2009).

According to the *Occupational Health and Safety Act*, the whole project team is responsible for safety on sites. This is illustrated by Section 9 of the Act that stipulate that the employer is responsible for the health and safety of every single person on the site. Additional sections allow the employer to pass the risk of health and safety onto the contractor. Nevertheless, the employer remains responsible to take action in a case of non-compliance to the safety regulations by the contractor (Government of South Africa 1993, Fouche 2008).

Besides these regulations, private institutions have developed their own accreditation schemes that correlates to the acts. The *National Occupational Safety Association* (NOSA) is one of these South African organisations. NOSA is an accreditation organisation that audits the management programmes that are used for health and safety, environmental and quality management. In terms of health and safety in the industry, the mandate of this association is to improve health and safety on sites, improve health and safety training and auditing (National Occupational Safety Association 2011).

By complying with similar rating schemes helps identifying risks and the impacts thereof. It enables categories of staff to participate in problem solutions and serves as an international benchmark of health and safety. Ultimately it improves commitment to health and safety, environment and quality assurance (National Occupational Safety Association 2011).

Although these organisations exist and the acts and regulations confines the project team, the health and safety on sites remain problematic. These statistics will now be discussed.

Safety statistics

In terms of the *Compensation for Occupational Injuries and Diseases Act no. 130 of 1993* (COID Act), all construction employers must be registered by either *Federated Employers' Mutual Assurance* (FEMA) or the *Compensation Commissioner* (housed within the *Department of Labour*). Furthermore, it is required that all accidents occurring on sites must be reported to these organisations within 7 days of occurrence. Unless otherwise stated the following statistics were obtained from the CIDB. These statistics incorporate statistics from FEMA and the *Department of Labour*, but excludes motor vehicle accidents (Concrete Industry Development Board 2009).

According to the 1999 *Department of Labour* health and safety statistics, the building and construction industry in South Africa was responsible for 25.5 fatalities per 100 000 workers per annum making it the 3^{rd} highest

fatality rate of all industries in the country. Table 3.10 illustrates the increase of construction related fatalities and non-fatalities in South Africa from 2004 to 2008 (Concrete Industry Development Board 2009). Although these statistics are not expressed as a proportion of the increase of the workforce, it does display a clear increase of accidents.

The severity of the situation is clarified when the South African safety on construction projects are compared to that of other countries. Figure 3.3 shows the accidents and fatalities per 100 000 workers in 2009 for different countries or geographical areas. The South African construction industry displayed the 2^{nd} highest accidents and fatalities worldwide, only followed by Asian countries (excluding China) (Concrete Industry Development Board 2009).

Table 3.10: Accidents and fatalities over a 4-year period in South Africa from the *Department of Labour* (Concrete Industry Development Board 2009)

Severity	**2004/05**	**2005/06**	**2006/07**	**2007/08**
Fatal	54	81	79	162
Non-fatal	159	250	245	396
Non-casualty	11	7	10	20
Total	224	338	334	578

Note: These statistics are reported cases for the year only and are not expressed as a proportion of the increase of the workforce.

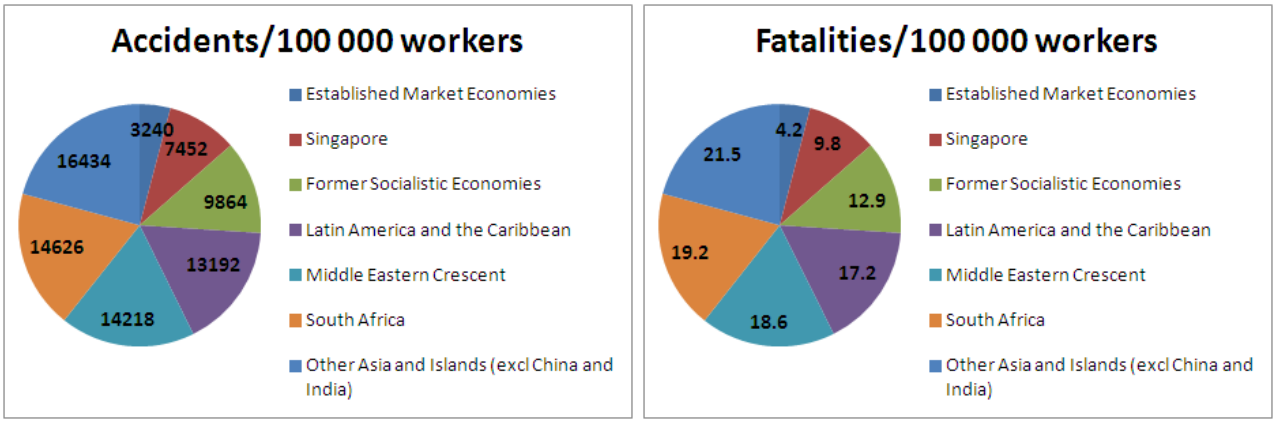

Figure 3.3: International accidents and fatalities per 100 000 workers (Concrete Industry Development Board 2009)

It was established that in 2006 and 2007 the main cause of these accidents on sites was workers being struck by, falling onto different levels and striking against objects. Fatalities were due to workers being struck by and falling onto a different levels. Most accidents occurred to the hands, head and necks of workers (Concrete Industry Development Board 2009).

When the United Kingdom's statistics are investigated, Egan (1998) reported that in 1998 the United Kingdom had poor safety statics. It is reported that their industry provided the second highest accident record of all industries in the United Kingdom. The reason for the accidents were claimed to be a lack of training within the

industry.

During a sudy by members of the *Association of Construction Project Managers*, *Association of South African Quantity Surveyors*, *Consulting Engineers South Africa*, *South African Institute of Architects* and general contractors it appeared that safety is not of high importance to the project team. The study was conducted to investigate what the importance of 5 pre-specified main parameters are on the project team. These parameters were specified as time, environment, quality, cost and health and safety. During the study, it was found that health and safety was rated fourth most important in a project. The traditional time, cost and quality retained top priority, indicating that health and safety was not carrying the same weight as the other parameters during project procurement (Concrete Industry Development Board 2009).

From the parameter study mentioned above, it was found that the environment was rated as the lowest priority of a building project (Concrete Industry Development Board 2009). The environmental aspects and especially "green" buildings are discussed in the next section.

3.6.3 Green Buildings

The *Green Building Council of South Africa* (GBCSA) accreditation process requires the building owner to submit documentation and project specifications to the GBCSA. The GBCSA assesses the building according to scoring toolkits and accredits the building with 4, 5 or 6-Green Star ratings. Currently, the "retail centre" and "office building" toolkits are the only available toolkits in South Africa (Green Building Council of South Africa 2011).

To date, no legislation requires building owners to construct according to "green" building methods. The GBCSA admits that accreditation must be voluntarily although they would support the legislation if it is implemented (Lewin 2011).

The GBCSA toolkits are base-building tools and additional investigation, expansion and updating is required (Lewin 2011). Additional concerns regarding the accreditation system and toolkits are discussed in Chapter 6.

As stipulated by both Latham (1994) and Egan (1998), training for the whole project team is of utmost importance. The next section discusses training in South African circumstances.

3.7 Training

During the late 1960's and 1970's, training of the project teams were structured in South Africa. The *South African Council for Professional Engineers* required all companies to offer young graduates an engineer-in-training programme. This programme encompassed a range of design, management, documentation and construction activities. Through it, young graduates were exposed to building methods and overcoming the barriers that may develop in the industry (Lawless 2007).

After the 1970's, the *Sector Education and Training Authorities* emphasised the utilisation of formal training courses. No clear distinction were made between formal training and workplace training. In public sectors, staff

spent numerous hours in formal training courses but their improvement regarding efficiency, expertise or decision making was not evident. The reason was due to the lack of guidance by experienced mentors (Lawless 2007).

Currently, the South African construction industry has a severe shortage of qualified expertise. Training procedures are required to improve the skills of the industry. As a result, several training institutes are implementing different methods of training to overcome the lack of skills within the industry (Construction Industry Development Board 2007).

The United Kingdom experience tremendous loss of trainees within the workforce. Egan (1998) reported that it was halved since the 1970's. Not enough people were trained to replace the ageing skilled workforce that was leaving the industry. Furthermore, not enough personnel were trained with the technical and managerial skills to achieve the full potential of new technologies and innovations.

In South Africa, the CIDB launched a 3-legged training framework to overcome the shortage of skills. It was structured around learnerships, Further Education and Training (FET) and Higher Education and Training (HET). All focus on methods of furthering education within the construction industry. These methods demand theoretical training in institutes and additional training at the workplace (Construction Industry Development Board 2007).

Tertiary training formed part of the HET programme. The effect that tertiary training has on the South African industry especially regarding the implementation of HCC will now be discussed.

3.7.1 Tertiary training

Tertiary institutions provide young graduates with the required skills to enter the industry. It is therefore necessary for tertiary institutions to provide a theoretical platform to implement HCC methods. In South African tertiary institutions that offer civil engineering were consulted to understand the exposure that students obtain of HCC during their studies. The objective was to establish whether tertiary institutions provide courses in precast concrete design for their students during under-graduate or post-graduate studies. Three years of information were received from participating institutions.

Appendix C, Table C.1 indicates that over the 3 years, only 9% of under-graduate and 8% of post-graduate students experienced some exposure to precast concrete design. Although students were educated in the field of principals and concepts regarding normal reinforced concrete design, they were still ill-equipped with the proper knowledge of pre-fabricated concrete design, construction methods and sequence.

Because tertiary institutions provide limited HCC courses, other training institutes were investigated to understand their influence in the industry. This is reported below.

3.7.2 Procedures and diversity

Lawless (2007) mentioned that several organisations assist with training in the construction industry. The organisations were investigated to establish their involvement in the field of pre-fabricated concrete construction.

Appendix C, Table C.2 indicates that limited training courses and seminars are available within the industry that will promote the use of pre-fabricated concrete. Training courses are provided for managers, designers and contractors involving different aspects of construction improvement such as management styles, procurement methods documentation, finite element design, waste and site management. Although these courses can influence pre-fabricated concrete utilisation, it is not their main focus.

The courses presented (both pre-fabricated courses and other training courses) are so-called one-dimensional. Training is provided either through lecturing or practical implementation of established methods (labourer training). This does not drastically improve the implementation of a specific construction methods especially HCC. Lawless (2007) affirms by stating that the public sector's expertise did not improve through a series of formalised training courses.

In addition to these organisations mentioned in Table C.2 some contractors have developed their own training schedules or business schools that provide training courses for both private and public sectors. These training courses are mainly centred around the requirements of the contractor and includes courses such as management strategies and procurement procedures (Niel Muller Construction 2011). The affect of training will further be discussed in Chapter 6.

Additional methods were required to investigate the requirements of the industry that are not found in journal articles. While interviews were able to target specific questions, questionnaires were developed to obtain an industry opinion regarding HCC. The questionnaires are discussed in the next section.

3.8 Questionnaires

In an effort to obtain information from the South African construction industry, questionnaires were created for different members of the project team (Appendix D). The objectives were to obtain information regarding the:

- company profile.
- project portfolio.
- procurement methods.
- pre-fabricated elements.
- methods to increase the use of pre-fabricated elements.

3.8.1 Questionnaire development

Separate questionnaires were created for the clients, consultants and contractors. The intention of the questions were different for each member of the project team. Although different information was requested from each of the 3 groups, the questionnaires were subdivided in 4 sections:

1. Company profile
2. Project portfolio and procurement strategies

3. Pre-fabrication information
4. General

The first three sections of questions were close ended questions that required simple selection of the appropriate statement. The last section was more open ended and it was encouraged that participants should elaborate on their answers. In order for the participant to return the questionnaire, different contact details were provided.

It was decided to distribute the questionnaires at three seminars:

1. CMP conference, 2010 (Stellenbosch University - Prof Jan Wium)
2. GCC 2010 seminar, 2010 (Cape Peninsula University of Technology - Mnr Willie Claassens)
3. Construction Law - JBCC seminar, 2010 (Stellenbosch University - Prof Jan Wium)

These seminars were attended by clients, consultants, contractors and quantity surveyors. The completed questionnaires were analysed and provided information on the project team's opinions on hybrid concrete construction. The information is summarised below.

3.8.2 Results

Twenty-two participants responded to the questionnaires of which 2 were clients, 8 were consultants and 12 were contractors. Two contractors and one consultant's replies were not used because their response were incomplete and their industries differed completely from the required building industry. From the remaining questionnaires 31% had transportation and 16% had other engineering backgrounds respectively. Only 49% (9 respondents) were involved with structural engineering that includes major infrastructure development (dam walls, harbour extensions etc.). The remaining 4% were involved with building projects that were not applicable for this study (such as bridge design)(Figure 3.4).

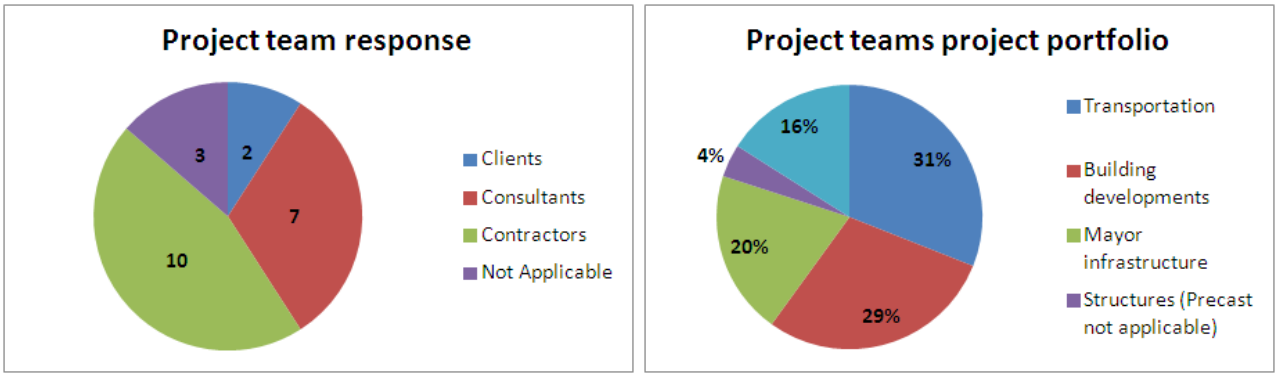

Figure 3.4: The response distributions from the questionnaires

Seeing that there was a lack of response, it was decided not to use the procurement information because it was not representative of the industry. Appendix D provides additional information that was obtained from the questionnaire. The comments that were provided by the respondents regarding the pre-fabrication industry

development were noted. The following recommendations were made in the questionnaires to improve the utilisation of hybrid concrete construction:

Design

1. Consultants must convince the remaining design team to utilise HCC, because they have the most influence on the design.
2. Pre-fabricated concrete products must be specified in the contract documents and consultants must nominate suppliers to contractors.
3. Design processes must be improved to ensure that precast elements fit in correctly with the rest of the system.

Management and exposure

1. Improve transport logistics, especially for larger elements.
2. Demonstrate the cost effectiveness of these elements.
3. Provide more exposure to successful implementation of precast units.
4. All the areas that require pre-fabricated elements are already being used.

3.9 Conclusions

This chapter illustrates how the South African construction industry compares to that of the United Kingdom. Furthermore, it illustrates aspects of concern for the South African construction industry that must be addressed. To obtain this information, the chapter recognise client involvement, project distributions, procurement strategies, different regulations and a questionnaire survey. The information is compared to the United Kingdom's industry before improvement methods were implemented.

The building industry is dependant on both private (48%) and public (52%) employers because of an almost equal distribution of building projects in 2009. Both public and private sectors tend to finance more non-residential buildings than residential buildings. Regardless of the building type, the importance of public and private clients are crucial, especially if drivers are required to enforce change in the industry (Chapter 8).

The *Joint Building Contracts Committee* (JBCC) contract document was predominantly used to procure building projects. When statistics of 2006 were analysed, it was evident that the JBCC was the preferred contract document and it was in use for several years. Because the JBCC is so recognised and familiar in South Africa, it may need to be amended when HCC is recommended instead of recommending the industry to make use of a new contract document.

Procurement methods differ slightly between public and private employers. Public employers utilised traditional open tender systems and private employers awarded projects according to a wider range of criteria. Both private and public employers remained traditional with employers that develop the design. Solutions that will improve the

utilisation of HCC in South Africa must accommodate the traditional procurement methods.

Several different regulations influence the construction industry in South Africa. One of which is the *Expanded Public Works Programme* that requires the implementation of labour-intensive construction methods. Although labour-intensive construction does produce less unemployment and improves skill development, it is physically demanding on the human body. The continuous strain results in accidents and permanent health concerns and must be investigated. Methods of improving the health and safety while improving the utilisation of HCC need to be considered.

Although green construction is not a requirement, it does provide positive advantages to the building industry. HCC needs to be in line with the the green building targets to be able to compete with traditional construction methods.

Several training institutes in South Africa produce a wide range of training programs, although it is not aimed to improve or increase the use of HCC in the country. Tertiary institutions do not provide students with the knowledge to incorporate HCC in designs when they enter the industry. It may therefore be required to alter the methods and content of training to improve the awareness and utilisation of HCC.

Private organisations such as NOSA provide accreditation schemes that are in line with different acts and guidelines. Such organisations can influence safety on site and in factories if it is implemented successfully.

Table 3.11 summarises the different aspects that are mentioned in this chapter that may influence the adoption of HCC in South Africa. Additionally, it illustrates that if South Africa wants to increase the utilisation of HCC, it is required to implement changes to these criteria. These items are discussed in more detail in Chapter 6.

Table 3.11: Summary of factors that may alter HCC adoption in South Africa

Criteria	Comment
Procurement strategy	Tender processes (open-tender) prohibit best value and result in best cost without early involvement by the contractor
Procurement procedure	Promotes cost instead of the improved value of the project
Design responsibility	Employer design cause for limited contractor involvement in the design
Manufacturers	Limited elements are manufactured by precast suppliers
Labour-intensive construction	Promote labour methods on site, while an advantage of HCC is the requirement of less labour
Green building	Make use of a base-tool that does not include the green benefits of precast construction

Table 3.12 provides a comparison between the South African and United Kingdom construction industries. The factors that resulted in the United Kingdom to alter their construction methods appear to be similar except for client satisfaction. It can be argued that these similar industries would need similar resolutions. Although HCC was introduced to the United Kingdom as a possible method of improving their construction industry, regulations such

as labour-intensive construction techniques are not relevant to them. Nevertheless, from the table it is evident that the South African construction industry is requiring change as a way of improving itself.

Table 3.12: Summary of the difference between the South African current state of the industry and the United Kingdom's industry before their transformation

Criteria	**United Kingdom**	**South Africa**
Procurement procedure	public - cost private - cost	public - cost and preference private - cost
Contractors	200 000 contractors, 48% less than 1 person	63 844 contractors, 92% grade 1
Profitability	low and unreliable	unreliable with losses
Client satisfaction	$>^1/_3$ dissatisfied	>80% satisfied
Training	skill shortage	skill shortage
Safety	2^{nd} highest accidents in the country	3^{rd} highest accidents in the country

A questionnaire was used to expose the industry's attitude towards precast concrete. While some indicated that the industry needs to be informed of the advantages of precast concrete, others provide specific measures to improve the precast use. The major recommendation is that there is a requirement for exposure to HCC projects. The next chapter provides a database as a method of providing exposure of some projects that were constructed over the last 7 years to illustrate the utilisation of HCC in South Africa.

Chapter 4

Example projects in South Africa

The previous chapter illustrates the current state of the South African construction industry and a need exists for exposure to hybrid concrete construction (HCC) projects. This chapter aims to present examples of HCC projects in South Africa to demonstrate some possibilities that exist for the use of HCC. It concentrates on hybrid concrete projects that were constructed in South Africa and provides some exposure of HCC projects to the industry. This chapter is subdivided into separate sections that focus on the specific pre-fabricated elements. The objectives of this chapter are to:

1. Provide some examples of HCC projects that were constructed in South Africa within the last 7 years to conclude the current state of the South African construction industry and especially the utilisation of HCC.
2. Describe the project's scale, duration, obstacles and construction method.
3. Identify specific reasons to choose precast concrete in similar projects.
4. Demonstrate that the creation of a database with project information can be beneficial to demonstrate the use of HCC in South Africa.

The project team members or suppliers involved in the projects are not mentioned throughout the text and will remain anonymous. Project information was obtained through articles published in several civil engineering magazines published in South Africa. Due to the nature of the magazines, some of these projects may be biased towards the use of concrete in construction, and a more in depth investigation will ultimately be needed to identify possible negative aspects of the projects. The different elements that are used in the projects will also be the section headings for this chapter.

4.1 Slabs

4.1.1 Steenberg social housing project

The human settlement development project provide affordable rental accommodation in the Cape Town area. Figure 4.1 shows a typical house that was constructed for this project. Estate agents partnered with the *City of Cape Town* and the *Western Cape Provincial Government* to develop this 8-hectare, medium-density, 2- and

3-storey housing units. A total of 450 units were constructed for households earning less than R7 500 per month. Units were constructed in a variety of studio, one- and two-bedroom apartments.

Figure 4.1: Steenberg social housing project (Lange 2011)

Pre-fabricated staircases and hollow-core concrete slabs were used for the structure and the slabs were designed as a double cantilever on the third floor (see Figure 4.1). These cantilever slabs ensure an increase in gross floor area on the top floor while providing shading to the floor beneath. No up-stand or down-stand beams were required for the construction.

It is reported that the slabs and staircases added value to the project and ensured speedier construction. The project team reported that this design method provided a more cost effective solution compared to in-situ construction. The project was awarded a CMA award for the use of pre-fabricated concrete elements and innovative design (Lange 2011).

4.1.2 Oakfields shopping centre

The existing *Oakfields* shopping centre in Benoni was extended by 4 600 m^2 in 2009. This addition to the existing shopping centre was proposed as a hybrid structure consisting of a structural steel frame and pre-fabricated concrete flooring. The pre-fabricated concrete floor units were installed onto the castellated steel beams on a 7.5 m grid. Although this project is a steel and concrete structure, it remains useful for the purpose of this chapter.

Some relevant issues were the high loading specification that these slabs were designed for. In certain areas design loads of 12 kN/m^2 were required and a 250 mm slab was used to accommodated these excessive loadings. Another issue was the irregular span lengths. The design solution included a 75 mm structural reinforced concrete screed topping on the slab to assist with these lengths.

The main benefits of using pre-fabricated slabs were the construction speed, the lightness of the structure and the cost effective solution. The precast element manufacturers provided the design and contracting teams with

sufficient drawings and, through effective communication, ensured that the project was a major success (Civil Engineering 2009).

4.1.3 Orlando station upgrade

Another *FIFA World Cup 2010* infrastructure development was the *Orlando Station* upgrade project in Soweto. Figure 4.2 shows the pre-fabricated slabs on the structure. This station is a critical link for the Gauteng public transport chain. Construction on this R60 million contract began in 2009.

Figure 4.2: Pre-fabricated hollow-core slabs installed at the Orlando Station upgrade project (Civil Engineering 2010)

Construction was required to take place throughout the day even though the station was in full operation. The foundations and main columns were constructed using in-situ concrete. Long lead-in times were necessary if the contractor wanted to work over the railway lines and thus forced the contractor to work during odd hours. To minimise the track occupation time by the contractor, pre-fabricated slabs were installed over the tracks.

Because of the train operation, the slabs and main horizontal beams were lifted together using 2 mobile cranes. Whilst the beams were pre-fabricated on site, the slabs were manufactured at the suppliers factory and transported to the site.

The Civil Engineering magazine reports that the use of the pre-fabricated slabs resulted in the project being within the budget and time constraints. Furthermore, the slabs ensured that the total weight of the structure was kept to a minimum compared to in-situ concrete construction. The supplier's elements were ensured to be of exceptional quality because the factory is SABS and ISO accredited (Civil Engineering 2010).

Other projects that made use of precast concrete slabs in South Africa were:

- Strelitzia residential complex (Gauteng) (Lange 2011)
- Protea Hotel (Kwazulu Natal) (Concrete Trends 2010*d*)
- King Shaka International Airport (Kwazulu Natal) (Concrete Trends 2010*b*)

- Soccer City kiosk (Gauteng) (Concrete Trends 2010*a*)

4.2 Walls

4.2.1 Gautrain sound insulation wall

The Gautrain project in South Africa was one of the largest rail construction project in the world in 2009. Several different elements and components were required to construct this mega-project. Pre-fabricated elements were in abundance and elements such as viaduct segments, pipes, beams and wall elements were used for quality assurance, to increase construction speed and to reduce costs (Mattheis 2009).

Wall elements were used as permanent insulation barriers against sound and air pollution during and after the construction of the Gautrain project. A total of 15 000 m^2 panels were required for the project. An environmental impact assessment (EIA) predetermined that a total reduction of sound levels of 65 decibels must be achieved. This resulted in extensive research to find a way of achieving these requirements. It was found that pre-fabricated concrete barriers would provide the best solution. These panels are shown in Figure 4.3.

Figure 4.3: Normal precast walling (left) and absorbtion walling (right) is used as insulation barriers on the Gautrain project (Beer 2010)

A pre-fabricated absorption concrete panel (4 m span, 100 mm thick and 0.75–1.5 m high) was developed using wood chips rather than aggregate. These panels were constructed for a life-cycle period of 100 years. This was regarded as standard for all the pre-fabricated elements on the Gautrain project. These absorption panels were installed adjacent to the face of the basic wall barriers for the additional structural stability. Although the panels were designed with wood chips, they remained rot proof and could be installed to any existing structure.

The elements were developed in a SABS approved laboratory and it was reported by Beer (2010) that it performed well against ISO standards during acoustic testing. These elements indicate how the properties of concrete can be adjusted to suit the requirements of the project (Beer 2010).

This is not the only use of precast elements on the Gautrain project. It illustrates how precast elements and in-situ concrete can be combined in a project to make full use of the advantages of each type of construction.

4.2.2 The Houghton luxury hotel and apartment's retaining wall

The Houghton development comprises of residential apartment blocks and a boutique hotel. The site is situated in an area with severe contours, making the design of the retaining walls quite complex. Pre-stressed hollow-core panels were used in 98% of the project's retaining wall structure. Figure 4.4 shows the propped wall elements for the hotel basement. The objective was to achieve as much standardisation as possible in panel sizing to simplify the manufacturing and installation procedures on site. In some instances, the use of these pre-fabricated panels were not appropriate due to on-site geometry or tight radii.

Figure 4.4: Hollow-core precast panels being propped into their footing positions at *The Houghton* hotel (Civil Engineering 2008*a*)

The hollow-core panels serve a dual role by providing the walling for the underground parking and by serving as a retaining wall for the embankment soil. The panels were 1.2 m wide and 150 mm thick, but ranged between 3.2 m and 5 m in length. In areas where 2 panels were suppose to be head-to-head, the bottom slab was 250 mm thick thus deviating from the standard 150 mm. Footing channels of 250 mm deep provided a foundation for the slabs. On the interior side, an additional 300 mm support was provided at the base. To deviate from a full cantilever action, steel right angels were fixed between the head of the panels and the first floor.

The Civil Engineering magazine reports that by making use of the pre-fabricated panels, the retaining wall was erected 3 times faster than normal in-situ retaining walls. The hollow-core panels were also easy to cut in areas where for example air-conditioning units needed to be installed. With a length of 2 000 m, this retaining wall project was South Africa's largest precast hollow-core retaining wall project in 2008 (Civil Engineering 2008*a*).

4.2.3 Dora Nginza hospital and Greenbushes business estate security walls

The *Dora Nginza* hospital in Port Elizabeth constructed a security wall around their premises in 2009. In-situ columns were positioned 6 m apart around the 1.5 km premises that accommodated the pre-stressed hollow-core panels that were 6 m long, 120 mm thick and 1.2 m wide. Three panels were installed horizontally in stacks. The

bottom panel was planted into the ground to a depth of 600 mm ensuring no potential digging underneath the wall.

The same process and elements were used at the *Greenbushes* business estate. The total length of the wall was 2.75 km around the estate. At this estate, only two panels were stacked horizontally and additional electric fencing were installed above the wall.

The Concrete Trends magazine reports that the elements were made in factory conditions and provided excellent quality. By implementing these elements, the construction speed of the walls was 3 times faster than with normal in-situ construction. Furthermore, the durability of the pre-stressed elements makes it a better material for security walls. Making use of such a strong material, improves the security by increasing the difficulty of entering the facilities (Concrete Trends 2009*b*).

Another project in South Africa that made use of precast concrete walling was:

- Cosmo City (Gauteng) (Concrete Trends 2010*f*)

4.3 Beams and columns

4.3.1 Volkswagen paint shop

The *Volkswagen* paint shop was an extension to the existing plant in Uitenhage in 2006. The total extension amounted to a surface area of 45 000 m^2. Although in-situ would be more economical, precast concrete construction was chosen as a construction method due to time constraints. The project was procured under a design-and-build venture by a local contractor.

The frame comprised of pre-fabricated bases, in-situ columns, pre-fabricated beams and pre-fabricated floor panels making it a total pre-fabricated structure. Most elements were post-tensioned and enabled designers to have beams of up to 26 m span lengths. The contractor established their own pre-fabrication yard for the beams and bases and were required to install these elements using their own resources.

Design alteration occurred throughout the project because the final design was never finalised during the project. Several different beam configurations were required, causing the manufacturing process of these elements to be time-consuming. Additional design confusion occurred due to a lack of communication between the project team and the precast-yard. The construction team was unexperienced with this construction method which caused additional initial delays.

Upon completion the project team admitted that a lack of commitment towards HCC from the whole team caused for several changes throughout the design. The contractor suggested that an external design manager and checking engineer is required if such projects are attempted again. This manager must be responsible for the coordination between the different teams on the project and to notify the design team of necessary changes or anticipated problems. Afterwards, a sub-contractor suggested the use of multi-storey precast columns instead of in-situ columns, because it would result in less joints and less construction time (Jurgens 2008).

4.3.2 Honda showroom

When the new *Honda* showroom was constructed in Polokwane, the private client set severe constraints. The project was situated between two operating businesses and the showroom was expected to be operational within a limited time frame. It is reported that the consultants designed the showroom as an in-situ building, but the client suggested a precast design based on the short construction period. Figure 4.5 shows the R13 million project that was redesigned using pre-fabricated elements.

Figure 4.5: Precast columns, beams and floors used at the Honda Showroom (Concrete Trends 2011)

Manufacturers were responsible to provide detailed designs for the pre-fabricated elements before it could be manufactured. Pre-stressed beams with a 12 m span were used to create a column-free space within the showroom as requested by the client. The finishing on the elements was of such high standard that many of the elements were never painted. Some of the interior elements were painted and thereby provided additional colour to the interior rooms. Honda's showroom was opened within 4.5 months after construction commenced.

The contractor acknowledged upon completion that it is important to limit the amount of variations of precast element sizes and shapes for future projects. The contractor emphasised this statement by adding that standardised elements will be more cost-effective and less time-consuming (Concrete Trends 2011).

Another project in South Africa that made use of pre-fabricated columns and/or beams was:

- Orlando Stadium (Soweto) (Civil Engineering 2007)

4.4 Other structures

4.4.1 Impala 20 shaft project

The R2.1 billion *Impala 20* project in Rustenburg opted for precast panels in 2004 when the project was on a critical path. The project was divided into 2 sections: two shafts (a 8.5 m diameter main shaft and a 6.5 m diameter ventilation shaft) and a surface and underground infrastructure development. The main shaft needed to be sunk to a depth of 1051 m and the ventilation shaft to a depth of 997 m.

The sinking process of the ventilation shaft was on the critical path. Pre-fabricated concrete panels provided a solution to enable the project to regain its original construction schedule by making tailor made pre-fabricated panels for the exterior walls of the shaft.

The sinking contractor was responsible to sink the shafts to -15 m. Due to constraints, the civil contractor was required to install the shaft within a limited construction period with the pre-fabricated concrete panels that were designed and shaped to suite its specific purpose. These panels were limited to a weight of 8.5 tons per element due to crane constraints. In-situ concrete frames (beams and columns) were constructed to ensure a stable and safe environment during mass concrete backfilling. The beams and panels were used as permanent shutters during construction rendering minimal support scaffolding.

Pre-fabricated concrete use to be considered in South Africa to be an expensive construction method but the construction speed has always been undeniable fast. The concrete panels reduced the construction time of activities on the critical path. After the building of the shaft, the fan ducts were constructed using in-situ concrete because the project was no longer on the critical path. In mining projects, it is vital to minimise the construction period to gain early returns on the investment. Precast concrete proved to be the cost-effective solution contributing to acceleration of the process (Henderson 2006).

4.4.2 Reservoirs

Lindley reservoir

The first reservoir to be built in South Africa by making use of precast elements was in 2008 in Lindley, Free State. To date, hollow-core slabs were used for the roof structure of reservoirs, but the Lindley reservoir was unique because of the pre-fabricated walls and roof. The reservoir was designed to accommodate a capacity of 1.2 ML. Although the walls and roof were designed as pre-fabricated elements, designers chose in-situ columns and floor.

An outer ring beam provided adequate shear resistance to the walls. Unlike the usual application of hollow-core panels, the wall elements were grouted to 1.2 m from the ground to add additional resistance to shear. All the joints were sealed with gunite and sealed with a waterproof sealant to contain the water and to eliminate natural interference from the surrounding environment. The columns within the reservoir provided support for the beams that supported the roof elements.

Major quality assurance is required when reservoirs are constructed to ensure the quality of the water that will be stored inside it. By making use of pre-fabricated elements, the element quality was always acceptable and it was reported to be due to the controlled environment in which it was manufactured.

Designers chose precast concrete due to a lack of skills, especially regarding concrete specialists and shuttering experts within the construction area. The pre-fabricated elements meant time and cost savings and ensured quality throughout the project. By making use of a pre-fabricated system, the construction of the reservoir was completed within 7 weeks. *The Civil Engineering* magazine reported that the designers believed that traditional in-situ methods would have required 6 weeks compared to the 3 days which it took to erect the walls of the structure, making the pre-fabricated system a much faster construction method (Civil Engineering 2008*b*).

Polokwane reservoir

The storage capacity of the existing reservoirs in the Polokwane district was unable to serve the rapid expanding area. The Municipality estimated that another 50 ML reservoir was required at the *Krugersburg* reservoir complex in 2009. With the approaching Soccer World Cup, traditional tender procedures were too time consuming. The 80 m in diameter and 10.5 m high reservoir was constructed as a turnkey project within a construction period of 12 months. This reservoir is shown in Figure 4.6 during its construction phase.

Figure 4.6: Parallel work in progress at the Polokwane reservoir (Concrete Trends 2010*e*)

The project team consulted a precast specialist and it resulted in the implementation of pre-fabricated columns, beams and hollow-core slabs. Geotechnical investigations unveiled varying in-situ ground conditions resulting in additional excavations and mass concrete backfill to provide a suitable base condition. The in-situ walls were constructed in sections (saw cuts were not acceptable) while the columns and beams were fabricated at the manufacturer and transported to the site. A mobile crane was used to install the columns, beams and hollow-core roof panels. A final in-situ concrete topping layer was cast to join all these members together.

Waterproofing and additional crushed stone were applied onto the roof that ensured an insulated structure. Design specifications instructed that due to the geotechnical difficulties the reservoir's floor panels could only be cast after the roof structure was installed. The construction of the roof with pre-fabricated elements while the walls

were installed meant that parallel work was taking place. The reservoir was completed, tested and handed over to the client within the allowable time and well within budget.

The Concrete Trends reported that the success of the project was due to the contractor being involved from the design stage and was able to make valuable input regarding practical execution methods of the project (Concrete Trends 2010*e*).

4.5 Façades

4.5.1 ABSA West Towers

The *ABSA* towers in Johannesburg consist of 3 different buildings. The contractor was required in 2009 to supply concrete brick-faced façade units of different shapes and sizes (varying between 300–3000 kg) for the towers.

The supplier is known for manufacturing non-standard and purpose-made elements and they insisted on using in-house moulds made of steel and timber to manufacture these façades. A total of 250 000 brick faggots were installed into silicone mats on the concrete elements that prevented mortar stains from forming on the surface. The biggest challenge of these units was to design the elements to accommodate for the brick size tolerances.

The Concrete Trends magazine reports that this initiative ensured exceptional product quality and decreased construction time (Concrete Trends 2009*a*). It is a good example of how the advantages of precast units are used in combination with in-situ construction on a project.

4.6 Conclusions

Although South Africa is characterised as a country that is not using pre-fabricated elements, the examples illustrate various projects where these elements are implemented. The main objective of this chapter is to provide evidence of the variety of elements used in HCC projects in South Africa. Table 4.1 provides information (that is not comprehensive) on some project which have been constructed over the past 7 years, including those that are mentioned in this chapter. There are many other examples of hybrid concrete projects in South Africa and a database is required to capture the information and serve as a reference for future projects.

From the examples it is obvious that the most commonly used elements are pre-fabricated slabs. These slabs are flexible and can also be used as walling elements. Where the slabs were used as walling elements, it was installed both on their heads and on their sides, making it an extremely versatile element.

The main reason (according to the projects that are captured in Table 4.1) project teams made use of pre-fabricated elements was the construction speed. In various cases the project teams opted for pre-fabrication during the construction process to help regain control of the construction schedule. Other reasons were due to the cost implication and quality of the products.

Table 4.1: Summary of some South African projects that made use of precast elements

Project	Year	Elements Used						Reason for using precast according to magazine articles
		Slab	Stair	Wall	Beam	Column	Façade	
Impala 20	2004	x		x				Construction speed
Volkswagen paint shop	2006	x			x			Construction speed
Orlando Stadium	2007				x			Quality
Lindley Reservoir	2008	x						Construction speed, skill shortage, cost, quality
The Houston Hotel	2008			x				Construction speed, flexibility
Gautrain walling	2009			x				Sound and vibration reduction
Oakfield shopping center	2009	x						Construction speed, light structure, time improvement
Orlando Station	2009	x			x			Construction speed, cost, excessive lengths (spans)
Polokwane Reservoir	2009	x			x	x		Construction speed
Port Elizabeth security wall	2009			x				Construction speed, durability
ABSA West Towers	2009						x	Construction speed, quality
Steenberg housing project	2010	x	x					Construction speed, quality,
Soccer city kiosk	2010	x						Construction speed, cost
Protea Hotel	2010	x						Construction speed
King Shake Int. Airport	2010	x						Construction speed transforms into cost savings
Cosmo City	2010	x			x			Construction speed, economy, labour savings
Honda Showroom	2011	x			x	x		Construction speed, restricted site, cost

During the past 7 years, advances were made with precast construction in South Africa. The largest precast retaining wall structure (Houghton) and first reservoir (Lindley) was built, illustrating that contractors and designers alike grow more confident in using pre-fabricated elements for construction. It clearly illustrates that the industry is experimenting with the elements although it remains limited.

By analysing the full precast structures (*Volkswagen* and *Honda*) it can be seen that during the first project (*Volkswagen*) several difficulties occurred, making the project an unpleasant experience for some of the project staff. During the *Honda* showroom project, contractors were more aware of precast concrete and were more

experienced working with it. For the *Volkswagen* paint shop contractors afterwards suggested the use of pre-fabricated columns and in the *Honda* showroom these elements were implemented with ease. Although these two projects were not related and different project teams were responsible for the projects, it does illustrate that the construction industry is moving forward regarding construction methods.

Design teams realise the potential of hybrid concrete construction and experiment with it. The reservoirs and shaft project clearly indicate innovative thinking from the design teams that provided success for the whole project team.

Although most examples provided in the chapter were obtained from non scientific magazines which favour concrete construction, it nevertheless serves to demonstrate the broad use of HCC in South Africa. By systematically making use of similar information and providing it as a database to the industry, project participants can be exposed to the broad variety of options available. Such a database should however be less biased and be structured to provide both advantages and disadvantages as experienced on projects.

After investigating the South African industry and some example projects, a total understanding is obtained of the construction industry and the utilisation of HCC. This next chapter investigates methods that were implemented in other countries that increased their utilisation of HCC.

Chapter 5

International hybrid concrete construction

Both of the previous two chapters provided evidence of the utilisation and involving factors that influence the use of hybrid concrete construction (HCC) in South Africa. By evaluating different criteria that influence the use of HCC throughout the world a clear scope of methods can be obtained to increase the utilisation of HCC in South Africa. The objective of this chapter is to illustrate different processes that were implemented from an international perspective to improve the utilisation of HCC while concentrating mainly on the United Kingdom's construction industry. The following criteria are discussed:

1. Circumstances that caused a movement towards HCC
2. Client's involvement and influence on the project.
3. Capabilities within the construction industry that assist the improvement of HCC utilisation.
4. Assistance that were provided to increase HCC utilisation.
5. Case studies of international projects that utilised HCC.

The information is obtained through personal interviews during a visit to the United Kingdom in 2011 (Appendix B), electronic correspondence, reports and journal articles. This chapter contains actions that were taken by different countries to assist movement towards off-site fabrication or HCC; it does not provide information the different the construction industry statuses.

It was estimated in 1996 that the most frequent users of pre-fabricated elements in the world were Denmark (43%), the Netherlands (40%), Sweden and Germany (31%). These values relate to the percentages of total building projects within the country (Chen et al. 2009). Although the United Kingdom was not within the list of top users, they have performed extensive research in the field of HCC and implemented several methods to improve their utilisation of the technology, making it a suitable country to investigate.

5.1 Construction industry movement

Over the last two decades, advances were made towards precast research and building techniques. The *"Latham Report"*, mentioned in Section 2.1 focussed on improving the United Kingdom's construction industry by reporting on several areas that were problematic within the industry. One method to improve the industry

was to promote off-site fabrication to be used as frequently as possible. The industry's perspective on precast construction subsequently evolved since stricter regulations, precautionary methods and "best practice" concepts were introduced (Goodchild 2011).

Since Latham's breakthrough report, various similar reports and procedures were developed to improve the pre-fabrication industry. A culture of "thinking precast" was established from the whole project team during project development to eliminate late design changes to a precast system. This culture has developed over years and did not suddenly develop. Because the term "precast" can relate to a wide variety of products, the term "off-site concrete" is the more frequent term used within the United Kingdom. It is admitted that a culture of "thinking off-site" has developed in the country. This was aided by many articles, research programmes, assistance tools for the project team and successful exemplary projects (Gibb 2011).

Due to off-site precast construction or HCC that was investigated by researchers, project teams realised the potential of this building method. It resulted in HCC to be used for 4 main reasons. These reasons are provided in descending order of importance (Soetanto et al. 2004*a*):

1. HCC allows completing a project within the required programme time.
2. HCC provides improved quality.
3. HCC allows projects to be completed within budget.
4. HCC increases client satisfaction.

Although Soetanto (2004*a*) rated client satisfaction as fourth, Egan (1998) regards client satisfaction as the main objective during all building projects. In order for the project team to satisfy the client, constant communication is essential between these parties. Egan mentioned that the client remains responsible to influence and drive the project team to ensure client satisfaction.

5.2 Client's involvement and driver

Latham (1994) and Egan (1998) mentioned that the client is the most influential role player within the project team. The client can affect not only the project specification, but also the procurement procedures.

5.2.1 Procurement documentation

In the United Kingdom, Latham (1994) identified that the contract documents that were in circulation, encouraged fragmented construction in which the design and construction were viewed as separate entities and where contractors had no design responsibility. Latham continued to illustrate several properties of a modern project and encouraged "best practice" that was reflective of such a project. Regarding contract documentation, the suggestion was for the United Kingdom to make use of the *New Engineering Contract* (NEC) document, although he recognised that the document needed to be updated. The decision was based upon the criteria that he found to provide "best practice" and a "win-win" situation for the project team. Making use of the NEC encourages design responsibilities and involvement by the contractors from an early stage. Additionally, he advised public clients to make use of the NEC on $^1/_3$ of all new projects and encouraged private clients to set similar

targets. Through legislation he wished to instigate the change in documentation.

Since Latham's report in 1994, the NEC document was amended and updated to suite the modern construction industry. According to Bailey (2011), the amended NEC document (NEC3) is currently predominantly used in the United Kingdom and it is the document of choice of quantity surveyors. It is iterated by Fullulove (2009) who stated that the full NEC3 suite was used for several different projects in preparations for the *United Kingdom Olympic Games 2012*. The *Construction Contract option C* was used for the Stratford stadium, while the *Professional Services Contract* was used to retain a joint venture delivery partner. Fullulove mentioned that this document suite was chosen because of its flexibility and its emphasis on trust and collaboration. The contract provides for proactive project management, project discipline, early warning procedures and fair risk allocation.

The procurement documentation can have an essential effect on the procurement method. Once it was amended, the NEC was flexible to be adopted to suit most procurement methods.

5.2.2 Procurement strategies and procedures

A major concern regarding procurement strategies was the tendering process that was time consuming and resulted in projects to be delivered at the lowest cost and not the best value (Latham 1994, Goodchild & Glass 2004). Latham (1994) suggested that the industry should move towards procurement methods that relied less on lowest cost and more on early involvement and partnering from the specialist contractors.

For this reason, the United Kingdom makes use of tendering processes on only $^1/_3$ of their projects. The remaining projects are procured according to design-and-build (large uncomplicated projects that require mass production) and contract management procedures (more complex projects). These procedures were recognised as the most suitable to encourage partnering and early involvement by the whole project team (Goodchild 2011, Bailey 2011).

The construction industry was encouraged to experiment with different procurement procedures resulting in a constant growth. Subsequently the capabilities of the project team have grown drastically to work with different methods and materials including pre-fabricated elements.

5.3 Capabilities within the construction industry

The capabilities of the construction industry rely on the potential of the design and construction teams (systems that can be designed and constructed) and the capability of the manufacturers. For this reason, this section is subdivided into two sections: the manufacturers' capabilities and design and construction capabilities. The capabilities of the manufacturers will firstly be investigated.

5.3.1 Manufacturers

The main function of precast manufacturers is to provide quality elements according to the specifications and expectations of the employer and design team. Manufacturers have adopted additional responsibilities to ensure client statisfaction.

Elements

When manufacturers are analysed according to the elements that they are able to manufacture, it appears that there is no shortage of skills and resources. Manufactures mainly make use of machinery to manufacture a wide range of products, while labourers are used to prepare moulds for non-standard elements such as curved sections (Bensalem 2011).

Table 5.1 illustrates the different elements that can be manufactured by some of the manufacturers in the United Kingdom. The function of this table is to illustrate the variety of structural elements that can be manufactured by the United Kingdom suppliers. Because moulds can easily be manufactured with timber (once-off element or short term use) or steel (long term use), manufacturers are able to create virtually any element expected by the design team. For larger projects, manufacturers invest in more permanent dies that can withstand constant use by the machines. Additional services such as sound insolation, electrical ducts, cut-outs and openings are installed in the factory ensuring less waste on sites (Bensalem 2011). Figure 5.1 shows shuttering that are used at *Bison Manufacturers* to manufacture wall elements and curved walls with pre-installed electrical services and ducting.

Table 5.1: Product range of United Kingdoms's pre-fabricated concrete manufacturers according to their websites

Company	Website	Slabs	Beams	Columns	Stairs	Culverts	Modular units	Other
Acheson & Glover Precast	www.achenson-glover.com	x	x	x	x	x		x
Barcon Precast	www.barconprecast.co.uk	x	x		x	x		
Bison	www.bison.co.uk	x	x	x	x		x	x
Buchan Concrete Solutions	www.buchanconcrete.com	x			x		x	x
Carter Concrete	www.carter-concrete.co.uk	x	x		x			x
Coltman Precast Concrete	www.coltman.co.uk	x	x		x			x
Ebor Concretes	www.eborconcrete.co.uk	x	x	x	x			x
Hanson Building Products	www.helderbergcement.com/hanson	x	x	x	x	x		x
Milbank	www.milbank.co.uk	x	x		x			x
Milbury Systems	www.milbury.com	x					x	x
Tarmac Building Products	www.tarmac.co.uk	x	x	x	x	x		x

Note: Items classed under "other" are products that are used for structural designs - typically *rib-and-block* systems or specially moulded structural members (including façades). Although many companies manufacture architectural columns or similar products, only companies that produce structural products are listed above.

In some instances, construction companies invested in manufacturing facilities. Contractors provided manufacturers with security to invest in additional resources by assuring use of precast element in their projects. These contractors regard themselves as drivers of the precast construction industry and insist on precast systems on building projects (Bensalem 2011).

Although there are almost no limitations to the elements that can be manufactured in factories, designs remain


Figure 5.1: *Bison Manufacturers* in Swadlincote, United Kingdom: left - Large shutters used for wall elements, right - curved wall with electrical services and fittings

traditional in the United Kingdom because of the predominant use of slabs, stairs and rib-and-block systems. In some situations beams are also used, although standard element sizes for beams or standard designs are non-existing (Bensalem 2011, Bailey 2011).

Compared to countries that have more experience with precast such as Denmark and Netherlands that build total precast structures (precast column, beam and slab), the United Kingdom is fairly traditional. The United Kingdom's concrete research institute (*The Concrete Society*) realises that the elements used within the country compared to other European countries remain limited and they intend on improving precast utilisation within the country (Goodchild 2011).

Manufacturers realise that in order to establish good relationships with their project teams they are required to assist designers with designs and to assist contractors during the installation procedures.

Supply and delivery

Manufacturers are known to be the specialist contractor in the project team. Because of the experience that manufacturers obtained over years of working in the industry, they insist on designing for the use of their own products. Although additional insurance regarding the product is provided to the design team by allowing the suppliers to design the elements, the design team remains responsible for the final approval of the design (Bensalem 2011, Bailey 2011).

In the United Kingdom the turn-over time of a precast solution was improved to increase the attractiveness of this building method. A larger manufacturer claims to be able to finish the design, approve it, manufacture the elements and install it within 3 weeks during the low season and 8 weeks during the high season after the specialist contractor is appointment. This lead-in time is sometimes overlooked by clients and must be recognised to overcome unnecessary friction within the project team (Bensalem 2011).

As a method to increase productivity, manufacturers provide products according to the "just-in-time" philosophy (Bensalem 2011). The philosophy is structured around the concept of providing the right products, according to accurate quantities and approved quality to site just before it is required for installation. Because precast elements

are usually bulky elements, large cranes are required to install it. It is therefore justifiable to consider just-in-time delivery to reduce double handling of the elements and less crane hoisting operations (Pheng & Chuan 2001).

The just-in-time production and delivery systems results in no additional requirement for storage area at the manufacturer's plant. It also allows for the manufacturer to ensure product sales when it is produced. Different techniques are used by different manufacturers to ensure that products are delivered to site as soon as possible (Bensalem 2011).

As an additional service, manufacturers install their own elements once it is delivered on-site. Because the manufacturers have trained their installation teams, it reduces the health and safety implication that occur when large precast elements are installed by unskilled labour. Contractors that insist on installing their own elements can arrange to construct accordingly. Contractors that are unfamiliar with precast construction are assisted during the erection processes especially when new elements or frames are used for construction (Bensalem 2011).

5.3.2 Frame development

Because HCC is still a relatively new technology, it remains an experimental construction method in the United Kingdom. A survey was carried out by Soetanto (2004*a*) to establish the different criteria that were regarded as important during frame design decision making processes. A questionnaire was presented to 275 project team members of which 52 usable replies returned. From the results almost 83% were aware of HCC technology while only 9.6% have frequently used it in their projects.

It is thus no surprise that the United Kingdom makes frequent use of traditional frames that only consist of precast slabs and in rare occasions, beams. In addition, they do make use of hybrid structures where slabs are used in combination with steel frame buildings (Bailey 2011, Elhag et al. 2011). Although Goodchild (2011) published a book that discusses 5 different HCC frames (Section 2.2), these frames are more frequently used in Denmark and the Netherlands.

Currently the knowledge within the United Kingdom database regarding precast frames is too small to encourage experimentation by innovative companies. The recession that occurred during the late 2000's, caused for clients to reside to procurement methods that provide the lowest cost for the building. Because HCC techniques frequently display higher construction costs, it is not regarded as a suitable replacement to traditional construction methods. For this reason, the *British Precast* and tertiary institutes developed packages and software to compare the cost of HCC holistically to traditional methods (see Section 5.4) (Gibb & Goodier 2011).

Regardless of this barrier in the United Kingdom industry, they do make frequent use of HCC in office buildings and multi-storey car parks. Other types of projects display limited HCC use (Soetanto et al. 2007). Drivers and believers of HCC or precast construction invest in the technology and insist on building with precast on several different types of projects with positive results (Goodchild 2011).

5.4 Assistance to increase hybrid concrete utilisation

Because HCC is a combination of precast and in-situ concrete construction it broadens the potential of the building method and frame selection. However, certain combinations appeared to be preferred, chosen on the grounds of the building design (spans, layout), technical requirements (thermal mass, fire protection) or performance expectations (cost, speed of construction) (Glass 2005).

Although the above mentioned criteria or combinations are preferred when frames are selected, additional resources and assistant tools were created to assist in this process. Training programmes are developed to equip the project team to deliver the best value project to the client.

These tools are not only software packages, but additional research and guidance is provided by research institutions.

5.4.1 Decision making criteria and research

While the advantages of HCC were promoted throughout the United Kingdom's construction industry, quantifying these advantages remained a difficult procedure. Simulation projects established that traditional in-situ construction usually provided a more cost effective solution. In defence the *British Precast* organisation recommend a holistic evaluation of the cost comparison and argued that if such an analysis is conducted, a precast solution will always be the cheaper option especially when projects are constructed that make frequent use of repetitive elements (Elhag et al. 2011).

The argument was based on the fact that simulations only compare products, such as a precast and an in-situ beam. In the process it neglects waste generation, labour costs, remedial work, finishing of the product and the number of repetitions within the structure. This is also where the "strength" of precast concrete lies (Elhag et al. 2011). Additionally, precast elements can be altered to integrate the services that are required for the projects, making it an extremely flexible building product (Bensalem 2011).

The above mentioned example is a typical scenario when HCC is considered for a project. Although it concentrates on cost of the two building methods, other considerations need to be considered such as safety on sites compared to safety in factories. Even though the precast elements are large and difficult to manage, factory manufacturing is always considered safer than in-situ site construction because of additional regulations that are applicable to factories (Gibb & Goodier 2011).

For these reasons, research institutions were actively involved in improving the United Kingdom's construction industry. Some universities participated in report writing, case studies, funding initiatives and tool development since 1993, a year before Latham released his report (Gibb 2011).

Decision making tools were developed by the research institutes to assist the design team during the decision making process. In 1999, the *COMPREST* tool was developed that evaluated the cost and value of a project. In 2000, the *IMMPREST* tool was developed that was more extensive than the previous tool. The *IMMPREST* tool was developed into an interactive software programme in 2003 and into a web-based tool (*IMMPREST-LA*)

in 2009. These tools compare the advantages of precast construction and the different project specification and evaluates whether HCC would be a more appropriate building method to traditional construction. The project team remains responsible to make the final decision whether HCC is to be used. Other tools such as the health and safety tool (*HASPREST*) was also developed to compare the effects that different construction methods and materials have on the health and safety of a project (Gibb 2011).

HyCon is a specific decision making tool that allows the project team to investigate alternative construction solutions. This decision making tool provides the best construction method based on a range of different criteria including initial and life-cycle costs, time, appearance, aesthetics etc. One of the main objectives of the *HyCon* programme is to improve the current understanding of performance prediction and evaluation by designers, making it possible for designers to dynamically predict the outcome of a project based on the material used for construction (Goulding et al. 2007)

While the tools mentioned above assist the decision making process, it does not assist the design team to design for HCC. For this reason, alternative methods of assistance are required. These alternative design assistance tools are discussed below.

5.4.2 Design assistance

When HCC is considered, designers need to be aware of additional considerations that must be analysed and inspected when compared to in-situ construction. Design assistance is provided to the designers in the United Kingdom by means of design courses. These courses focus on the different design criteria and considerations that especially relate to connections. Educational courses are presented at universities to assist and increase awareness of the young designers before they enter the construction industry. Similar courses are provided to engineers that has just entered the industry. These courses cover a range of relevant information including the (Elliott & Hasan 2011):

- history of precast concrete.
- manufacturing of precast elements.
- precast concrete design concepts including stability, connections and progressive collapse.
- precast construction with different building materials that includes steel.

Additionally, design manuals and example project designs are provided by manufacturers to assist with the designs. These design manuals provide additional information that can be used during the design (Bensalem 2011).

Software design tools are promoted to encourage designers to experiment with different technologies including HCC systems within a cyber-safe environment (Goulding et al. 2007). Unfortunately, to date, no software package is available to assist with the design of pre-fabricated elements especially the connections. While software companies started developing such software, it is not available for industry use. As a result, designers are hesitant to design for these elements and connections without sufficient computerised tools to evaluate the design (Elliott & Hasan 2011).

Additional assistance is provided through training centres to the construction industry. The training is either programmes or courses, similar to any other training operation.

5.4.3 Training

Different methods of training are utilised within the United Kingdom. These methods consist of traditional training methods such as teacher-class methods, peer training and simulation training (Elhag et al. 2011).

Many companies were established to provide courses reflecting typical teacher-class ("chalk-and-talk") methods. The "chalk-and-talk" method is a presentation where the trainee discusses the notes that are provided to the trainees. This is also referred to as one-dimensional training. The contents of these training courses range from design and construction assistance to skills development. Training courses relating to skills development in line with ISO standards, quality standards, environmental regulations, construction design, management, installation and crane operation are some of the training courses presented to improve the industry. While these courses remain a favourite to many attendees, different measures of training are preferred by others (Elhag et al. 2011, Campbell 2011).

Because the construction industry functions as an unit, *The British Precast* created the *Charge* initiative in the United Kingdom. The initiative was aimed to improve the health and safety of representative companies on their projects by creating an environment of peer learning. Companies were encouraged to share their successes and failures with other competitive companies during scheduled monthly meetings. Through this initiative, the representative companies can improve their procedures to create a safer working environment. Although other relevant aspects are discussed in these meetings, the main concern remains health and safety, especially within the precast industry (Elhag et al. 2011).

Another method of training is through realistic simulations. Simulation training has been used in Europe during the last decade and provides trainees the opportunity to have a 4-D training experience. It is not a scheduled training course; instead it is a unique professional course that is formulated for each participating company according to their training needs. The training company must be informed of the specific training requirements to create a programme or realistic setup of the situation. The training commence with a briefing during which the "construction" scenario is explained to the trainees. This is followed by taking the trainees to a mock-up site with site offices and a simulation projector that projects the "site" onto a wide screen. The simulated projects are actual site(old projects) that are programmed into the system and can be controlled by a joystick, making it an extremely realistic scenario. Individually, the trainees are confronted by trained "actors" that play different roles as would be expected on an actual site and the attendees behaviours are investigated by the training institute from a control centre. After the simulation (usually a 1 week course), the trainees receive feedback from the "actors" and training staff. Although this method of training is expensive, it is regarded as the most realistic method of training with the most impact on the trainees (Campbell 2011).

Because the scenario can be adjusted according to the individual requirements, it is applicable to everyone, including quantity surveyors, engineers and contractors. Universities started implementing simulation training during post-graduate studies of civil engineering students (Campbell 2011). Figure 5.2 illustrates the simulation screen, mock-up offices and control room at the *ACT-UK Simulation Centre*.

Figure 5.2: *ACT-UK Simulation Centre* in Coventry, United Kingdom: Large screen simulating a site (left), mock-up site office (right), control room to evaluate different participants (bottom)

The Bristish Precast is involved with additional training and informing the public of the benefits of precast construction. Targets that are set by the government regarding the construction industry are brought forth by them.

5.4.4 Government's involvement

Through legislation the government expects the construction industry to perform according to their expectations. Such regulations are for instance the sound insulation or thermal protection regulations. *The British Precast* is an organisation that serves as a conduit between the government and the construction industry. *The British Precast* makes use of training courses, research programmes or "best practice" guidelines to achieve the targets that the government expect. The national CO_2 emission targets is a typical example of a target that was set by the construction industry on projects. Furthermore, frame or element preference allows for the *The British Precast* to comfortably measure and control the industry's performance (Elhag et al. 2011).

5.5 Example projects

Studies have indicated that the selection of the structural concept of projects tend to focus on cost and time requirements (Soetanto et al. 2004*b*). The objective of this section is to provide 2 case studies of projects that made use of HCC because of other benefits. Additionally, a list of some of the HCC projects that were constructed are added to illustrate how HCC can be utilised in a variety of projects. The two case studies are a historic art gallery and an office building with a car park (Soetanto et al. 2004*b*).

5.5.1 Art gallery

This project in the United Kingdom consist of 3 separate projects that needed to be integrated into one - the refurbishment of a historic gallery, a listed building and a new building project adjacent to another listed building. The 4-year project was subjected to a £25 million budget and the public client procured the project as a construction management project. This project was an award winning HCC project under the 'luxury' market segment.

The architect responsible for the design was renowned for his artistry and has a reputation for designing concrete buildings using precast components. The building owner (management of the art gallery) was interrogated with project queries to establish what the requirements of the building were. It was established that the following two criteria were most important with regards to the building material:

1. The long term effect of the construction material on the paintings (conservation of the art).
2. The functionality and aesthetics that the building material has on the final project.

The material was required to be performance based (certain level of reflectivity, colour, consistency with extremely strict tolerances). The architect opted for a pre-fabricated structural frame after close collaboration with the engineer, although neither the engineer nor the client had any influence on this structural frame selection. The frame was designed as a precast concrete frame although small parts consisted of structural steel.

The precast manufacturer was required to develop a bespoke concrete mix and to resolve connection design complications between the elements. Additional advice on buildability and manufacturing (size, joints, connections) were provided by the contract manager. Various shapes and sizes for the different elements were designed, causing the project not to make full use of the advantage of repeatability of precast concrete.

For this project it was decided to make use of precast concrete for 4 reasons:

1. **Internal functionality and aesthetics**
   Thermal mass properties of concrete established a controlled environmental which was required for the preservation of artwork. Finishing of the concrete created a calming aesthetic interior to emphasise the artwork. The special mix design created a certain degree of reflectivity of light without the need for additional reflective finishing. Flexibility of moulds allowed for different shapes and sizes of the precast elements to accommodate additional services such as speakers and lightning.

2. **Execution**
   Because of tight tolerances (±3 mm) on the element sizes, it was faster to make use of pre-fabricated elements that are factory made than to make use of in-situ construction. To obtain these tight tolerances during in-situ construction is an immense task that requires special attention. Although the project was located in the city centre, the pre-fabricated elements were delivered to site without defects.

3. **External aesthetics**
   Two listed buildings surrounding the new building were both built with sandstone materials. It was required for the new building to blend into its surroundings and therefore the precast elements were made from stone or a cementitious type of material.

4. **Weathering and maintenance**
   Concrete was characterised as the building material requiring the least maintenance and displayed the best ability to withstand weathering. Because the building was designed for a 60-year life-period, it required a material that will achieve a longer design life.

Several problems were encountered throughout the project. Due to uncertainties with the refurbishment section, construction management procurement was considered not to be the appropriate procedure. It caused interface problems with some of the contractors and suppliers because of contract scope changes. The distance between the design team and the contract manager made communication difficult. The concrete mix design, quality of concrete and connection details between the pre-fabricated elements were challenging. Other encountered problems are not of relevance to this section.

Members of the project team expressed satisfaction towards the project, and it resulted in several lessons learnt. The experience obtained from this project can be used in future projects. Some of the experience are the architects that devised methods of improving the precast design and the engineer that designed connections and joints. Furthermore, the precast manufacturer invented new pre-fabricated systems (Soetanto et al. 2004*b*).

5.5.2 Office building and car park

This project in the United Kingdom comprised of an office building and car park. The total building area was 48 000 m^2 and needed to be completed within 76 weeks with a budget of £57.42 million. The project was procured as a private-finance-initiative (PFI). The project was already 6 months in its construction period when the study was completed.

A consortium was selected to run with the project after 3 stages of evaluations by the client's project team and advisors. The consortiums were requested to complete a pre-qualification questionnaire. The second stage was to submit a list of potential suppliers who were asked to provide outline proposals for the project. These proposals were quantified according to costs by the different consortia. A final consortium was awarded the project and was requested to develop a full proposal.

The consortium defined the project specifications and established the procurement route as a contractor's design-and-build project. The contractor appointed an architect, engineer and suppliers. The suppliers provided by the contractor had worked on previous projects with them and together they provided a supply chain partnership

that ensured improved project delivery.

The end-user steered the choice of the structure frame material. By considering the benefits of concrete, the consortium agreed to use a hybrid concrete frame. Compared to steel construction, a hybrid structure would not have provided additional savings in time and cost on this project. Because this was a PFI and design-and-build project, the architect and engineer had less influence on the design than with traditional tender procurement methods.

It was decided to make use of HCC for 3 reasons:

1. **Robust and fire protection**
   The end-user requested a concrete building that would be able to withstand bomb blasts and terrorist attack. Concrete provided more robustness and fire protection than steel.
2. **Aesthetics**
   The final concrete finish provided value to the external aesthetics of the building
3. **Thermal mass**
   Due to government requirements, this building had to be naturally ventilated to reduce operational running costs of the public building. Thermal mass characteristics of concrete aided this cause.

Several practical considerations were associated with this hybrid frame. Steel moulds were used instead of timber moulds for the precast coffers because of the additional durability, and no in-situ topping was required on the precast slabs. In-situ beams were used to enhance the buildability and speed of construction. Much effort went into the design of the precast coffers to optimise handling with the tower crane (Soetanto et al. 2004*b*).

5.5.3 Other

Projects constructed with HCC technology displayed in a variety of projects throughout the world are summarised below (Soetanto et al. 2007):

- **Offices**
  Australia Square (Australia), Citycorp Centre (Brazil), The Messetürn (Germany), VNO building (Netherland)
- **Industrial**
  Munich Mint (Germany), Clinker silo (Italy), Factory (Honduras)
- **Retail**
  Whitefriars Shopping Centre (England)
- **Community buildings**
  Justice Centre (United States of America), Islamic Cultural Centre (Italy), London Planetarium (England), Sultan Qaboos University (Oman)
- **Medical**
  Bangor District General Hospital (Ireland)

- **Private housing**
  Accommodation block for University of Aston (England), St George Wharf (England)
- **Leisure**
  Jupiters Hotel (Australia), Bari Stadium (Italy), Melbourne Cricket Ground (Australia), Rugby Football Stadium (Scotland)

This information is superficial and further research is required by means of a database to establish reference projects for future building projects. The list does indicate that hybrid concrete construction is not a method that can only be used for a specific type of structure, instead it is versatile and an effective building method for many types of buildings.

5.6 Conclusions

The purpose of this chapter is not to illustrate the shortcomings or advances in other countries, instead the objective is to provide relevant information regarding methods that are initiated in countries that realise the benefits of HCC as a structural frame solution. Although other countries are mentioned in this chapter, the focus is mainly on the United Kingdom's construction industry.

Clients are depicted as the drivers of the industry and are urged to drive the procurement documentation towards the NEC contract and procurement methods towards partnering methods. This may be affective within a South African context if the NEC can become more popular. The design-and-build and contract management methods are regarded as the most suitable to encourage partnering and early involvement. Although these methods are not used often in South Africa, it may be suitable for future projects.

While manufacturers are able to construct many different structural elements, additional services that are completed by the manufacturers such as precast design remain essential to improve the attractiveness of the precast solution to the project team. Nevertheless, designers remain traditional and make use of slabs, rib-and-block and staircases frequently neglecting other structural elements. Standard element sizes may need to be investigated to improve the utilisation of beams or columns. Other European countries make use of several elements to construct complete HCC buildings. Services of manufacturers rely on just-in-time production and delivery that ensures minimal turn-over times and no requirement for additional storage space.

Decision making tools, training and research assist the project team of HCC projects. Software tools were developed to holistically compare traditional and precast solutions. Although these tools remain in a developing phase, it assists during the decision making process. These tools allow the project teams to experiment with different construction methods in a "safe" virtual environment.

Training is provided by means of traditional teacher-class methods, peer training and simulation training. Peer training is provided for companies to exchange their successes and failures regarding HCC to improve learning and competitiveness. Advanced simulation training make use of project simulations and "actors", resulting in the most

realistic training experience.

The government make use of organisations within the country to act as a conduit between the government and the industry. These organisations are responsible to achieve the expectations and goals set by the government by means of training, element preference or "best practice" guidelines.

Two case studies are used to illustrate the use of precast construction within a project for reasons other that cost and time. The case studies illustrate that projects can utilise HCC for more reasons than cost, quality and construction time.

The information from this chapter is essential to obtain examples of solutions for the barriers that a country may experience. The barriers that prohibit the use of HCC in South Africa can be analysed and the procedures mentioned in this chapter can be of assistance when solutions for these barriers are investigated. The next chapter will analyse the barriers of HCC in South Africa.

Chapter 6

Barriers to hybrid concrete construction

Innovative methods that result in breakthrough technology contributes both to private wealth and it provides the industry with social benefits. Hybrid concrete construction (HCC) is still recognised by many as a new innovation within the construction industry. Although the industry benefits from such inventions, it also allows the innovative companies to attain a competitive advantage over competitors (Ahuja & Lambert 2001).

In the previous chapters the current state of the South African industry is explained and different measures are investigated that are implemented in other countries to increase the utilisation of HCC. This chapter concentrates on reasons preventing HCC from being used more dominantly within the South African industry, even though the benefits will affect all the involved parties.

This chapter is subdivided into sections that concentrate on a range of issues that act as barriers to the adoption of HCC. The objectives of this chapter are to:

1. Identify the barriers to HCC within the South African construction industry.
2. Identify innovation barriers that affect the utilisation of HCC.

The required information is obtained from personal interviews, e-mail correspondence and journal articles. HCC is recognised as a new innovation and many barriers are said to be "innovation barriers", but it can be translated to HCC barriers as well.

6.1 Identification of barriers

The construction industry has long been characterised as an industry that is suffering from a deficiency in innovation and being slow to adopt new ideas and technology. These factors are regarded by some as the source of its inadequate performance. The challenge is to diffuse this innovative technology by promoting HCC's benefits and to communicate and discuss the associated risks in relation to its adoption (Soetanto et al. 2004*b*).

While other industries thrive on innovative activities, the construction industry is portrayed as being resistant to change. Construction firms are challenged to be more innovative to improve client satisfaction while still being

competitive with opposition companies (Sexton & Barrett 2003).

Several barriers are recognised here that prevent more frequent use of HCC. These barriers are subdivided into 9 sections and are discussed in this chapter:

1. Design
2. Procurement
3. Production
4. Industry traps
5. Training
6. Regulations
7. Supplier distribution
8. Fragmentation
9. Market conditions

6.2 Design barriers

Although the structural frame design is only a small proportion of the total construction cost of a building, it influences the interfaces between several elements that make up part of the building. In the process it influences the buildability and specifications and ultimately the cost of the total project (Soetanto et al. 2004*a*).

The barriers that are recognised as design barriers are subdivided into 4 subsections. These subsections will first introduce different design criteria that the designer must adhere to. Secondly, the importance of early involvement by the whole project team to provide the best value project for the client is discussed. Thirdly, additional design assistance is essential to provide value to the design. Finally, the external effect of late changes are discussed.

6.2.1 Design criteria

During a survey by Soetanto (2004*a*), the 31 most important design criteria of the structural frame development were established and discussed. The top 5 criteria presented here are provided in descending order of importance (rated by the whole project team):

1. **Integration of layout, structure and engineering systems**
   Well-integrated systems will positively influence the quality and quantity of the construction.
2. **Design for safety**
   Designers are responsible for safety as part of their design.
3. **Client satisfaction and best value**
   It is proposed to make use of value management techniques to evaluate alternative building techniques to exceed the expectations of the clients.
4. **Well-designed and buildable connections**
   Contractors must be able to construct according to the provided designs.
5. **Minimising costs of the project**
   It is important for both the client and the project team.

A "best practice" model was established based on these design criteria. Building according to good practice, HCC can improve the integration of the layout of the structure, providing an integrated design approach. Other designers such as electrical, mechanical or HVAC designers that take part in the design from an early stage of the project, increases the integration process and services.

Safety of the design not only ensures that elements are of good quality, but it also ensures the workability and buildability of the elements. Making use of HCC concepts, input can be obtained from contractors and suppliers regarding the different sizes and shapes of precast elements to ensure that the elements are regarded as "safe". Because the precast elements are handled inside a well controlled environment, the supplier can provide recommendations to make the elements easier to manage before it is delivered to site.

Best value engineering can be improved by incorporating HCC in the design due to the high quality finishes that can be achieved on the products for both aesthetical and functional purposes. Advanced planning, careful detailing and improved communications between parties can increase the potential of HCC for buildings. Although no guarantee can be provided that HCC can produce a more cost effective solution regarding building material, many of the projects mentioned in Chapter 4 illustrate cost savings due to the use of precast elements within the structure. It is mentioned that the lack of a holistic comparison method to compare the cost of HCC with traditional in-situ construction, allows many to regard HCC as a more expensive construction method (Soetanto et al. 2004*a*).

As mentioned before, early involvement from the whole project team is crucial to provide the client with the best value solution. Latham (1994) regarded early involvement by the whole project team as the most substantial part of HCC design. This is discussed in the following section.

6.2.2 Early involvement

The importance of early involvement is noted throughout several literature documents. Latham (1994) emphasised partnering as a possibility to ensure early involvement and as a method of improving coherent construction. Partnering between the client and contractor is important to obtain a project that results in a "win-win" situation for the whole project team. Additionally, it is required throughout the project team to build relationships and trust between parties to improve the effectiveness of the team.

Egan (1998) recommended partnering as one of the four key elements towards improving the United Kingdom's construction industry. Although procurement methods that rely on partnering is deemed to be more difficult to procure than a traditional method, the benefits obtained from it is much greater. Not only does it provide a more effective project team, it also builds long-term relationships. Early involvement by the contractors is regarded as essential; more so for HCC frames compared to traditional in-situ frames because HCC is considered to be more complex. Early involvement would additionally reduce costs through rationalisation of details and improved buildability (Glass & Baiche 2001).

In order to create an effective HCC project, early involvement from especially the specialist contractors is a necessity. These specialists must be used to obtain design assistance from the conceptual design phase and that will result in an increase commitment from the specialists to the project (Goodchild & Glass 2004). Through early involvement, a learning environment is established that results in the concept of *whole-system* thinking

when different project team members exchange information. This is especially valuable when unfamiliar building techniques are discussed that create a growth of knowledge (Forgues & Koskela 2008).

Early involvement translates into a project team that thinks coherently. Because the project team is involved from the early stages of the project, time is not wasted during separate clustered meetings to dissolve problems. The wasting of time reduces the effectiveness of a project team (Forgues & Koskela 2008). This includes a waste in time for designs. Designers are frequently required to design from first principals that is regarded as time consuming and it translates to unnecessary waste.

6.2.3 Design assistance

A shortage of locally available precast construction design manuals result in an industry that is not familiar with precast design specification. Therefore, designers are required to design from first principles. This does not only require additional design input, but translates in longer lead-in times to complete the designs. Additionally, in the United Kingdom it was recognised that a high level of inexperience and a lack of exposure with designs is a main cause for the narrow diffusion of HCC within the country (Soetanto et al. 2004*a*, Goulding et al. 2007).

Computer packages and tools that can assist with the designs remain to be developed. While programmes that can assist in the decision making process between HCC or in-situ construction are unavailable such as *HyCon* or *Immprest LA*, an actual design package (similar to the finite element programmes such as *Strand 7* or *ABACUS* packages) is not available to assist with the complex design connections between elements (Elliott & Hasan 2011).

Besides the above mentioned design problems, the designer's ability to design is also challenged. Designers are unable to think "out-of-the-box" and remain traditional in their designs. For this reason, designers are characterised as being unable to adopt new technology (Goulding et al. 2007).

Criteria for designs and the lack of design assistance are regarded as a barrier towards the implementation of HCC within the industry. Unfortunately, late changes to the project specifications cause for an additional design barrier and will now be discussed.

6.2.4 Late changes

Because complex designs can hamper contractors to construct effectively, the contractor's input on the design from an early stage can assist in the construction methods. Some of the projects mentioned in Chapter 4 were originally constructed according to traditional methods, but due to constraints that developed during the project the construction method was altered towards HCC techniques. In addition to time savings that were gained on many projects, there were also additional costs involved.

Figure 6.1 indicates the influence of change on project specifications in terms of the cost and the potential to achieve the expectations (Perrine 2007). From the curve, the cost of change increases as the project progresses through the phases. Similarly, it becomes more difficult to accommodate change or to accomplish the expected change as the project progresses. By applying changes early in a project, the costs will be low and the possibility

of accommodating such changes will be plausible.

Late changes are a constant factor that contractors must adhere to because HCC is known to be less flexible than traditional in-situ construction for changes to the design. The effect of early involvement of the contractor is critical to ensure early commitment to the project specifications and minimising the late design alterations (Glass & Baiche 2001). The construction industry has developed the lazy habit of making late changes on site instead of in the design office (Gibb & Goodier 2011). De Villiers (2010) stated that it is easier to make use of precast systems with bridge designs than for building construction because changes are more frequent in building construction.

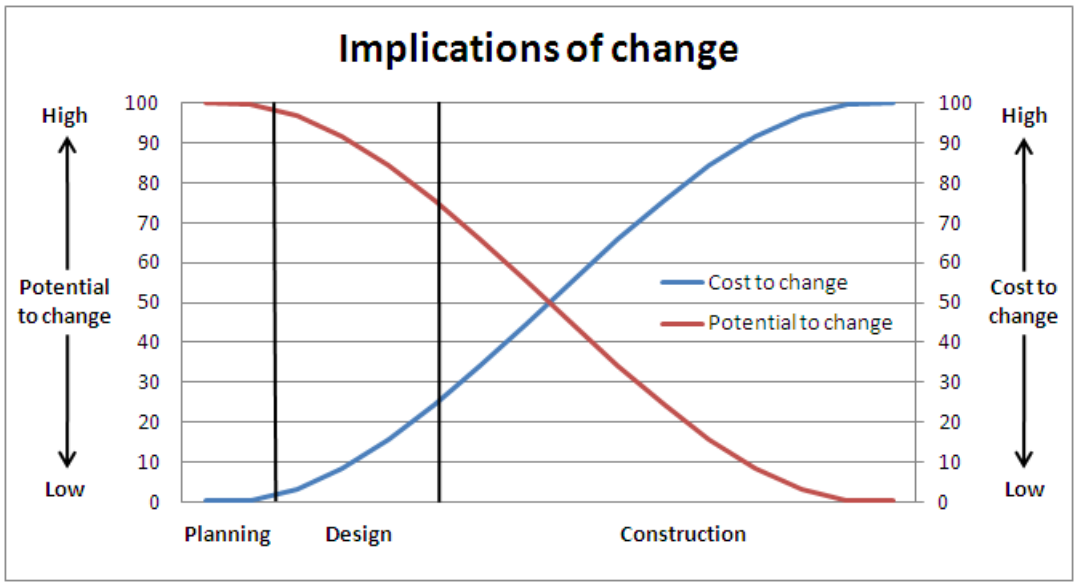

Figure 6.1: The effect on the cost and influence of change over the duration of a project (adjusted from Perrine 2007)

6.3 Procurement barriers

Traditional methods of structural frame selection are based only on cost and time criteria and it is not sufficient on its own (Soetanto et al. 2004*a*). The method of procurement does not only affect the tendering method, but also the performance of the project team. A case study between an integrated project team (relationship between the client and the supply chain) and a fragmented project team (design and delivery though an iterative process) was conducted by Forgues and Koskela (2008) to investigate the effect of procurement on the design of a project.

The integrated project team was established according to the prescriptions provided by Latham (1994) and Egan (1998). This team was focussed on partnering, encouraging collaboration, increasing innovation and building relationships between the client and the supply chain. The fragmented team was a more typical project team that relied on each team member to work in isolation with limited collaboration (Forgues & Koskela 2008).

The observations of this case study illustrate the effect of procurement on a project team. These observations are presented in the following sections.

6.3.1 Coherent project team

The fragmented process was defined by the distribution of the arising problems between the team members that developed and solved these issues in isolation. Meetings were scheduled for coordination purposes only and is typical to normal traditional procurement methods. The study concluded that the fragmented team operated as follows (Forgues & Koskela 2008):

1. The team appeared dysfunctional.
2. The team remained fragmented and formed separate teams consisting of clients, consultants etc.
3. The architect used his power to impose rules and provide team cohesion to the team.
4. The separate meetings between the client's executives and other networks resulted in parallel decision-making to take place.
5. The team efforts were channeled to meet contractual deliverables instead of defining the optimal solution.

Due to constraints set by the architect, the structural engineer's insight and specification of the building system was strictly controlled. Traditional approaches caused for a lack of shared ownership of the whole project. Each member took ownership of their share of the project instead obtaining input from the other members and therefore the best value project was not provided.

The integrated team concentrated on strong client leadership to establish the goals and objectives from the onset of the project. Active participation from the client, builder, operators and future owners was required to design for the whole project life-cycle, while creating an environment of continual learning. The integrated team focused on improving their performance and operated as follows:

1. Cost-plus concepts were followed to accommodate the client through the different stages of the project.
2. Problems that existed regarding efficiency were due to socio-cognitive reasons and not technicalities.
3. Cost reduction was achieved through innovation, standardisation, value engineering and process improvement.
4. Waste reduction within the design process was achieved not only by avoiding duplication of roles but also with value engineering.
5. A hierarchy of responsibilities was clearly redefined.

The study concluded by stating that a more coherent team can not be established by changing the procurement methods alone, but also the mental models (Forgues & Koskela 2008).

It is evident from the above study that a coherent team effort provides improved quality, performance and satisfaction for the whole team and best value to the client. To acquire this coherent team, early involvement is essential (Goodchild & Glass 2004).

During the procurement process, Glass and Baiche (2001) advise to procure in a manner to ensure single-point responsibility. It was proven that single-point responsibility provided the best environment for HCC projects. Unfortunately, single-point responsibility depends on the suitability of the conditions of a project. Contract documentation used for contracts can influence the effect and degree of coherency within the project team and affect the responsibilities and risks and will now be discussed.

6.3.2 Contract documentation and procedural barriers

Although a contract document does not affect the use of HCC directly, it can influence the procurement and design procedures. As seen in Section 3.3, the contract documentation must also influence the health and safety on sites. In the United Kingdom, the suggestion was made to create a contract document that was applicable for several different types of projects and contract procedures. Latham (1994) suggested that the contract document needed to:

- clearly define the duties of the different project team members.
- be written in easy and comprehensible language.
- define and allocate risks.
- be user friendly for a wide range of procurement methods, especially the ones that enhance partnering.
- be adaptable for both complex and simple projects.

Only contract documents that comply to this benchmark criteria were regarded by Goodchild (2011) as suitable for projects. In the United Kingdom, several measures were introduced to improve the contract documentation that was used in the industry. One of the measures was to write a contract document that complied to the above mentioned criteria and another was to encourage the construction industry to utilise the new document.

From the criteria mentioned above, one of the critical aspects was to increase the use of partnering within the construction industry. It is not surprising to realise that construction in the United Kingdom is procured either according to design-and-build methods or management contracts. In the process, the risk factors of HCC are discussed and addressed. This results in more frequent use of HCC technology within the country (Goodchild 2011).

Considering the South African industry (Section 3.3), projects that make use of partnering are not frequent. Instead projects are procured according to traditional open tendering methods with the employer being responsible for the design. South African companies continue procuring projects in a fragmented manner and thus the use of HCC are limited to certain elements or projects.

As mentioned previously, South Africa's public clients are required to procure according to certain procurement criteria. Besides the procurement strategy, it also affects the contract documentation. According to Goodchild and Glass (2004), the use of HCC will increase when procurement methods are used more frequent which encourage partnerships, close working relationships and contractors' participation from the start of a project.

6.4 Production barriers

Production barriers are not only applicable to the production of precast elements. It is also related to the manufacturers' capabilities and the contractors' ability to construct with the precast elements. This section investigates this barrier by making reference to the manufacturer's capabilities, standards that affect the production of precast elements and the capabilities of the contractors.

6.4.1 Manufacturers

The manufacturers in South Africa were thoroughly discussed in Section 3.5. The South African manufacturers appear to focus on a limited number of elements such as slabs, stairs and rib-and-block systems, while limited contractors experiment with beams and columns (Table 3.9). The reason was established to be a shortage of resources including equipment and regulations that require labour-intensive construction.

While some manufacturers are able to implement labour-intensive construction methods in their construction process, others prefer to commit to limited elements to ensure quality throughout the delivery process. In a growing pre-fabricated concrete market, all manufacturers are competitive and eager to provide the industry with the best quality products at the most affordable price. Manufactures are confined with standards that ensure quality and an effective and safe working environment.

6.4.2 Production standards

The *South African Bureau of Standards* (SABS) was established in terms of the *Standards Act no. 24 of 1945*. In terms of the latest edition of the *Standards Act no. 29 of 2008*, it operates as the national institution for the promotion and maintenance of standardisation and quality on commodities and services. Suppliers are urged to accredit their company and products to the SABS 1200 (or the new edition SANS 2001) or ISO 9000 standards. To qualify for the accreditation, suppliers are audited according to their compliance to a wide range of pre-determined specifications. A substantial fee is required from the suppliers prior to the audit. Once accredited, it ensures that the supplier produces superior quality product that can be used in the industry (Concrete Trends 2010*c*).

The Concrete Trends (2010*c*) magazine explains that although some suppliers implement these standards in their products, many suppliers are not fazed by these standards. Suppliers claim to manufacture their products according to these specified standards, but ignores the accreditation process of their products because of the financial costs involved. Others are simply not interested in the accreditation process for other unknown reasons. These suppliers are able to supply products at lower costs per unit. This immediately provides these suppliers with an advantage over accredited suppliers when costs are compared (Concrete Trends 2010*c*). Suppliers that do not accredit their products are under the impression that if they are "not obliged to accredit their products" and the industry and clients do not request accreditation, it is not worth the effort and money (Angelucci 2011, Rooyen 2011).

The hazard of constructing with these unaccredited elements is the possibility that (Concrete Trends 2010*c*):

- substandard material is used.

- shortcuts are taken with production methods.
- immediate or latent defects occur.
- the industry loose confidence in precast elements that gives a negative image to the precast industry.

Additionally to manufacturers being unable to produce a wide range of products or quality assured products, some designers are not overconfident in the contractor's ability to construct with a wider range of products (Bennett 2010).

6.4.3 Contractors' ability to construct

South African construction projects are mainly designed for traditional in-situ systems instead of HCC projects, because some designers believe that contractors are unable to construct with precast elements. Contractors that are eager to construct with precast systems, are responsible to either design or request an alternative design to incorporate these precast elements into the building. It is conceived that designing for HCC, may exclude many contractors from the tender process and the most cost effective solution would not be provided to the client. Designers believe that if all contractors were able to build with precast systems, designers will design accordingly (Bennett 2010).

6.5 Industry traps

A specific trend and tendency exists in all industries to favour traditional methods over innovative methods. Due to an inability or lethargic movement towards innovative methods and concepts, the ability to grow becomes a slow process. This is known as the *familiarity* trap or as it is also referred to, the *maturity* trap.

Mature technologies are well known, accepted and used for several years within a industry. The associated risks were recognised and improvements on these methods were developed to overcome these risks. Typically an industry would rather increase its knowledge of a familiar technology because it is more likely to provide immediate returns than invest in unfamiliar technologies. Unfortunately, by not experimenting or exposing an industry to new technologies and innovative methods results in a delay in growth (Ahuja & Lambert 2001).

This can clearly be seen in the construction industry regarding HCC and in-situ construction. Methods of improving in-situ construction methods, shuttering methods or concrete materials were investigated thoroughly and explained in an abundance of literature. In contrast, HCC is only recognised as an additional construction method that can be useful in specific projects. Further studies related to technical aspects, procurement methods and implications of HCC remains unavailable within South Africa. The industry would rather stay loyal to traditional methods that are tried and tested than to explore methods out of their so called "comfort zone" (Goulding et al. 2007).

In Section 3.8 the South African industry responded in a questionnaire that additional successful projects need to be accessible to the public by illustrating it in a database. Another participant mentioned that according to his knowledge all pre-fabricated products are already in use. From the response, the deficiency of exposure to the international utilisation of HCC is evident. Nevertheless, the industry remains willing to adapt new methods if the

required resources and examples are available.

Although the willingness exists, it must be mentioned that the transition process to a new technology is regarded as a "chaos" period. The "chaos" is characterised by high levels of uncertainty in the market's demand, technological attributes, quality, risks and prices. Because HCC is still a relatively new concept, it is regarded as a "disruptive" construction method compared to traditional, "sustainable" methods. Ideally, technology must reach a point of exploration into new methods rather than only exploiting it. HCC must be more than just an once-off experiment for a specific project, but rather a comforting environment that allows for an exploration field for designers and constructors (Goulding et al. 2007).

The frequent question remains within the industry, if HCC is used within a project, who is willing to take the risk of those experimental projects that are constructed during the *growing* phase of the technology? Additionally, which client will be willing to support such a speculative project (Bennett 2010)? As a result of these questions, the construction industry's take-up of HCC is not increasing dramatically because of the constant hesitance from the industry. Some contractors do experiment with HCC and experience positive outcomes as well as some negative notions towards specific methods (Chambers 2010). Ultimately the company that does make use of innovation or HCC specifically gains a competitive advantage over other companies within the industry (Ahuja & Lambert 2001).

6.6 Training

Training within the construction industry is critical to improve its performance, equip the project team with skills and to improve alertness to problem areas. Training programmes must also cope with increasing numbers of ethnic and migrant workers entering the industry at all levels that lead to additional problems and risks. The training institutions and application methods were discussed in Section 3.7. In this section, the relationship between the institutions and the industry in South Africa are discussed and the way institutes operate are scrutinised.

Training institutes focus their programmes on specific members within an industry for example management, designers and construction workers. These training courses are presented by members of the industry, allowing a growing knowledge within the industry. Appendix C, Table C.2 illustrates that the courses presented by the industry for HCC were limited (Section 3.7). Figure 6.2 illustrates that a relationship exists between tertiary institutions and the industry. Young employees from tertiary institutions that commence on their career must be aware of HCC to encourage growth, interest, knowledge and experimentation in the industry. Members of the industry that have knowledge of HCC must train these young engineers through training programmes that will result in more HCC projects and thus a larger knowledge base. This will result in a more experienced construction industry.

The way by which these institutes offer the training courses are critical to its effectiveness within the industry. Cherrett (2009) conducted a case study to evaluate the effectiveness of training methods in the United Kingdom. A sample group of 55 training providers were investigated for this study. From this sample, 95% of courses presented by these providers were according to the "chalk-and-talk" method. This is also referred to as one-dimensional training.

In South Africa, training programmes are also based on "chalk-and-talk" methods. Construction training does

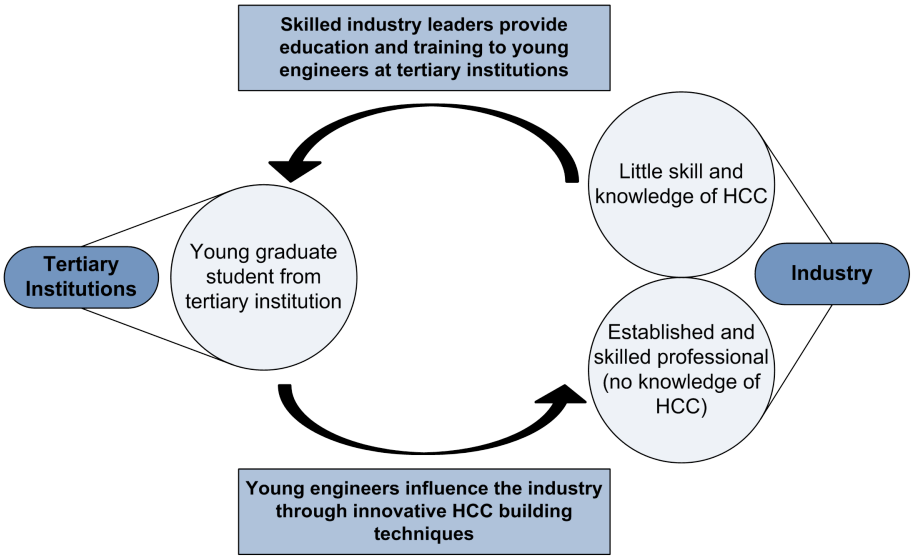

Figure 6.2: Illustration of the relationship between young engineers and a less-experienced industry

allow for practical application by providing practical problem situations. Although construction workers are stimulated through more cognitive training methods, other trainees are secluded (Cement and Concrete Institute 2011). Research indicated that cognitive training methods must be implemented to increase the effectiveness of training (Cherrett et al. 2009).

During the same sample study by Cherrett (2009), training was depicted as an ongoing process. Training is a process by which trainees must be "guided" to perform or work according to the expected methods. Additionally, courses must be updated as the industry evolves to keep trend with new methods, materials or processes. South African suppliers echoed this statement by mentioning that training methods and procedures need to be addressed continuously within the workplace (Angelucci 2011). Unfortunately the training courses that are presented in South Africa indicated no post-training evaluations.

While many companies make use of training institutions, others prefer to make continuous training a major priority. An example of such continuous training was seen during the FIFA World Cup 2010. The contractors that constructed the *Cape Town Greenpoint Stadium* consulted a business improvement consultant because of a delay in their schedule and the contractors struggled with unskilled labour, language barriers and absenteeism. Instead of training the labourers through training courses, the consultant implemented a continuous training programme or tool. This tool was called *INVOCOMS*®. It was based on a daily *"doing-the-right-thing"*-talk for the whole construction group in separate teams. It included daily updates of the project, each labourer's responsibilities and duties within the team, health and safety and environmental aspects for the coming 2 days. Additional *"tool-box"* talks were still taking place in which the workforce were reminded of safety and methods of construction. All the feedback from the meetings were noted and reported to management within a specific time frame (Construction World 2010). *The Construction World* (2010) magazine reported that the project was handed over two months ahead of schedule due to this tool and other initiatives.

6.7 Regulations and accreditations

Policies and regulations are regarded as a frequent source of barriers to innovative technology. These regulations may give rise to barriers in both direct or indirect measures because of the inadequacies when it is implemented. By complying with these regulations, companies become discouraged to enter new innovative techniques because of the increasing uncertainties and risk (Shavinina 2003). Regulations are viewed by designers and builders as additional burdens and barriers with which they have to conform. Performance limits for components and materials are set for manufacturers while clients are provided with instruments with which product standards are maintained (Gann et al. 1998).

Contrary to the above mentioned statements, in some countries it is believed that regulations serve as a driving force to innovation. The United States adopted new informative technology through regulations. Bossink (2004) stated that in the United States, governments and regulations stimulated innovation by guaranteeing markets of innovative technology.

In South Africa the regulations that limit the use of HCC technology are the labour-intensive operations and green building accreditation system. Shavinina (2003) iterates this by mentioning that labour legislations and environmental regulation are additional barriers to innovation. This section investigates the effect of labour-intensive construction and green building accreditation on the adoption of HCC in South Africa.

6.7.1 Labour-intensive construction

The concept of labour-intensive construction is beneficial to the unemployment of the country, although the application is not beneficial to the whole construction industry. It is stated that innovative methods and materials are available (Rooyen 2011), but the implementation of these methods are restricted due to regulations, such as enforcing labour-intensive construction.

HCC is promoted throughout the world because it requires less labour on site. In South Africa, labour-intensive construction methods are encouraged through the strict *Expanded Public Works Programme* (Section 2.4). Precast manufacturers admitted that precast concrete results in less labour on site, although more labour is required within factories. For this reason some manufacturers implement labour-intensive construction methods within their factories (Angelucci 2011, Rooyen 2011).

Although less labourers are employed for precast manufacturing, the labourers within factories are less exposed to excessive lifting operations because of overhead cranes (Angelucci 2011). Providing the labourers with additional lifting machinary, exposes the labourers to a healthier environment. Skills development are of high priority within factories and are either implemented through in-house or external training courses (Angelucci 2011, Rooyen 2011).

As mentioned in Section 3.6, labour-intensive construction does not only affect the product development, but it is also a major health concern for the labourers. While programmes enforce labour-intensive work it remains a human right of every worker to leave work in the same physical condition as he commenced that day (Concrete Industry Development Board 2009).

6.7.2 Green building regulations

The *Green Building Council of South Africa* (GBCSA) accredits buildings according to the *Green Star* rating tool. The rating toolkits that are used within South Africa are limited and many areas of improvement are visible. The shortcomings of these tools, regarding HCC implementation within the industry, are summarised below.:

1. There is not a tool that can be implemented to an industrial building while it is in operation (Green Building Council of South Africa 2011).
2. The toolkits have only in operation for a short period of time and needs to be re-evaluated (Lewin 2011).
3. The rating systems appear to be negatively bias towards precast construction.
4. The rating systems do not allow for the accreditation of double points, influencing precast construction dramatically (Lewin 2011).
5. The accreditation system does not re-evaluate an accredited company after a specific period of time (Lewin 2011).

The GBCSA admits that an operational toolkit will be beneficial to the industry, but no strategies are in place to develop such a tool (Lewin 2011). Additionally, the tools that are in operation have only been used over a short period of time (<5 years) and have not been re-evaluated.

The system is negatively bias towards precast construction. An example of this is when the materials that are utilised are analysed. (see Appendix C, Table C.3 for a partial of the Material-accreditation (MAT) criteria descriptions). Precast construction utilises no timber and due to the pre-stressing of the elements, it also reduces the concrete quantities drastically. In contrast, in-situ construction may use less timber and concrete during a project. According to the toolkits, the precast situation can only be allowed the points for the reduction of concrete and not that of timber because no timber was used to begin with. In-situ concrete may be awarded the points for both timber and concrete because of the reduction of both materials. According to the GBCSA, these scenarios will be analysed and points may be awarded accordingly although it is not guaranteed. Furthermore, the GBCSA remain unbiased and does not want to promote one building method over another (Lewin 2011).

The *Green Building Council of South Africa* is of the opinion that it is not required to re-evaluate buildings that were accredited because it is believed that the advantages that "greener" buildings provide to the client will influence the client not to make any alterations to the building (Lewin 2011). After an investigation of the tools, various items were found to be changeable without affecting the advantages to the client, but it will affect the star rating for example acquiring additional vehicle parking spaces. Table 6.1 illustrates a list of possible criteria that can cause for precast construction to be awarded "green" points according to these toolkits (Green Building Council of South Africa 2011).

Contrary to the GBCSA, the *British Precast* organisation promote the "greenness" of precast construction in several manuals. These manuals mention different reasons why precast construction may be "greener" than traditional in-situ construction. Some of these reasons are that (British Precast Concrete Federation 2008):

Table 6.1: List of criteria according to the *Green Building Council of South Africa* toolkit that will award pre-fabricated buildings additional points

	Reason	Toolkit clause	Points
1	Constant temperature (exposed concrete) - less HVAC	IEQ-9 or IEQ-10	2+2
2	Improved noise reduction (compared to rib-and-block)	IEQ-12	2
3	Reduction in Portland cement use	MAT-5	3
4	Recycled steel use or aggregate	MAT-6	3
5	Design for disassembly	MAT-9	1
6	Less concrete, less timber, less steel	MAT-10	1
7	Contractor is ISO compliant	MAN-6	1

- it conserves water within factories.
- it allows for a design that can be disassembled.
- if more suppliers can supply precast elements, it will cause for less transportation.
- minimum waste on site and factories are generated.
- material can be reused or recycled.

Unfortunately, it is unknown whether these criteria are recognised in the accreditation rating systems that are implemented by the *United Kingdoms Green Building Council*.

6.8 Supplier distribution

A study was undertaken to investigate if a relationship exists between a country's size and the number of precast concrete suppliers within that country. It was argued that the more suppliers there are within a country, the greater the accessibility there is to precast elements, causing a reduction in the transportation cost and eventually increasing the precast usage. Even though the results that are obtained from this study are doubtful due to uncertainties during the investigation, principals can be formulated from it.

The information is obtained as follows:

- Statistics of the country's size is obtained from an internet source - *The World Bank* (The World Bank 2011).
- Precast suppliers are obtained from internet sources. These sources are either at precast concrete associations based within that country or internet sites that advertise precast concrete manufacturers.
- Figure 6.3 is used to stipulate the location of the suppliers within South Africa (1,214,470 km^2) and Australia (7,682,300 km^2) (The World Bank 2011). The *Northern Cape* is known to be semi-desert while in Australia a large portion of the country is part of the *Australian Outback*. These areas are approximations and encircled within the yellow blocks.

- Countries that have a smaller area, such as Belgium (30,280 km^2) are also investigated and illustrated in Figure 6.3 (The World Bank 2011).

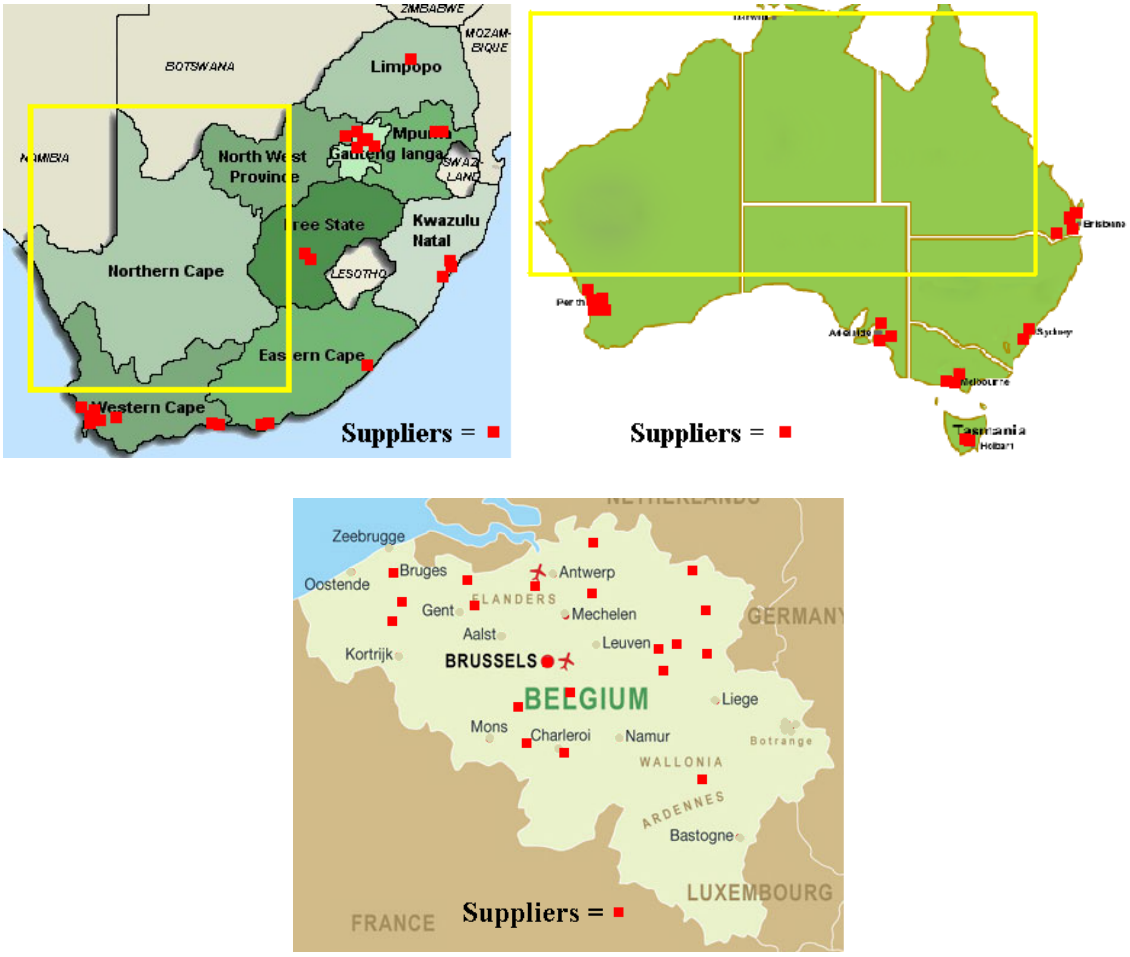

Figure 6.3: Graphical presentation of the distribution of the South African (left), Australian (right) and Belgium (bottom) precast suppliers over the geographical areas

The following shortcomings are noted during this investigation:

- Suppliers with different branches were only counted as a single supplier.
- Suppliers that are not registered to the precast association, are consequently not included in the statistics.
- Sizes of suppliers are not evaluated and compared.
- Only suppliers that are able to manufacture floor units (hollow-core or standard precast units, not rib-and-block) are investigated.
- Large areas within countries that have minimal population (an approximation) compared to the country's population are excluded from the country's size (for example the *Northern Cape* in South Africa or the *Australian Outback* in Australia).
- Ratios that can be regarded as minimal are an approximation to the country's population and size.

Figure 6.4 indicates the relationship between a country's size and the number of precast suppliers (thousand km^2 per supplier). Three conclusions are drawn:

1. Smaller countries have more suppliers per square kilometer. Thus, the suppliers within a country are not proportional to a country's size.

2. Countries with large "unpopulated" areas may have difficulty with transportation especially to these unpopulated areas (yellow blocks in Figure 6.3). Transportation of elements from a supplier to a town situated somewhere inside these "unpopulated" areas may be extremely costly and thus alternatives or traditional construction would rather be preferred. Countries such as Belgium or England are much smaller compared to Australia and the population and suppliers are spread out throughout the country. This is highlighted by the questionnaire response in Section 3.8, where it is suggested to improve the transportation logistics as a method of increasing the use of precast within the industry. Figure 6.3 illustrates that the precast suppliers within a small country such as Belgium are distributed and may result in more frequent precast utilisation.

3. As it is stated in Chapter 5 it appeares that smaller countries (Denmark, Netherlands, Sweden) made more use of precast construction than larger countries (Chen et al. 2009). Whether the increased usage was due to the supplier distribution within the countries or whether it was related to improved transportation logistics, remains unknown and needs to be investigated.

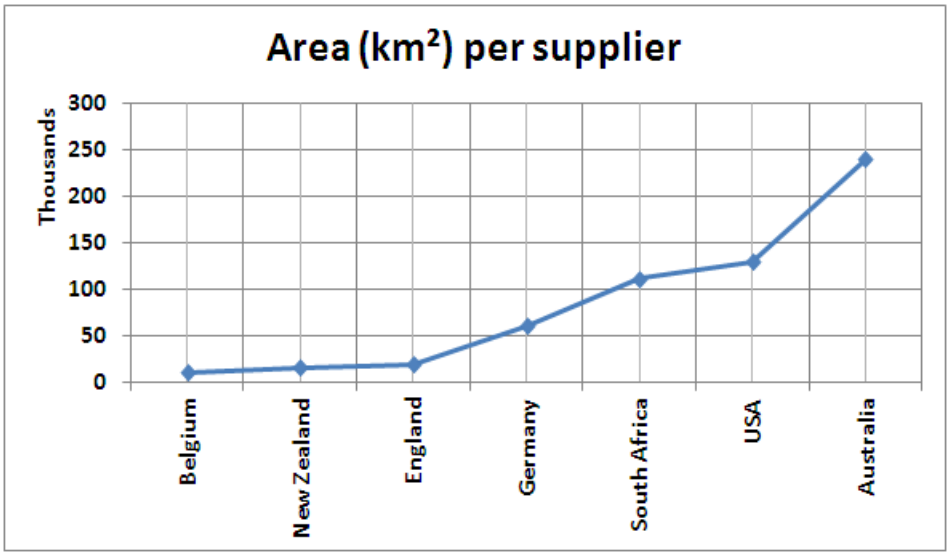

Figure 6.4: Illustration of the comparison of different countries' suppliers and area

6.9 Fragmentation

The construction industry is a conglomerate of small organisations of which most are exceptionally small (Section 3.4). The high volumes of contractors working on several projects or even on the same project is known as fragmentation in the construction industry.

Fragmentation can have both positive and negative influences on the construction industry. It does provide flexibility for variable workloads, although the excessive subcontracting causes for additional contractual relations and prevents continuity between the teams (Egan 1998). The constant subcontracting causes for different companies on projects to meet only for coordination purposes. Additionally, after a specific project, the teams fragment to different projects without building any unity. This causes for little opportunity for optimisation of a process or for innovation development (Forgues & Koskela 2008).

Not only is there fragmentation within the industry but also within companies. Project teams work in close relations on a specific project, but after completion of the project, the team disperses to new projects. The opportunity is lost to build on the knowledge obtained from each project within the team (Soetanto et al. 2007). This results in a spread of knowledge over several projects instead of a specialised team that works coherently together.

There is also a phycological side to fragmentation. The behavior of experts from different disciplines working on the same project illustrates the effect of "groupthink" and "compartmentalisation". "Groupthink" is a mode of thinking within a cohesive group, generally people from the same company. The thinking pattern is based on their objectives and methods while they exclude themselves from outside groups. This contributes to closed-mindedness to any information from the other groups. "Compartmentalisation" is a fragmentation of viewpoints and a lack of shared mental models. A group tends to discuss shared knowledge amongst themselves instead of including unique information from other groups. With as many fragmented construction companies, each company only focusses on their speciality and neglects external input. The result is the inability to share and exchange knowledge on the same project. Fragmentation may thus result in experts not being able to "speak the same language" (Forgues & Koskela 2008).

6.10 Market conditions

The global financial recession had dramatic impacts on all industries causing unemployment due to fewer construction projects. Martin (2009) reports that the construction industry provides for 7% of global employment. Due to recession and unemployment it resulted in low investment in the construction industry. This scenario of low investment can be seen within the South African construction industry as well.

As shown in Table 3.3 projects were frequently adjudicated according to the financial offer especially within the private sector. HCC's is a more cost effective building method when the life-cycle costs are compared to other construction methods. Unfortunately, HCC does display large initial costs (during the construction phase) (Goodchild 1995).

Literature is also sceptical to consider one construction method more cost effective than the other (Goodchild 1995). The result causes for a preference towards traditional in-situ construction because of the *familiarity trap*. Methods of establishing a holistic comparison between HCC and other construction methods appear to be difficult or impossible. The reason being that these advantages of HCC remain difficult to quantify (Zell 2001). Due to this financial barrier, the industry tends not to expose itself to the risk of an unsuccessful or failed project by introducing modern construction methods.

Because there is such a low demand for HCC, it results in another market barrier called the "supply and demand" deficiency. This deficiency is closely related to production barriers, whereby the market results in a low demand for HCC and typically, suppliers are unable to supply the required products when it is requested. A South African example is the need for innovative users to improve the demand (Shavinina 2003). The shortage of a demand, results in low investment in improved methods or equipment from the suppliers resulting in a stagnated precast industry.

6.11 Conclusions

The previous chapters recognise the current state of the South African construction industry and investigate different measures that are implemented in other countries especially the United Kingdom to increase the utilisation of HCC. This chapter investigates the different barriers that are applicable in South Africa that cause for HCC under-utilisation.

As stated previously, early involvement from the whole project team is of utmost importance. By including the construction team in the design, additional input can be obtained that will assist with the design. Design assistance software or tools are not available that cause for designers to design from first principals and not have a package to test the design. To develop software packages or design assistant tools may result in greater HCC utilisation. Late changes reduces the possibility of HCC dramatically not only because of the additional costs, but because precast is not as flexible as in-situ construction. To improve the utilisation of HCC, it is necessary to combat these design barriers.

Coherent teams provide projects that are according to "best value" and allows the project team to discuss design and construction problems. Unfortunately, the South African procurement method is traditional and does not permit partnering that frequently ensures coherent teams. Methods that implement partnering strategies are required to increase the use of HCC.

Manufacturers that are not accredited with quality standards pose a threat to the industry. It must be enforced by legislation or regulations to only construct with accredited precast elements. Furthermore, project designs are prepared according to in-situ construction methods because some designers believe that contractors do not have the ability to build with precast. Methods are required to change the designs to ensure that contractors are exposed to these construction methods.

Industry traps cause for the industry to remain traditional and not to experiment with innovative methods. Although these traditional methods are regarded as safe and secure methods of construction, it does not allow for growth within the industry. To change an industry, these traps must be overcome.

The training that is available in South Africa is of great concern. Training does not only encompass the courses that are presented, but also the manner in which it is presented and whom it targets. The training in South Africa is one-dimensional and relies on formal training methods. It was shown that an informal continuous training

programme resulted in positive returns for the project. It is therefore required to investigate different training methods (even in tertiary institutions) and implement it in the whole industry.

Labour-intensive construction and green building regulations pose a threat to the utilisation of HCC. If HCC can be accredited as a labour-intensive and green building method, it will be utilised more often in South Africa. Furthermore, if the toolkits, that are in use for the accreditation process by the *Green Building Council of South Africa*, accommodate the "green" advantages that precast construction provides, it may influence the utilisation of HCC.

The geographical area of South Africa illustrates that a large portion of the country does not have any suppliers. This may cause for transportation problems and limits the HCC utilisation within these "unpopulated" areas. Smaller countries that have an even distribution of suppliers over the country, indicated a greater utilisation of HCC. The reason for the greater utilisation of HCC in smaller countries may be investigated to evaluate the effect that the size of a country has on its HCC utilisation.

The next chapter will concentrate on methods to eliminate or decrease the effect of these barriers on the South African construction industry in order to improve the utilisation of HCC in the country.

Chapter 7

Discussion of the barriers to hybrid concrete construction

The previous chapter unveiled the different barriers that decrease the utilisation of hybrid concrete construction (HCC) in South Africa. Some of the barriers mentioned in Chapter 6 can either be controlled or solved by implementing specific procedures during procurement stages. The effect of other barriers can be minimised by introducing additional resolving procedures prior to or during the construction process. The objectives of this chapter are to:

1. Subdivide the barriers mentioned in Chapter 6 into barrier groupings.
2. Recommend possible methods and procedures that provide a solution to these groups for improving HCC usage in South Africa.

Many of the solutions are either obtained from measures adopted by other countries that experienced similar barriers or from other industries. Additional information is obtained from journal articles and personal interviews with both South African and United Kingdom project team members.

7.1 Grouping of the barriers

The barriers mentioned in Chapter 6 are closely related and similar in nature. There is thus a need to identify comprehensive barrier groupings that will include previously mentioned barriers. Solutions for these barriers need to adhere to the following criteria. It must:

- be applicable to South African conditions.
- be achievable.
- be applicable to small and large companies.

The barriers mentioned in Chapter 6 are grouped according to their origin and relation to each other. These groups are subdivided into different descriptive sections that will clarify the solutions. The following section headings are identified as topics for barriers to overcome:

1. **Procurement documentation**
   Documentation is the base to procurement methods. The documentation will assist the procurement method that is regarded as most accommodating towards HCC development. It can also improve the health and safety of a project.
2. **Procurement method**
   The procurement method can improve earlier involvement, reduce late changes and assist the project team to become more coherent. Partnering, professional relationships and fragmentation will be covered within this section.
3. **Training**
   Training is required throughout the whole construction industry. It will improve the design capabilities, contractor's skills, health and safety and will assist towards the movement away from the "industry traps".
4. **Regulations**
   The implementation of regulations will improve the construction industry and improve the attractiveness of precast construction. This section will cover items such as labour-intensive construction methods, green building accreditation and product standards.
5. **Manufacturers**
   Several topics such as resource application, supplier distribution and quality improvement will be addressed within this section.
6. **Database and knowledge development**
   The development of a database will improve the knowledge of HCC and will create reference projects to assist in the decision making.
7. **Environment for innovation**
   An environment that is accommodating towards innovation is required for HCC to be adopted.

A brief description of each section is provided above. These sections will now be discussed in further detail.

7.2 Procurement documentation

In Chapter 3, tender documentation is identified for its indirect effect on HCC development. The tender documentation creates a contractual agreement between members of the project team. It is responsible to establish the project specification, project specific regulations and legal legislation to which the teams must adhere. It can also affect the health and safety and environmental impacts of projects. In order for the documentation to promote best value and thus HCC development, it needs to promote partnering, coherent project teams and early involvement. The document must provide clear work stages and predetermined responsibilities (Latham 1994).

While some documents may be more effective in certain disciplines of construction, other documents may prove to be more accommodating towards partnering within a project. By investigating the procurement documentation used within the United Kingdom, a reference document can be recommended for South African conditions.

Because the *NEC3* suite was used on a variety of projects such as the Olympic Games 2012 preparation process, it is evident that the *NEC3* suite is flexible to be used on several different size and types of projects. Many positive aspects within the contract contribute to improve the construction industry as a whole for example the early warnings and clear risk allocation. Although the *NEC3* does not make special reference to "risk" within the contract itself, it does make use of terms such as "danger", "possible loss" or "adverse situation" that can be translated to risky conditions (Watermeyer 2010). A clear reference within the document creates boundaries and risk allocation to the whole project team. The early warning system allows for possible risks to be identified and assists in controlling the impacts of these risks (Watermeyer 2009).

An additional clause within the contract results in the so-called "pain or gain"-sharing of additional expenses. As a result, a "win-win" situation for the whole project team is created. Health and safety clauses improves safety by requesting health and safety measures to be implemented on sites (Concrete Industry Development Board 2009).

Investigating the utilisation of tender documentation within South Africa, the *General Conditions of Contract* (GCC) document is more applicable to civil construction and the *Joint Building Contracts Committee* (JBCC) document is more applicable to building construction. In contrast, the *NEC3* document is used on few building projects (Marx 2011). Although the *NEC3* is regarded as the most sufficient tender document for the construction industry in the United Kingdom, the South African construction industry is not familiar with this document (Table 3.2). South African project teams are encouraged here to increase their knowledge of the *New Engineering Contract* (NEC) document and utilise it in a similar manner as in the United Kingdom. Alternatively, the *JBCC* can be amended to be similarly appropriate to early involvement and partnering as the *NEC3*. Caution must be taken not to make excessive amendments resulting in ambiguity within the document.

It is recommended here to make use of the *NEC3* document or to amend the more familiar *JBCC* document to ensure early involvement from the project construction team, flexibility within the document, clear risk allocation and strict health and safety regulations. It is advised that clients need to identify with a specific contract document that promotes coherent project teams and to enforce it on projects.

This section illustrates that the most important characteristic of the tender document is to promote coherency within the project team and to ensure early involvement from the contractors to incorporate HCC within the design. HCC is regarded as a 'high-tech' construction method that requires careful co-operation between the architect, engineer, contractor and suppliers throughout the design and construction process (Glass 2005).

One of the most important changes that need to take place to increase the utilisation of HCC is to alter the procurement method to accommodate partnering, early involvement or close working relationships. This is discussed in the next section.

7.3 Procurement method

The importance of early involvement extends beyond additional design assistance. It assists the project team to establish consensus on the construction methods and on building materials from an early stage. Because of early involvement, the whole project team can establish "cut-off" times regarding decision making to minimise late

changes on projects (Gibb & Goodier 2011).

Early involvement establishes professional working relationships within the project team. Trust can be built within the team which improves the relationships between the team members to produce the best value to the client. Because the project team is working so closely together, the different teams (architect, engineer, contractor etc.) can learn from each other, increasing the knowledge of the building materials and methods and reducing the effects of fragmentation in the industry. Clients can continuously ensure that the projects are according to their expectations. The extent of the involvement of the client in the project team will affect the end product (Egan 1998).

In order for the tender procurement method to be changed, it remains important for the contract documentation to reflect this *new* tender style. Although several procurement methods require a close relationship between the project team to be successful, the design-and-build, public-private-partnerships and construction management methods appear to be most successful in other countries.

Other methods of procurement can be adopted to encourage additional design input or buildability assistance from other members of the project team. The *Koeberg Interchange* (Cape Town) infrastructure development was recognised as a "breakthrough" interchange project in South Africa. The magnitude of the project and the large precast elements that were used for construction while the highway that passed under the bridges remained operational was extra-ordinary. For this project the procurement method was according to the traditional single-stage method. The designers wanted to make use of precast beams for the interchange bridges but were unsure of the capability of the South African industry regarding dimensions and buildability of precast elements. Prior to the tender notification, the design team invited contractors above a certain grade to discuss the project. During this discussion, the contractors were encouraged to mention aspects to the design that may be of concern, buildability, construction methods as well as crane operation and availability. This ensured that the project's expectations were achievable once it was advertised (Bergmann 2010). Although this was a bridge project, similar concepts can be used for building construction.

Although the above mentioned project appeared to successfully implement HCC, it is advised for the construction industry to move away from tendering processes. It is rather advised to procure according to design-and-build, contract management or private-financed-initiative (similar to public-private-partnerships) methods. These methods are more likely to provide clients with best value in the long run owing to its flexibility and ability to draw in specialist advice at an early stage (Glass 2005)

7.3.1 Design-and-build

In South Africa, the opinion regarding design-and-build remains uncertain. From a contractor's point of view, Chambers (2010) regards design-and-build to be the next generation for procurement in South Africa. He raises concerns about companies undertaking design-and-build projects that do not have the required resources to manage the scale and responsibility of such projects. Additionally, he admits that many contractors that are not familiar with the design-and-build strategy experience difficulties and problems during the project (Chambers 2010).

Bennett (2010) is a consultant that designs for a contractor during design-and-build operations and believes

that it results in a good working environment. De Villiers (2010) contradicts this opinion, stating that during design-and-build projects, the engineer is under severe pressure to design specific sections according to the contractor's schedule. The process may result in the lack of a systematic design approach that consultants are accustomed to. A 2002 survey revealed that clients and quantity surveyors appreciated the cost certainty involved with design and build projects, while engineers and architects felt more pessimistic about the method (Bowen et al. 2002).

7.3.2 Public-private-partnerships

A public-private-partnership is a method that is used by public clients to construct large infrastructure projects when the required funds or management resources for such a project is not available. Although it is mainly used in South Africa within the civil construction industry, projects are starting to be procured to this method within the building sector (Bouwer 2010).

Although a public-private-partnership is usually a long project (usually 30 years), Goodchild (Goodchild 2011) warns that there is a risk involved with this procurement method. Figure 7.1 provides a graphical illustration of this risk. When public partners procure according to this method, both partners invest with an initial cost. After the construction period, the project is maintained by the private partner for the duration of the project. When this project period has past, the project is the sole responsibility of the public partner until the end of the project's life. While the revenue from the project should be able to sustain the maintenance costs, the public partner remains responsible to undertake the management processes of the project. When many projects are procured according to this method, public partners are warned that a significant management capability will be required to control this portion of the project to reduce deterioration and making it usable for its projected life (Goodchild 2011).

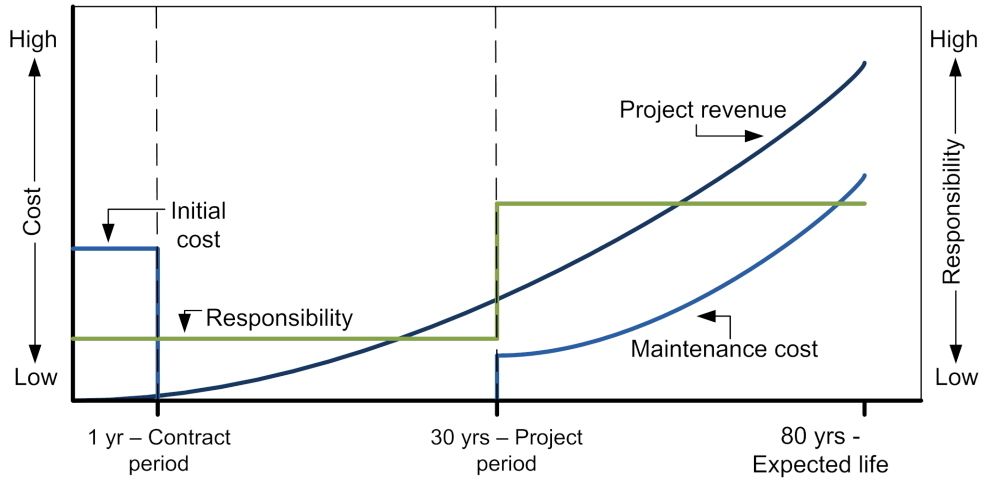

Figure 7.1: The effect of a public-private-partnership on the public partner (not to scale)

Although this risk does exist, governmental clients in the United Kingdom prefer this method of project procurement. Similarly, when projects are procured according to the contract management method with an additional maintenance contract (an usual occurrence) the risk of management of the project after this maintenance period is also applicable (Goodchild 2011).

Figure 7.2: Illustrating the relationship between innovation, experience and competitiveness (adjusted from Ahuja & Lambert 2001)

7.3.3 Contract management

According to the statistics provided in Section 3.3, contract management and public-private-partnerships are not a regular procurement method within the South African construction industry. In the United Kingdom, contract management is preferred because it eliminates the tender process, it provides the best value for the client and clients remain confident with this method. It is also able to provide early involvement of the project team to ensure the best solution for the client.

Throughout this section, clients are encouraged to be more involved during the procurement method. This is because clients are believed to have the most influential role on a project. That is why clients are also encouraged to be a driving force for change within the industry. In order for the client to be more involved in the project they must be trained to equip themselves with knowledge of both strategic (procurement methods) as well as more technical (construction methods and materials) issues (Egan 1998).

7.4 Training

Training remains the backbone to progression and growth within the country and any industry. Figure 7.2 schematically illustrates the relationship between innovation, training and competitiveness. Training is required to equip innovators with the required skills to develop these HCC techniques. Experimentation with innovative techniques will increase the experience with the specific innovation. Due to self confidence and competence, additional usage will be ensured and greater competence can be acquired. In the process, a greater advantage is obtained over other competitive companies, which will result in additional innovation initiatives to be used. Training is required throughout the process to smoothen the transition to new technology application. Companies that implement a new technology gain a competitive advantage over other companies. In order to create sustainable change and sustainable application, this cycle requires constant iteration in the industry (Ahuja & Lambert 2001).

The constant flow of innovation and absorption eventually leads to improved problem solving skills. This experience in innovative techniques are more likely to yield immediate returns resulting in a preference to invest in unfamiliar technologies. Alternatively, it can be argued that mature technologies offer the benefit of being reliable. Although new technologies may promise superior performance and competitiveness, it can also be expensive and difficult to implement (Ahuja & Lambert 2001).

Nevertheless, the importance of training can not be neglected even with traditional approaches. By managing the method and process of training it can be beneficial for the project team. Training and learning is said to be good, although it must be aligned with the actual customer's benefits (Zell 2001). Within this section the effect of training will be displayed on the design, contractor's abilities, health and safety and industry traps. It will be illustrated by subdividing this section into 3 subsections:

1. Methods of training
2. Specialised training for specific project teams
3. Peer training

7.4.1 Methods of training

The importance of the training method is just as valuable as the training content. Training needs to be presented in a multi-disciplinary manner. By implementing only one-dimensional training methods, the attendees remain somewhat disconnected from reality situations and only a state of surface learning is adopted (Cherrett et al. 2009).

By introducing trainees to a more realistic interface where they can fully interact with the medium, provides a major benefit to the training course. One such measure is through video streaming as a support tool. By synchronising it with other support tools such as graphics, slide presentations or notes, the intensity of visual and verbal interaction is enhanced and develops "deeper learning" (Cherrett et al. 2009).

Another method is to create simulators that provide the trainee with a 4-D experience similar to practice. By challenging the trainee with prototype problems, the trainee can learn within a safe environment (Campbell 2011). Furthermore, by giving the trainees practical applications (for example by building a wall for a bricklayer trainee) the effect of the training is much more effective. Simulators that are used in the United Kingdom and the Netherlands are extremely expensive and more cost effective methods of training needs to be investigated while retaining the value that the expensive equipment provides.

7.4.2 Specialised training for the project team members

It is believed by some individuals that South African contractors are unable to build with precast elements (Bennett 2010). Although this might be a generalisation, it is advised here that additional training is required for the contractors in a wide range of construction areas especially precast construction. The training contents must be applicable to the whole sector and include machinery operators training (crane operators and banksmen), storage training (applicable storage areas and methods) and construction procedures (correct method of placing and constructing with these elements).

Suppliers that are usually the specialist contractors must be trained in methods of improving production, design specifications or methods of incorporating labour-intensive construction methods into the manufacturing process. As found in Section 3.6, if HCC can become a more labour-intensive construction method, especially in controlled factory conditions, it would become more appealing to clients.

Because products are manufactured off-site and installed on site, both site workers as well as factory workers need to be trained to handle and manage these elements in a safe manner. Accidents within factories are less than on site because factories remain a more controlled environment (Angelucci 2011). Thus by training the production and construction teams to work safely with these elements it will reduce accidents on site.

It remains important for the design team to be educated and trained to realise potential elements that are buildable and to design for such elements especially for the conceptual design. Although suppliers indicated that they provide the final design for the work on site, it remains the design team's responsibility to perform the conceptual design and approve these designs before construction (Angelucci 2011, September 2011, Rooyen 2011).

Another method of providing design assistance is by developing a design tool or software package (see Section 6.2). Although a software programme is not directly a training programme, it can be used to provide security for the designer.

Young designers must be exposed to precast construction while they study at tertiary institutions (see Section 3.7). Part of tertiary institutions' design courses must incorporate or expose students to precast design and construction to create awareness in this field. These young engineers will be able to influence future projects with the knowledge gained at their institutions.

Because the client's role in the project team is important, they must be trained to provide valuable input to the project. If client training programmes are presented in South Africa, the lack of a database of private clients may cause for problems when programmes are advertised (Thumbiran 2011). More specifically, there is no knowledge of the recurring private clients within the country. There is a database of the public sector clients. If it is possible to provide these public and the recurring private clients with the training on procurement methods, the concept of best value and not lowest cost, construction methods and on identifying projects that can be constructed with pre-fabricated elements, then it may be possible to improve the utilisation of HCC. This is iterated by both Latham (1994) and Egan (1998) that frequently mention in their reports that by equipping these clients with the necessary skills will allow them to become the drivers of change within the industry.

Another measure to educate the project team is to learn from other project teams that performed similar projects. Innovative HCC users within the industry must be encouraged to freely discuss projects with their peers.

7.4.3 Peer training

Peer training is based solely on the concept of learning from others' mistakes or triumphs. By implementing measures to increase peer training, it allows for participants to learn from each other and not to make similar mistakes. This will improve the attractiveness of the industry and improve it as a whole. This training technique

is not unique to the construction industry.

In the computer industry, peer consulting helped *Hewlett Packard's* managers to accelerate the implementation of redesigning-efforts in the company. This was accomplished through the sharing of advice about different working methods with their peers. Peer training programmes were developed within the computer industry to allow companies to share their experiences. While, originally, sharing was problematic, managers soon became more comfortable and provided feedback. By providing feedback, it resulted in the industry to rely less on internal consultants and more on peer guidance and advice. By learning from each others' mistakes, as well as successes, the companies involved were able to learn and change faster than their competitors (Zell 2001).

Initial difficulties were identified with peer training. Firstly, to create a safe environment for companies to share their knowledge especially on innovative techniques, remains difficult because these techniques provide the companies with a competitive advantage. During the *Charge* initiative, it was reported that companies remained hesitant to collaborate with competitors until the advantages of knowledge sharing were discovered by the representing companies (Elhag et al. 2011).

Another problem was that companies considered this as an opportunity to boast their successes and techniques. It needs to be highlighted that these sessions are solely a learning experience and it is important to discuss only the successes and disappointments of projects at these meetings (Elhag et al. 2011, Zell 2001).

If a concrete organisation in South Africa such as *Cement Manufacturers Association* (CMA) or *Cement and Concrete Institute* (C&CI) could orchestrate a similar initiative as the *Charge* programme (see Section 5.4), companies can discuss industry problems. This can result in the sharing of not only health and safety issues as with the *Charge* initiative, but also difficult construction and design methods (especially regarding HCC). In doing so, it could create an opportunity for faster learning and greater competitiveness amongst companies while retaining best practice and best value for the client, which is similar to what was experienced in the computer industry.

Regarless of the disadvantages, the advantages of peer training outweigh the disadvantages. Methods of establishing such training methods need to be investigated. Peer training can additionally be implemented to the whole construction industry and not be restricted to HCC development.

7.5 Regulations

Regulations and standards are required to ensure the industry remains confined and safe in its procedures. Alternatively, regulations can hinder innovation from entering the industry. The regulations mentioned in Section 6.7 are subdivided into 4 subsections:

1. Work to the required standard and quality.
2. Work according to labour-intensive programmes.
3. Accreditation according to the green building regulations.
4. Accreditation of the project team and processes.

No matter how beneficial precast concrete may be to the construction industry, the use of pre-fabricated concrete elements will not increase if the quality of the products is not to the required national or international standards. This influence of standards and quality is discussed below.

7.5.1 Standard and quality of precast elements

In order to increase the popularity of precast concrete, the quality and standard of the elements must be adequate. This standard must be provided by a single organisation (for example SABS) and all manufacturers must be required to adhere to these standards. Allowing manufacturers to sell products that are not approved by this organisation, not only affects the quality of the products, but can result in unsafe structures.

Many manufacturers claim that their products are manufactured according to the specified standards without accreditation, because regulations do not require them to have their products accredited. In effect, unaccredited products that should not be used for projects are sold to clients. It was found by *The Concrete Trends* magazine that the private sector insists on using accredited elements, while the public sector ignores the relevance of it (Concrete Trends 2010*c*).

It is extremely important that all clients enforce the use of accredited products for their structures. This can be accomplished by either stipulating specific precast manufacturers within the contract document or by stipulating that only accredited products may be used for construction.

Clients must also constantly be aware of the additional costs that are involved with accredited products and allow for such costs within their budget (Concrete Trends 2010*c*). Although these costs may initially be higher than unaccredited products, the quality and standard of these elements are much greater, decreasing the possibility of defects during the expected life of the structure.

Accredited products affect best value engineering and can improve health and safety on sites. Because the manufacturers are governed by health and safety regulations to obtain a clean and safe environment, factory manufactured precast elements remain safer compared to site fabrication. When HCC is considered, many of the wet works are off-site, providing a site with reduced waste and a healthier environment for the workers (Soetanto et al. 2004*a*).

A positive movement towards standard enforcement has developed in South Africa. It is reported that the *Cement Manufacturers Association* (CMA) and SABS are drafting new standards for the precast concrete industry. These standards are in line with the international best-practice standards. Although South Africa is not such a popular user of precast elements, the manufactured elements should comply with world class standards. SABS priority workshops are prepared for several public sector departments (various governmental departments). These workshops aim to make clients aware of the value of these standards and to ensure that it is requested and installed in public projects (Concrete Trends 2010*c*).

These standards are not only targeting the quality of the products, but it does affect the construction method. Due to South African regulations, labour-intensive construction methods are predominantly promoted throughout the construction industry and will be discussed in the next subsection.

7.5.2 Labour-intensive construction

One of the major advantages of HCC is the requirement for less construction workers on site. As a method to increase the attractiveness of precast concrete in South Africa, some manufacturers invested in labour-intensive construction methods. These suppliers regard their method of construction as healthier and safer than site methods because of additional cranes within the factory that can be operated to minimise the constant strain on the human body. As stipulated in Section 3.6, labour-intensive construction cause for severe body strain that can cause additional long term health problems. Additionally, workers are not exposed to severe weather conditions or unexpected site conditions as on sites (Angelucci 2011, Rooyen 2011).

These innovative suppliers also state that their construction method may require the same amount or even additional construction workers to manufacture the elements. They claim to provide these labourers with more focused training and it results in a worker with more developed skills (Angelucci 2011, Rooyen 2011).

Although the application of precast construction may result in less job opportunities on site, government and clients are encouraged here to be lenient regarding the labour-intensive construction method because of the additional advantages obtained in the factory setting. The *Construction Industry Development Board* (CIDB) promote off-site manufacturing to increase the health and safety of the workers. They encourage off-site manufacturing because it will potentially contribute to the health and safety and ergonomics of the construction process (Concrete Industry Development Board 2009).

The CIDB also encourages manufacturers to promote the benefits of their products to ensure additional use within the industry. One such benefit is the "greenness" of precast construction.

7.5.3 Green building accreditation

The "greenness" of any building or construction method and materials remains ineffective as a promotional characteristic unless it is recognised by an accreditation company. To effectively promote HCC as a "greener" construction method, the "green" advantages need to be identified and accredited accordingly.

It is important for the *Green Building Council of South Africa* to develop a tool that can be used to rate industrial buildings during its design, construction and operational phases. The implementation of such a tool will additionally allow for contractors to ensure that the contracted supplier is accredited according to a specific star rating. This star rating that the project team must adhere to can be supplied within the tender document by the client to ensure that even the products used within the structure originates from a "green" factory.

Currently, accredited buildings are not re-evaluated after construction except for mandatory report delivery on the building within the first period of operation (Green Building Council of South Africa 2011). It is advised here that buildings must be re-evaluated every 5 years. It will ensure that building owners can make minimal changes to the building without altering their rating.

Concrete as a whole is credited for its characteristics as stipulated in Table 6.1, the specific points allowed according to the accreditation tools can be viewed as negatively biased towards precast construction. It is therefore

advised here to investigate and re-analyse the point scheme. Construction methods that make use of zero building materials (such as timber) should be allowed more points than methods that make limited use of certain building materials (see Section 6.7 for an example).

Additionally to the *Green Building Council of South Africa*, other management accreditation schemes can be implemented within the construction industry to improve the procedures of construction and provide best value to the client. These schemes will now be discussed.

7.5.4 Accreditation of the project team and processes

Several companies exist that grade companies, sites or factories according to their management programmes that enforce prescribed standards that are in line with national standards. *National Occupational Safety Association* (NOSA) is one of these management accreditation companies. *NOSA* focusses on the specific project processes that are developed by the employer and evaluates it to comply with the *NOSA* regulations that are in line with South African acts and regulations. This accreditation results in companies, sites or factories to be accredited according to a set of regulations that are standardised by *NOSA* to ensure improved management procedures (National Occupational Safety Association 2011).

It is recommended here that members of the project team accredit themselves as well as the project to such an organisation. *NOSA* is only one of many organisations (another example is *IRCA*) that perform similar work. The benefits of the accreditation translate to a safer, healthier and environment friendly project. It can also be a requirement from the tendering documentation to enforce project accreditation to similar standards.

7.6 Manufacturers

It is regarded as vital for effective HCC application if manufacturers provide design assistance during the initial stages of the design phase (Goodchild & Glass 2004). The assistance not only concerns the design procedures but also the capabilities of the manufacturers. The manufactures' capabilities are restricted by regulations, product range, resource shortage (equipment) and supplier distribution as illustrated in Chapter 6.

When the product range of the South African manufacturers (Table 3.9) are compared to that of the manufacturers in the United Kingdom (Table 5.1) it is evident that the South African manufacturers are not capable of manufacturing a larger variety of elements at a sustainable bases and that the demand for additional elements are not strong enough within the country.

Manufacturers admit that the cost involved to acquire additional resources are too risky due to the unreliable market that cannot ensure the sustainable utilisation of precast products in future projects (September 2011). Figure 7.3 illustrates the current situation in South Africa. If the design of a structure includes HCC, then manufacturers are unable to supply non-standard elements. This results in either a redesign of the structure or contractors decide to operate a private precast yard. Alternatively, if designers neglect to design for HCC systems, manufacturers do not realise the demand for non-standard elements and traditional approaches of construction continues. It is advised here that a feasibility study be undertaken to investigate the demand for non-standard

elements within South Africa. Such a study will indicate the necessity of additional elements and provide security to manufacturers to invest in additional resources and equipment.

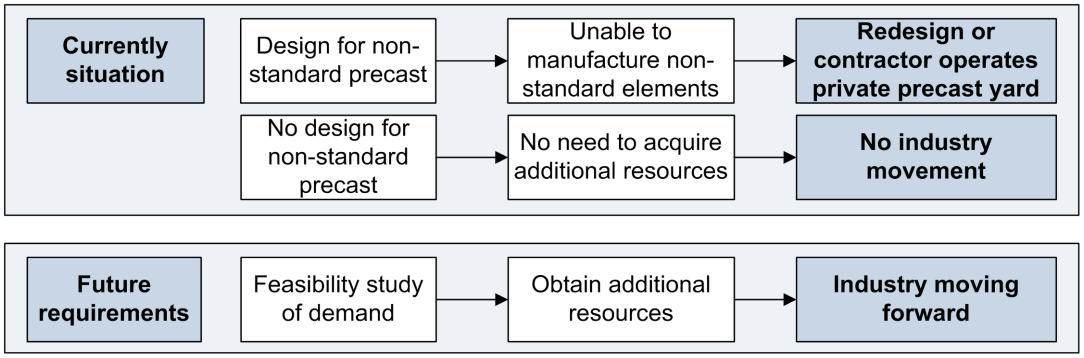

Figure 7.3: Demand and resource requirement scenario for manufacturers in South Africa

Whether standard or non-standard products are manufactured, the quality of the elements should meet the required specifications. Section 7.5 highlighted the necessity of standards to be applicable for precast construction and production.

Goulding (2007) warns manufacturers that the perception is incorrect that an increase in quality of the products will automatically increase the product's utilisation. It remains important to create a high degree of accessibility to these products. Manufactures are advised here to operate more smaller factories that are situated throughout the country instead of fewer large factories. The practicality of this recommendation may not be feasible because it will implicate additional financial costs to obtain the required resources for such *satellite*-factories.

Whether the United Kingdom is able to make use of "just-in-time" processes because of different manufacturing processes or because their management style is different, the advantages cannot be overlooked. South African manufacturers are encouraged here to investigate different manufacture and delivery systems to obtain similar advantages.

7.7 Database and knowledge development

One reason why HCC remains under-utilised in South Africa is the lack of exposure to different elements and projects as found in the questionnaire feedback (Section 3.8). By creating a database of HCC projects where several precast elements are used in different circumstances, additional exposure of the techniques can be provided to the industry. Such a database will reinforce the concept of peer training in a sense that the industry can relate to such projects when HCC is considered for a project.

Companies within the construction industry are not operating within a vacuum, rather they are situated in a number of inter-organisational networks. A database of projects can promote and facilitate the development and exchange of knowledge and resources within such an inter-organisational network. It is especially meaningful to companies without the required knowledge or skills to be able to exchange information with other companies in

the network (Sexton et al. 2006).

Because of fragmentation within the industry, project teams are rarely able to learn from their current projects. For this reason, Glass (2005) established that a knowledge database can be build if 3 conditions are followed:

1. Firstly, the database must be structured to reflect on the project from the views of the whole project team.
2. Post-project reviews, intra-nets and centers of excellence are identified as methods to capture information required of the different projects for the database.
3. Lastly, clients are singled out to apply lessons learnt on future projects and to provide feedback in the database.

Goulding (2007) found that designers will break away from traditional approaches when three criteria are met. He mentioned that the criteria will be obtainable within a database of knowledge. The criteria are to:

- have sufficient knowledge about the technology.
- be adequately persuaded of its merits.
- have these merits confirmed in practice.

Goulding (2007) found that the required database can be modelled into 3 closed groups or links (Figure 7.4). These links are used to create a decision-making software tool. Although this model is used for software development, the concept can be applicable as a database collection tool to transfer technology and innovation. The links are:

1. **Knowledge creation**
   Designers must have sufficient knowledge of the technology they want to adopt. This knowledge can be obtained from previous projects.
2. **Knowledge application**
   Designers need to combine existing knowledge and the newly gathered knowledge in projects. Experimentation with this concept must be concluded within the initial stages of the design to create deep understanding into the characteristics and application capabilities of the technology.
3. **Knowledge storage and retrieval**
   This provides the ability to store and learn from previous projects and to be able to access this information for future projects. This link serves as a database of projects

Figure 7.4 illustrates the inter-connective relationship between these links. The project team gathers and equips themselves with knowledge to construct a specific building and applies this knowledge to projects. Lessons from projects are collected and stored within a database. When the knowledge base is increased, experience is constantly gained. By creating a database of information regarding HCC projects, the designer can increase his knowledge and use the reference projects for future developments (Goulding et al. 2007). This database can be similar to the database in Chapter 4.

7.8 Environment for innovation

Glass (2005) investigated the criteria to increase the utilisation of HCC or to adopt HCC in a country. She established that HCC will be adopted more easily if the following information is available:

1. HCC specific guidance is required. This guidance must consist of a combination of:
   - buildability and manufacturability aspects of precast elements,
   - "lead-in" time issues with contracting procedures,
   - appropriate pricing mechanisms,
   - appropriate contract routes and
   - practicalities such as tolerances for HCC.
2. Awareness must be created of HCC. Again, the awareness must concentrate on the criteria mentioned in item 1.
3. Opinions and views from clients must be noted to ensure continuous improvement within the industry.

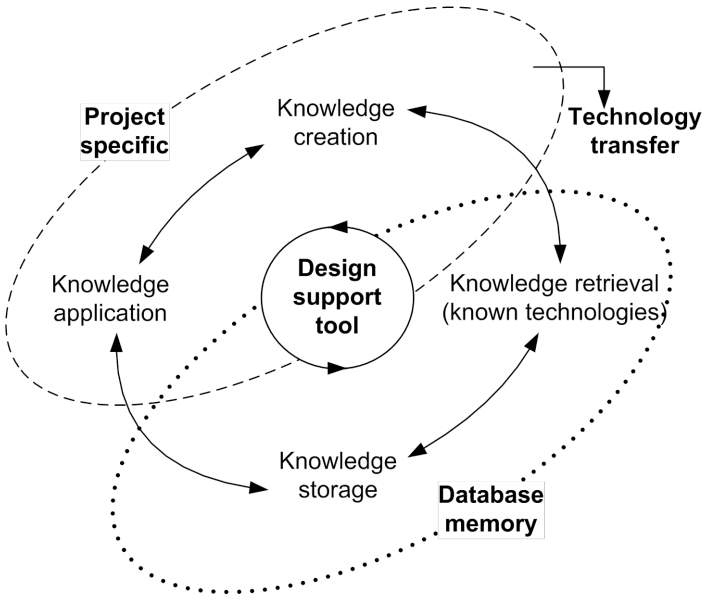

Figure 7.4: Knowledge cycles that need to be defined for the designer (adjusted from Goulding et al. 2007)

These items are discussed throughout this chapter. Guidance can be provided by providing design assistance, by early involvement and through procurement procedures. Awareness and clients' opinions can be captured within a database. Although these criteria can be met, any innovation and specifically HCC's success is based on the environment in which it must be applied. Within an industry, the possible gains and losses of employing such an innovation must be weighted against each other to evaluate the acceptability of the environment. These weighting functions are unknown and will differ between countries. Nevertheless, if these weighting functions can be identified, the environment will become a measuring tool of the acceptance of the innovation.

Methods of establishing the most suitable or appropriate environment for HCC construction remains unclear, which creates another risk for the applicant, whether it may be the client or contractor. If the appropriateness of the environment is too weak, there will not be enough incentive for a company to innovate (Sexton & Barrett 2005). The difficulty of measuring the advantages on cost and programme, shortage of understanding of the design, technical and production issues, and poor familiarity with HCC increases the difficulty of establish an appropriate environment for HCC innovation (Soetanto et al. 2007).

Table 7.1 is created with advantages and possible gains or implications of the application of HCC within the South African construction industry. The advantages of application are obtained from the advantages of using HCC, illustrated in Chapter 1 and Chapter 3. The implications of application are obtained from Chapter 3 and Chapter 6.

Table 7.1: Weighting the environment for innovation growth

For	Against
Life-cycle cost	Initial cost
Quality	Against traditional procurement methods
Time	Early involvement required
Value engineering	"Greenness" accreditation
Health and Safety	Requires more design effort
Cleaner site	Less labour-intensive
Less waste	New construction method
Skills development	
Increases competitiveness	

An organisation or company needs to evaluate the environment and establish whether the risk of applying HCC within the company is worth taking. While many countries may benefit from applying HCC to their building industry, South Africa's barriers may weigh more than the advantages obtained from it, making HCC an unsuitable construction method at this period of time.

Innovators that do insist on using innovative concepts are the drivers of the construction industry. These drivers and methods of becoming a driver of change will be discussed from a client and company perspective in Chapter 8.

7.9 Conclusion

The objective of this chapter is to provide solutions to the barriers that are discussed in Chapter 6. Although these solutions may in some cases be unrealistic for the current state of the industry, it is noteworthy for future circumstances.

Table 7.2 is created with all the solutions that are provided throughout this chapter. The impact that these solutions will have on the HCC utilisation as well as the construction industry are provided in the table. The solutions are applicable to the whole project team except in cases where specific project team members are stipulated.

Ultimately, the willingness of the construction industry to change towards HCC techniques remain dependant on the environment in which it needs to change. When the gains and losses of the innovation are compared with relevant weighting functions, the appropriateness of the innovation within the environment becomes evident. The value of the weighting functions needs to be evaluated to establish the acceptability of HCC within an environment (South Africa).

The solutions provided in this chapter need to be implemented by "innovative champions". Although the influence the client has on a project is frequently mentioned throughout this study, other drivers are required to increase the implementation process of change within an industry. The next chapter discusses different drivers that can enforce these solutions in the industry.

Table 7.2: A summary of the recommendations from Chapter 7

Subject	Recommendation	Reason
Procurement documentation	Adopt NEC3	Improve partnering, early involvement, reduce fragmentation,
	Amend JBCC	improve health and safety, construct according to best practice
Procurement method	Design-and-build	Improve early involvement, partnering,
	Public-private-partnerships	improve client involvement
	Construction management	
Training	Multi-dimensional training	Relevance to reality situations become evident
	Contractor	Greater skilled with precast construction, safety improvement
	Supplier	Labour-intensive construction, production and design specifications
		safety improvement
	Designer	Improve design skills and expertise, create knowledge of buildability
	Design software	Additional design assistance
	Tertiary training	Exposure to HCC to young designers
	Peer training (CMA and C&CI)	Best practice improvement, faster learning
Regulations	Accreditation of products	Best value, quality assurance
	Leniency on labour-intensive construction	Improve attractiveness of precast elements, more beneficial for labourers
	Green Building developments	Improvement of the construction industry, improve precast concrete attractiveness
	Project team accreditation	Improve management skills and processes
Manufacturers	Expand product range	Improve HCC use, more flexibility with elements,

Continued on next page

Table 7.2 – continued from previous page

Subject	**Recommendation**	**Reason**
	Quality accreditation	quality assurance
	Create satellite factories	Transport logistic improvement, transport costs
Database	Create database of HCC projects	Reference projects, create knowledge database, skill and experience improvement

Chapter 8

Drivers of the solutions towards industry change

In the previous chapter, solutions are introduced to eliminate or minimise the effect of barriers of hybrid concrete construction (HCC) on the construction industry. This chapter concentrates on the drivers that are required to enforce the solutions in the industry. The objectives of this chapter are to:

1. Identify the required drivers which would enforce the solutions within the industry.
2. Validate these drivers that are identified.
3. Develop a change model for a company.

The information required for this chapter is obtained from literature reports, electronic correspondence and journal articles. As mentioned in Chapter 7, institutions and organisations (similar to the *The British Precast* organisation in the United Kingdom) are required to drive change by means of different regulations and initiatives. This chapter will not view such organisations as drivers of the industry.

8.1 Innovation champions

In order to establish a new innovation in an industry, the industry must undergo a "mindset" change that includes the utilisation of the new innovation. This does not signify that the previous methods are wrong, instead it captures the ability of the industry to evolve and improve through a process of change. The changing of "mindsets" is known to be a slow process because a behaviour change is required (Jennings 2006). The United Kingdom established a "thinking off-site" mindset, and similarly the South African industry needs to alter their mindset to incorporate precast concrete elements in their structures.

Although many solutions are provided to change the construction industry (Chapter 7), the need exists for a driving agent to implement these solutions. Some recognise these driving forces as "innovation champions" (drivers). These "innovation champions" are companies that realise the potential of a new technology or market, adopts and commits to the technology on their projects. Furthermore, they generate support from others and

advocate the technology using their projects as examples of innovation application (Shavinina 2003).

To obtain the true potential benefits of HCC, it is dependent on the transition smoothness of the "innovation champion" and his efficacy regarding management of all project phases during the "transformation" process. The "transformation" process relates to the process where the "champions" stray from traditional methods and move forward with innovative methods. The ability to effectively communicate with other members often result in a smoother transition process because all the involved members are informed of the champion's (driver) intentions (Soetanto et al. 2004*b*).

The ability to communicate with the rest of the project team members is the most important factor to overcome innovation failure. Poor communication often results in poor relationships that consequently evolve in an innovation failure. A combination of a shortage of resources to train the employees and the lack of sufficient leadership to manage the transition from traditional to innovative methods is the other reason why innovation may fail (Zell 2001). It is therefore critical for the driver to provide leadership to make difficult decisions and to manage the teams.

As stated previously, it remains important when the utilisation of HCC is considered to decide on the structural frame at an early stage of the project. It is therefore important for the driver to take part in the project development from an early stage (Soetanto et al. 2004*b*).

For the purpose of this document, drivers are investigated that make sacrifices in order to change. Although these "champions" remain bound by restrictions as mentioned in Chapter 6, such as procurement method or additional training, their willingness to innovate drives them to investigate possibilities beyond these barriers.

8.2 Driver considerations

When drivers consider innovation within the HCC industry, it can either be triggered or hampered by 4 factors. Figure 8.1 illustrates the factors that influence the drivers. The individual factors are factors inherent within the characteristics of the individual decision maker and may for example be the attitude towards risk, age or background. The project factors are project specific for example the procurement route, client or project type. Organisational factors are more related to the organisation that is responsible for the project and their receptiveness of the new technology. It may for example be the management's attitude towards innovation, culture or the organisational structure. Finally the industrial factors are the characteristics within the industry that create a suitable environment for innovation such as the policies, codes of practice or competitiveness. If an opportunity arises where all these factors are favourable for innovation, HCC will be a suitable construction method that enjoys assistance from the whole project team and the industry (Soetanto et al. 2004*b*).

Some of the above mentioned factors are addressed in Chapter 7 while others are specific characteristics related to the driver such as the individual and organisational factors. For this reason, the drivers are either required to be able to influence the project specifications or alternatively the company are required to innovate in spite of these factors with the support of the project team.

Literature frequently mentions the necessity of the client to be the HCC driver of innovation (Egan 2002, Bossink

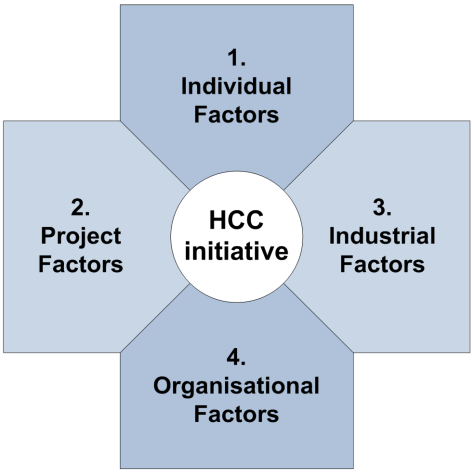

Figure 8.1: Factors that influence drivers of innovation when hybrid concrete construction is considered

2004, Glass 2005). The client has the ability to change procurement strategies, be involved from an early stage of the project and influence the design specifications. It is therefore evident that the client is an obvious driver of change. The clients mentioned within this section relate to the public clients. Because of the shortage of a database of recurring private clients, they are neglected as a driver. This does not implicate that private clients can not be drivers of change; instead it identifies the difficulty to train private clients especially non-recurring clients to drive a project.

Alternatively, it is recommended here that innovative private consulting and construction companies become a driver to change. Clients that do not have the required knowledge of different construction methods, can be influenced by these "innovation champions" to select HCC as a construction method. Especially within a country that may experience difficulty to equip clients with the required skills to guide a project team (Section 3.2 and Section 7.4), the requirement for alternative driving forces are essential.

Public clients and companies as "innovation champions" are discussed in Section 8.3 and Section 8.4 respectively.

8.3 Clients as drivers

As mentioned before, the client's involvement in the project team is crucial and the extent of the involvement influences his capabilities as a driver. If the client has the ability to coordinate the project team throughout the innovation process, it makes the client an important driver (Bossink 2004).

It was found that the ill-trained or shortage of knowledge of the client regarding building construction and procurement makes it difficult for clients to lead the project (Section 7.4). If clients have the financial resources, an alternative method of driving the industry is for the client to appoint an advisor. These advisors are not part of the project team although they assist the client through procurement phases, management, design and construction processes (Egan 2002).

Besides the many advantages that HCC provides to the client and the project team, it is crucial to identify criteria

that will motivate public clients to invest and promote HCC.

8.3.1 Client's motivation to drive

During the identification of barriers, different criteria are found to be beneficial to public clients especially on public projects (Section 3.6). Because all the criteria are discussed in other sections, only a reference will be provided to the relevant sections. The criteria are listed below:

1. **Cost effective**
   When HCC is analysed holistically, the initial cost and especially the life-cycle cost of the project are more economical compared to traditional construction methods. (Section 5.4).

2. **Improved health and safety**
   Because of additional regulations that are applicable to manufacturers, the health and safety within factories is better than on sites (Section 7.4).

3. **Improved training**
   Training techniques within a factory remain more specific and professional than on sites (Section 7.4).

4. **Labour-intensive construction**
   Some manufacturers are able to construct precast elements within the pre-fabricated factories according to labour-intensive construction methods (Section 7.5).

5. **Greener building method resulting in a more sustainable project**
   Although the green potential of HCC is not recognised in green rating procedures in South Africa, precast construction is regarded as a greener construction method by countries that make frequent use of HCC (Section 7.5).

HCC is promoted in the United Kingdom due to its cost effectiveness, greenness and improved health and safety (Section 2.2). Improvements regarding the labour-intensive construction and training are discussed in Chapter 7. In South Africa, additional research is required to investigate whether the criteria mentioned above is applicable for the industry. A cost analysis or software package is required to investigate the initial and life-cycle cost comparison between traditional methods and HCC. Although interviews have proved that HCC provides labour-intensive construction in factories, healthier and safer working conditions and improved training, it remains subjective opinions and must be analysed. The *Green Building Council of South Africa* are hesitant to promote precast construction as a greener construction method although they believe that it can be justified with an actual project or case study (Lewin 2011).

Although this criteria needs additional research, clients are encouraged to experiment with HCC to improve their knowledge and drive the industry. Alternatively, private companies with more experience with the construction industry are also prompted to drive the HCC industry.

8.4 Company as driver

The companies that are reviewed as drivers, refers to all companies within the design team. It was illustrated that South Africa tend to predominantly procure according to tendering procedures (Section 3.3), that requires separate teams to design and construct the project. Therefore, while tender procurement methods are used, companies that form part of the design team are able to influence the industry more easily. Typically the design team consist of architects, quantity surveyors and engineers. The influence that the construction companies has on the project is not neglected, although it remains difficult for these companies to influence the construction method if they are not involved early except if a design-and-build or contract management procurement route is used.

The ability of companies to innovate is hampered by people related barriers. These barriers are either due to a lack of will or the staff's inability to manage new innovations. While "will" relates to the attraction of the proposition or the fear of the unknown, "inability" refers to the inability or lack of creativity and knowledge (Shavinina 2003, Ahuja & Lambert 2001). Therefore, if people within a company increase their competence to manage innovation and their will to improve, this barrier is bridged. This makes it possible for the innovation to evolve and it increases the possibility to change people's "mindsets".

By implementing a "mindset" change within a company to be innovative and proactive with technology, such a company can transform an industry. Besides being a catalyst for change within the industry, a "mindset" change can result in these companies becoming innovation leaders and gain additional competitiveness against other companies (Shavinina 2003).

Because companies are not used to change, a model is required to indicate the processes that a company must undergo to bring forth change within itself and in the an industry. The model must incorporate change within the company that transfers into the industry. For this reason, a model is proposed here and will now be discussed.

8.4.1 Developing a model

Different models were considered to illustrate proper change within a company that translates into industrial change. The *Kotter*-model is a 8-step model to change within a company and is published in the book, "Leading Change" in 1995 (Kotter 2011). The *Construction Excellence*-model for industry change is a 8-step model for industry change that is known in New Zealand (Construction Excellence Ltd 2010). It is decided to propose a new model because the *Kotter*-model is more focused on company development while the *Construction Excellence*-model requires assistance from the government and legislation. Although it would be ideal to obtain assistance from the government, the concept of the proposed model is to be applicable on companies within the current state of the South African industry.

Kotter's model for company change is the most relevant for the proposed model and it has already been validated in case studies (Kotter 2011). The *Kotter*-model is scrutinised and amended to be more applicable to industry change. Additional influence from other models is used where it is appropriate.

8.4.2 Industry change model

The proposed model is supposed to incorporate different change processes to finally achieve industrial change. Figure 8.2 illustrates how the proposed model can be subdivided into 4 parts that have a ripple-effect on each other. With enough leadership, personal change within a company will cause for a company to change. The company will implement the "mindset" onto projects that will allow other companies to copy it, resulting in an industry change (Construction Excellence Ltd 2010).

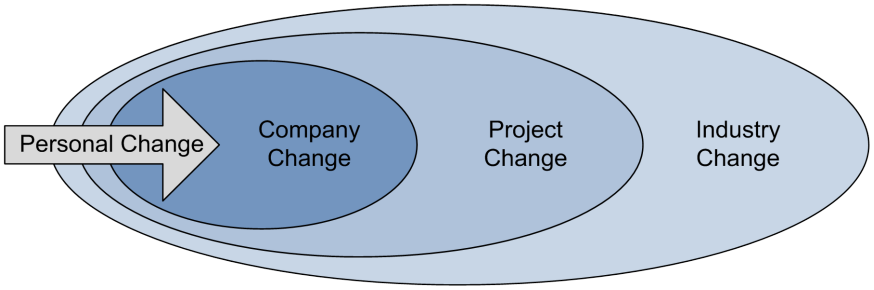

Figure 8.2: Proposed change model indicating the development from personal to industry change

Figure 8.3 illustrates the proposed 7-step industry change model that is based on *Kotter*'s model (Kotter 2011), although its progression is similar to that of the *Construction Excellence*-model (Construction Excellence Ltd 2010). This change model is applicable to any industry that is implementing an innovative technique. For the purpose of this document, HCC is the innovation. To clarify this model, the relevance of each step will now be discussed in detail.

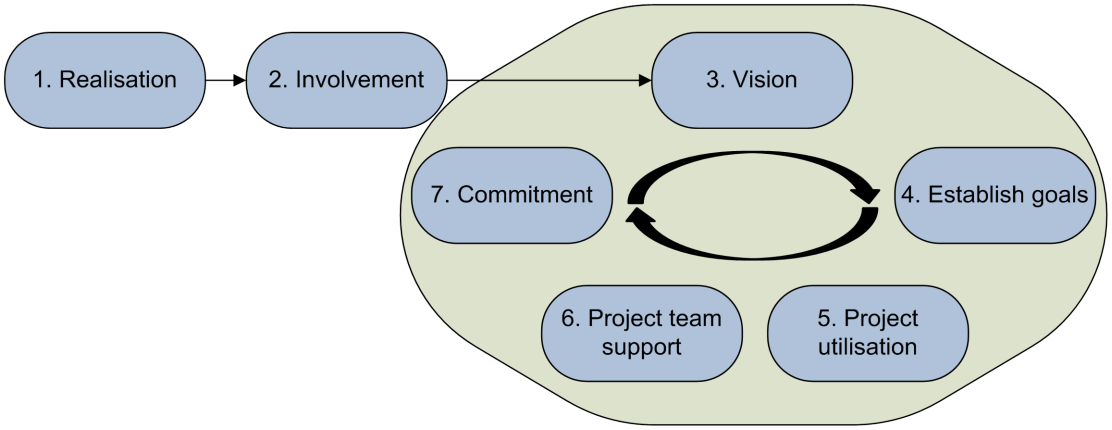

Figure 8.3: Proposed seven-step industry change model

1. Realisation

It is seldom that a whole company realises the potential (advantages) of an innovation at the same time. Usually, one person within a company discovers the potential of an innovation. This point of discovery is often referred to as the trigger event that sets change in motion. When a personal "mindset" change has developed, the willingness to promote the innovation has already been developed. With enough leadership, the innovation can be promoted

to the rest of the company (Kotter 2011). Change can not be obtained in a company through personal advances and therefore additional assistance is required.

2. Involvement

Through continuous promotions and leadership, a personal realisation can influence a group within the company to investigate the innovative methods. It must be remembered that innovation can be adopted within a company through innovative strategies and a supporting environment (Sexton et al. 2006). Within companies that are unwilling to change, the effort required to alter these resistances is worse than for innovative companies. The lack of commitment and support from management will result in an environment that does not tolerate failure and that cause additional pressure on the innovators in the company (Shavinina 2003).

The involvement process relies on getting the right group of people (respected leaders) within a company to drive the innovation into the company. The group must be willing to gain experience and knowledge of the innovation to reduce the risk of failure when the innovation is applied. The group must consist of both managers and innovation drivers that work together as a team (Kotter 2011). As a group, a vision of the company must be created.

3. Vision

To create a vision is the most crucial part of the "company change" process. A vision illustrates the imaginary and desirable future of the company while keeping the objectives as feasible as possible. Additionally, the vision must remain easy to understand and easy to convey to the other members of the company (Kotter 2011, Construction Excellence Ltd 2010).

When a vision is created for innovation application, it remains crucial not to compromise company believes. If the beliefs are jeopardised, it will cause additional frustration and confusion during the execution process. A clear and focussed vision must take into account the current realities of the company status, although it is advised to be truly ambitious (Kotter 2011).

Finally, a clear, strong and credible strategy is required to execute the vision. The strategy is supposed to provide guidance to the company. The strategy is not supposed to entail the desired goals of the company (Kotter 2011).

4. Establish goals

Goals must be established over a long and short period of time to finalise the "company change" process. Each of these goals is essential for its own specific purpose.

Long term Long term goals provide a destination objective to a company strategy. It therefore goes hand-in-hand with the vision of the company. Achieving these long term goals illustrates proper management and leadership within the company. These long term goals do not simply happen and is a result of careful planning and commitment to short term goals (Kotter 2011).

Short term When long term change is applicable within an industry, short term goals and successes are essential. These goals provide guidance, ensuring that the company does not stray from the strategy of obtaining long

term goals. Obtaining these short term goals increases morale and the motivation from within that encourages additional willingness to improve (Construction Excellence Ltd 2010). Short term goals must be reasonable and obtainable within the provided period of time without being too simple that can cause the goal to loose effect (Kotter 2011). It is crucial to link the goals to the use of precast elements within projects to be able to measure the progression towards a "thinking precast" mindset.

5. Project utilisation

The movement forward for HCC within South Africa can be measured by the utilisation of pre-fabricated elements that are used, number of the different project types over a period of time and the success of the utilisation of these elements. When the goals are related to the number of projects that are constructed with these elements, the transformation becomes real (Goulding et al. 2007).

Projects allow for companies to experiment with different elements and construction methods that increase the experience of the companies involved. When projects utilise pre-fabricated elements, all the companies involved are exposed to the elements that increase the knowledge database that is required for training and ultimately industry change (Goulding et al. 2007). To orchestrate project utilisation, support from the project team is essential.

6. Project team support

When companies of the project team are exposed to pre-fabricated elements and they become intrigued and willing to promote the use of the elements, support is obtained. Support from other companies is reliant on communication between companies regarding project specifications, technical and practical issues. To obtain support from other companies in the project team, they must be convinced of the innovation's advantages as well as the implication thereof. Through successful communication, the whole project team can realise possible risks and these risks can be solved before it results in issues (Construction Excellence Ltd 2010). Throughout the process, different companies are involved that assist in the "industry change" process.

When project teams are supportive of an innovation, they will utilise it on their future projects resulting in a growth of the innovation within the industry.

7. Commitment

The commitment phase is a compilation of 4 separate processes. These processes rely on companies to constantly work on the innovation and establish techniques of improving it to develop quicker industrial change.

Firstly it is dependant on innovative companies to constantly work and improve the implementation of the innovation. Even when projects are successful at early stages, a relaxed culture can cause for resistance to emerge later in a project that results in additional problems. If the momentum of working hard is lost, regression can easily follow. Furthermore, if projects are unsuccessful, it results in disbelieve in the innovation (Kotter 2011).

Secondly, partnerships must be created with other innovative companies in the project team. These companies will be more willing to make use of innovative methods on projects because of the experience and history of previous

projects. Constant leadership is required to ensure that the transformation process does not stop within a project team, but expands to the rest of the industry (Kotter 2011).

Thirdly it relies on the post-evaluations of projects. Project teams are required to analyse projects that make use of innovation to identify risks and additional advantages (Glass 2005). These can be implemented within the company's vision or goals (steps 3 and 4).

Finally it remains essential to illustrate the successes and advantages of an innovation to the company and other members of the project team to obtain constant positivity and high morals. Management that are aware of successes will be more supportive and will promote the utilisation of the innovation within the company (Kotter 2011). Eventually, if the success of an innovation is constantly acknowledged, project teams will experience a cultural change and obtain an "innovation thinking" (HCC) mindset that results in an industrial change.

8.4.3 Model example and validation

To provide an application of the model, a simplistic pseudo example is presented: An engineering design company that is known to be an innovation driver strives to provide their clients with better quality products and requires a method to implement a quality culture in the industry. The following steps illustrate how the proposed change model can be used to improve the utilisation of HCC on projects:

1. **Realisation**
   An employee realise that HCC has the potential to improve the quality and finishes of different structural elements.

2. **Involvement**
   A group consisting of 2 employees and 2 managers is established within the company to investigate different elements and finishes that can be obtained with pre-fabricated concrete in South Africa.

3. **Vision**
   A vision is created to be the engineering company known to have innovative strategies to obtain superior finishes and structurally sound elements. The strategy is to achieve this recognition by proposing the method of HCC to the design team during the project development phase on all new projects where HCC can be utilised.

4. **Goals**
   Short term goals are the successful application of hollow-core slabs and precast façades in 40% of the projects that are procured within the next 6 months. Long term goals are to use precast elements in 80% of all industrial buildings in 5 years.

5. **Project utilisation**
   It is decided to implement hollow-core slabs on industrial buildings that do not require additional ceilings and in parking garages that require no concrete finishes.

6. **Project team support**
   Construction teams are assisted to improve the installation process. The improvement of the concrete finish on the buildings is identified and pre-fabrication is promoted throughout the construction industry.

7. **Commitment**
   Projects are analysed that were delayed due to façade or slab installation problems. Contractors are influenced to change their "mindsets" regarding the installation and construction processes because of shorter construction times and less scaffold usage. The advantages of HCC is advocated to the whole project team. The company's short term goals to make use of HCC is altered to only 30% of projects in 6 months.

Although this is only a simplistic example that concentrates on one aspect of HCC development, each step of the model can extensively be formulated to suit the "innovative company's" requirements.

The model is largely dependant on two existing models - the *Kotter*-model and the *Construction Excellence*-model. While the proposed model does make frequent reference to these models, it also includes information that are obtained thoughout this thesis. The proposed model has not been implemented on a case study to investigate its validity. It is therefore suggested that this model be investigated in research projects in collaboration with an industrial partner to investigate the practicality and to validate the model in the South African environment. If required, it can be modified to suit the specific requirements.

With the solutions provided in Chapter 7, both public clients and companies can implement these solutions in the construction industry to ensure that a HCC "mindset" is developed.

8.5 Summary

This chapter provides drivers ("innovation champions") to promote and improve the utilisation of HCC in the South African construction industry. Two main drivers of change are identified i.e public clients and private companies.

It is identified that both drivers are influenced by 4 main factors namely individual, project, industrial and organisational factors. When these factors are in favour of HCC development, it will be advocated throughout the industry.

Because clients have the most influence on the project team, they are an obvious driver of change. For this specific purpose, private clients are not included because of the lack of knowledge of these clients in South Africa. The shortage of knowledge makes it difficult to provide these clients with the required skills and training to manage the project team. Five incentives are identified for clients to utilise HCC. It is observed that these incentives are not quantified or proven in South Africa, but it is acknowledged in other countries. The incentives are as follow:

- Cost effective construction
- Labour-intensive construction
- Greener building method, more sustainable
- Improved health and safety

- Improved training

Companies that assist during the design phase (architects or engineers) are identified to have a mayor influence on the design in the South African construction industry because of current traditional procurement methods that do not allow early involvement. For this reason, contractors and suppliers are not included in this group although the effect that these team members have on a project is not neglected.

A model is proposed to assist companies to develop change within the construction industry. The model cause for change to take place in 4 areas namely personal change, company change, project change and industrial change. The proposed model is an alteration of two existing models namely the *Kotter*-model and the *Construction Excellence*-model. The proposed model is as follows:

1. Realisation
2. Involvement
3. Vision
4. Establishing goals
5. Project utilisation
6. Project team support
7. Commitment

Table 8.1 illustrates how the different steps of the model assist the different parts that are required to create industry change. The main functions of each step are provided in the table. The proposed model is not tested on a case study and its validity needs to be investigated in future research.

This chapter provides drivers that can implement the solutions in the industry to establish a HCC "mindset". The next chapter provides a summary of the conclusions and final recommendations from this study.

Table 8.1: Summary of the main functions of the requirements of each step

Part	Steps	Main functions
1. Personal change	Realisation	Become willing and enthusiastic
2. Company change	Involvement	Encourage company team, management involvement
	Vision	Clear vision with specific strategy
	Establish goals	Establish long and short term goals that are ambitious but not absurd
3. Project change	Project utilisation	Utilise the innovation as often as possible in projects
4. Industry change	Project team support	Increase project team involvement
	Commitment	Learn from projects, create supportive attitudes from within the company

Chapter 9

Conclusions and recommendations

The chapter provides the conclusions and recommendations that can be taken from this document.

Problem statement and objectives

Hybrid concrete construction (HCC) is a construction technique that makes use of both precast and in-situ concrete products in the same project. This is performed to utilise the advantages of all these products simultaneously. Although the advantages of HCC is well known, it remains under-utilised in South Africa.

The ultimate objective would be to initiate an industry "mindset" change towards HCC techniques to provide best value to every project. It is therefore critical to understand why HCC is not used more often in South Africa and to investigate what can be performed to improve its utilisation. For these reasons, the main objectives of this study are to:

- Investigate the current state of the South African construction industry by investigating the factors that influence the utilisation of HCC and inspect the current use of HCC in the country (elements, projects etc.).
- Identify the different measures that other countries have enforced to improve their HCC utilisation while concentrating on the United Kingdom.
- Identify the barriers that result in the under-utilisation of HCC in South Africa and provide suitable solutions to these barriers.
- Identify drivers that can implement these solutions in the industry.
- Develop a model that can be used by companies that can ultimately lead to an industry "mindset" change towards precast construction.

The study illustrates that the utilisation of HCC is directly connected to different project parameters. To improve the utilisation of HCC in South Africa, the following 6 parameters need to be addressed:

1. Procurement
2. Design assistance
3. Manufacturers
4. Training

5. Regulations 6. Drivers of the solutions

A summary of the conclusions and recommendations regarding these parameters is provided below.

Procurement

Because the procurement method in South Africa is structured around tendering processes and the project is designed by the employer (or employer's agents) the procurement is regarded as traditional. The current practice in the building industry is to make use of the *Joint Building Contracts Committee* (JBCC) contract document. Clients are advised here to make use of the *New Engineering Contract* (NEC) because of its flexibility although it is recognised that the well known JBCC can be amended to be equally flexible.

It is recognised that the best procedure of improving the utilisation of HCC in South Africa is to make use of design-and-build, contract management or public-private-partnerships procurement procedures. Although these procedures are not frequently used in South Africa, it is found to allow for early involvement by the whole project team and results in the best value for the client.

Tendering strategies result in lowest cost projects instead of the best value. Certain regulations in South Africa cause for the utilisation of tendering processes to allow for a fair project adjudication. Although it is advised not to make use of tendering processes, a proposed model is developed here (see Section 8.4) that allow for tendering processes and improves the utilisation of HCC by private companies.

Design assistance

When HCC projects are designed, especially the connections, designers are required to design according to first principals. Furthermore, there does not exist software packages or tools to verify or provide assistance to these designs. Software tools that assist with the decision making process are in use in other countries, although tools that assist with the design of HCC structures are not developed. Tools that can assist with the decision making process and design must be developed according to the South African conditions.

It is advised to assist designers (design guidance and software tools) especially during the early stages of the design. This can be accomplished by ensuring that procurement methods are used that encourages early involvement by the construction teams or suppliers such as these mentioned in the previous section. Additionally, software tools that can verify the final design are essential to reduce the risk of the "unknown" design. More training programmes and courses can assist designers to develop confidence to design for HCC structures and must be encouraged by the *Construction Industry Development Board* (CIDB), *South African Institute of Civil Engineering* (SAICE) and the *Engineering Council of South Africa* (ECSA).

Manufacturers

Some manufacturers are accredited according to national or international quality standards (SABS or ISO). Because the accreditation of elements are not currently compulsory and that the financial cost for this accreditation process is high, many suppliers are not troubled with the process. Manufacturers in South Africa are constructing

limited variety of element types. Furthermore, suppliers are hesitant to improve their resources because of insufficient knowledge of the precast demand of future projects.

It is recommended here that manufacturers be forced by the *Cement Manufacturers Association* (CMA) and through construction regulations to accredit their products to ensure that safe and quality products are used in the industry. Furthermore, clients and the client's agents must ensure that only accredited products are used for construction as a method of overcoming additional quality risks. Manufacturers are advised to develop construction partners and industry relationships to improve their knowledge of the future demand and thus improve their resources to manufacture additional "special" elements.

Training

The training that is provided does not stimulate the utilisation of HCC within South Africa. It is therefore recommended here that SAICE and the *Cement and Concrete Institute* (C&CI) must develop and encourage cognitive training courses that are directed towards the whole project team to ensure overall "HCC thinking". Additionally, ECSA must be responsible for ensuring that tertiary institutions implement courses to ensure that students are familiar with HCC concepts when they enter the industry.

Regulations

Regulations in South Africa that affect the utilisation of HCC are labour-intensive construction methods, green building techniques and health and safety regulations. Although HCC is known to require less labour on site, it is established that labourers within factories are provided with improved health and safety conditions and training provisions. Suppliers are encouraged to ensure that factories allow for labour-intensive construction methods and allowance should be made within the regulations to accommodate less labour on site and provide improved health and safety conditions in factories.

The *Green Building Council of South Africa* (GBCSA) is established in 2007 and makes use of 2 toolkits to accredit office and retail buildings. The GBCSA are encouraged to ensure that the toolkits that are used in South Africa are not bias and that it accommodates precast construction methods. It is recommended here to revise the toolkits that are in use and an industrial toolkit needs to be developed. Furthermore, as a method of improving the accreditation process, the star accreditation are advised here to be revised every 5 years to ensure that "green" practice continues within the company.

The health and safety of the South African construction industry is of special concern because when it is compared to other countries (areas), it has the second highest accident and fatality rate. As a method of improving the health and safety on sites, HCC is recommended because of less wet-works, less scaffolding use and safer working conditions. The *Department of Labour* needs to understand the health concerns of labour-intensive construction on labourers in the building industry and investigate precast manufacturing in healthier and safer factories as a method of maintaining labour-intensive construction even though less labour are employed.

Drivers of change

While it is mentioned that clients are the drivers of change within the construction industry, it is advised to provide these clients with additional training courses to improve their knowledge and managerial skills. It is recommended that public clients are suitable drivers, because sufficient knowledge is available of these clients and therefore the provision of training would be easy. Public clients are advised to drive change towards HCC in South Africa due to 5 incentives:

1. Cost effectiveness
2. Labour-intensive construction within the factories
3. Greener building method resulting in a more sustainable project (if the GBCSA accredits the green effects of precast construction)
4. Improved health and safety conditions
5. Improved training for factory labourers

Furthermore, it is recommended here that companies should be the drivers of change because of their insight in the construction industry. Companies that are involved with the design process of a project are targeted to encourage earlier change towards HCC because of the traditional "employer design" procurement method that is currently used in South Africa. Innovative companies are provided a proposed change model to encourage and assist with the transformation process. Additionally, companies can drive a movement towards HCC even though tendering adjudication processes are used in South Africa.

Proposed change model

The change model that is proposed here allows companies to accommodate change towards HCC development although the circumstances are not ideal for HCC (for example procurement methods, regulations etc). The proposed model takes into account that designers can influence the design towards HCC while encouraging best practice and best value for the project.

The model consist of 7-steps that results in 4 different "change processes". Firstly, a process of personal change will encourage company change if it is driven with sufficient leadership. With adequate support from the company, the changing of the construction method will be reflected in projects that can ultimately lead to industrial change. The seven steps of the change model are:

1. Realisation
2. Involvement
3. Vision
4. Goal establishment
5. Project utilisation

6. Project team support
7. Commitment

Although this model is a combination of different change concepts and change models, it has not been validated in the industry with a case study. It is recommended that companies that are enthusiastic to change their construction methods and provide best value to projects, adopt the model and drive the industry to improve the utilisation of HCC and develop an industry "mindset" change.

Suggestions for future research

The following suggestions are made as a result of this investigation to improve the knowledge of HCC and the construction industry of South Africa.

1. **Standard elements** (Section 5.3)
   During the investigation, suppliers argued that standard beam or column elements do not exist and therefore it cannot be made in a similar manner as slabs. A study is required to investigate the possibility of designing standard beam or column elements (similar to lintels) that can be made in factories and altered slightly on site. These elements can be designed and prescribed according to loading capabilities, similar to precast slabs. If these elements can be constructed, standard elements can be mass produced and provided to sites.
2. **Training programmes** (Section 7.4)
   During this investigation, it was found that the training provided to the industry is not sufficient to improve the utilisation of HCC. Research is required in close collaboration with the CMA and SAICE to investigate the type and content of training programmes that are required to educate the construction industry with regards to HCC.
3. **Software packages and tools** (Section 7.4)
   Software packages and tools that can assist with the decision making process such as *HyCon* or *IMMPREST-LA* needs to be developed. Furthermore, tools such as *Prokon* that are able to assist with technical aspects of the design such as the connections need to be developed according to the South African standards. The C&CI can develop these tools because of their involvement in the construction industry.
4. **HCC database** (Section 7.7)
   The database that is created in Chapter 4 needs to be elaborated and extended with more South African HCC projects and presented by the C&CI to the construction industry to increase the exposure of precast construction.
5. **Weighting function values** (Section 7.8)
   An investigation needs to analyse the different advantages and barriers of HCC and establish the weighting functions of each item. These weighting functions can then be used to establish the country's acceptability (that can be translated to the project's acceptability) of HCC.
6. **Proposed model validation** (Section 8.4)
   The proposed change model for companies needs to be validated with a case study. The validation will

confirm whether the proposed model is a suitable change model within the construction industry.

From this study, the solutions to the barriers can ultimately improve the utilisation of HCC and the construction industry as a whole in South Africa.

Chapter 10

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Appendix A

Interviews and correspondence with project team members - South Africa

Interviews

The following persons were interviewed (only interviews and e-mail correspondence are displayed in this Appendix):

Andriano Angelucci	*Cobute concrete building technology*
Herkie Bouwer	*Department of Public Works - Western Cape*
Jarrod Lewin	*Green Building Council of South Africa*
Mervin September	*Topfloor*
Michael Bennett	*Sutherland Consulting*
Nico Geldenhuys	*Bobcrete*
Paul van Rooyen	*NMS Specialised Precast Elements cc*
Steven Chambers	*NMC Construction*
Terence Bergmann	*HHO Africa*

Date: 25 April 2010 @ 14:00

Terence Bergmann

Company: HHO Africa Consulting

Profile: Geotechnical engineer

E-mail: terence@hho.co.za

Address:

HHO Africa

14 Bree Street

Cape Town

8001

1. **Why do you think is there such a shortage in the utilisation of pre-fabrication in South Africa?**
   In South Africa it is not seen as an economical building method. There are limited suppliers that manufacture pre-fabricated elements.

2. **Are you currently involved in any projects**
   We are currently involved with the construction of the *Koeberg Interchange*. It is the intersection between the N1 and the M5 in Cape Town. *HHO Africa* is the engineering consultants on this project and *Power Construction* and *Group 5* have formed a joint venture as the main contractors. New off- and on-ramps are built between the N1 and the M5. This includes new bridges and extensions of existing structures.

3. **Can you be more descriptive regarding cost, time and size of this project?**
   The *Koeberg Interchange* is subdivided into different phases. The first phase (R800 million) will be constructed from June 2008 to June 2010 to ensure limited discomfort during the 2010 World Cup. The structure itself consist of 150 pre-stressed U-beams (35 m long) and 150 pre-stressed T-beams. The construction of the U-beams amount to 10% of the total cost. The project is a *Western Cape Provincial Government* project.

4. **Describe the tender procedure - what method was used to procure this project?**
   Before the tender procedure started, contractors with a grading of 8 or higher were invited to attend a briefing. During the briefing, the contractors' opinions were asked regarding buildability, crane capabilities, precast design and construction sequence. This was required to ensure that the project was not impossible to build and to see the willingness of contractors to construct to the innovative building technique. After this process, final designs were completed and a normal open-tender procedure was used to procure the project.

5. **Would you recommend this method to obtain information for other projects?**
   Yes and no. By inviting the contractors, we were able to understand their capabilities. This ensured that we designed elements according to their recommendations. By involving the contractors at an early stage helped them to understand the project and it helped us with more practical matters. It must be said that it

was time consuming, but it is advised for projects of this magnitude.

On the other hand, I do not believe that it is feasible to undergo this kind of investigation with smaller projects. With smaller projects, the designer is usually aware of contractor's capabilities and do not need to investigate it. If the project is more complicated or new technology is recommended, such a procurement strategy is advised.

6. **Why did you choose using pre-stressed precast elements?**
   The main reason was to save time. While preparations were taking place on site, the elements were constructed on a separate precast yard close to the site. Both processes occurred at the same time without any loss in time. By making use of the precast elements, the site remains cleaner and there is no need for additional shuttering during installation.

7. **Did you experience any difficulties with the fabrication of the elements or with the structural systems?**
   All the issues were due to the abnormal spans and size of the elements. We fabricated the elements on our precast yard. No South African company was able to pre-stress the beams for us. We contracted a company from England to pre-stress the elements.

   Another issue was the transportation of the elements. A special carriage was constructed by the contractors to transport these elements from the yard to the site.

   Cranes were required to lift the elements to their specific position. Tandem lifts were not covered by the assurance should these elements be lifted. With the *Gautrain* project attracting significant attention, most cranes of the required size were used on that project. From what we were aware of only 2 cranes in South Africa were capable of lifting these proposed large elements alone. It became quite a logistic issue to ensure 1 of the 2 cranes to be used at our project.

Date: 25 April 2010 @ 15:30

Steven Chambers

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1. **Give a brief overview of NMC?**
   We are the biggest private construction company, although we are mainly based in the Western Cape. We are currently expanding to the Eastern Cape and Kwazulu-Natal. We are a construction company, but we strive to work on design-and-build as well as turnkey projects. Currently, 40% of our work is design-and-build, with *Granbuild* being our biggest competitors on this front.

2. **In what type of projects do you make frequent use of precast elements?**
   It is mainly used in office blocks, parking blocks and fireproof walling.

3. **If possible, supply me with details of such projects? (contract period, contract amount, percentage of total concrete used were precast)**
   Typical the projects are 6–12 months contracts. The contract amounts differ greatly so I will not be able to supply you with that information. The percentage are unknown, but we try using precast slabs and precast beams on as many projects as possible.

4. **How do you find working with precast elements?**
   It is a much faster and neater building method that produces less waste on site.

5. **Are there any elements you do not want to work with anymore?**
   We used precast columns on one project. The detailing of the connections to the base was unclear and it resulted in additional and unnecessary expenses. I would not build with precast columns except if the detailing of the connections are clarified and simplified.

6. **How did working with precast elements benefit the construction phase (positive or negative)?**
   Positive - speed, quality control improve, costs, house keeping, scaffolding, waste. Negative - flexibility is less than for in-situ, cannot change designs, detailing of columns.

7. **Do you make use of a specific precast suppliers or do you make your own elements?**
   We usually make use of a local supplier in Cape Town. They are also able to manufacture non-standard elements. We fabricate beams on site if required in the design.

8. **Do you think there is a shortage of knowledge or expertise concerning the use of precast elements in the construction industry and how can that be changed?**
   No, it is a better product for the client; skills are in place to build with it. In fact, less skill is required to build with these elements because the suppliers install the elements.

9. **Why does NMC use precast concrete? Is it enforced by the client or is it your own initiative?**
   No, NMC use precast because it is a better product for the client. It is easier to work with and it proved to deliver a good end product. It is a cost effective building method.

10. **What caused NMC to embrace the use of precast elements (the change in mindset)?**
    NMC has done several studies on different precast construction methods and products (such as tilt-up) and will be able to deliver such products to innovative clients.

11. **What is NMC's involvement in improving the precast construction industry?**
    We are involved with several concepts to improve structural systems. One such a system is to improve the utilisation of tilt-up panels within the Western Cape. We have financed many programmes to increase the image of tilt-up in the Western Cape and we even casted several wall sections as demos for clients. Unfortunately, to date it is not being used by clients.

    We invested in a mobile-staircase machine that can be delivered to a site to manufacture precast staircases according to the project specifications.

12. **How has the procurement method affected the utilisation of precast elements in projects?**
    Contractors are generally not included during the design phase. When construction starts, the contractor may find that utilising precast elements might be beneficial for them. Unfortunately, if the contractor decides on using precast elements, the consultant must redesign the structure to incorporate this change - this usually takes additional time resulting in the contractor to ignore the use of precast elements (for longer contract periods, the new design may not influence the total progress). Being involved from the start of a project allows us to provide input in the design and alter the design towards precast concrete construction.

13. **What influence does the government or labour-intensive construction have on the use of precast elements?**
    It does not really have an influence on the construction method. The frame does not amount to the biggest part of the project. Usually it is just the outer frame that is pre-fabricated and the internal work can still be labour-intensive to comply with the regulations.

14. **What can be done (from the start of a project - design phase) to encourage the use of precast elements in such a way that it will benefit the whole project team?**
    The only way it will be improved is to ensure that the whole project team is aware of the advantages of precast construction and contractors must experiment with different elements to ensure that they are capable of utilising it.

Date: 05 July 2011 @ 9:30

Andriano Angelucci

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1. **Describe your precast systems?**
   We fabricate a type of rib-and-block system that is imported from Italy. The ribs can span up to 8 m, without any problems. Slightly different to normal rib-and-block system, we make use of *foamalite* as a void filler and by varying reinforcement heights we can create slabs of different thicknesses. This floor system is generally used within South Africa up to the 3^{rd} floor.

   We are able to manufacture staircases and foundation products that are constructed in a similar manner.

2. **Who designs and installs your products?**
   Usually the client or architect request our designs. We have an out-of-house consultant that designs the systems for us. We are either contracted to install the elements ourselves or to supply the systems. When it is required to install the elements ourselves, we sub-contract it to a contractor that is trained to install the system correctly.

   Contractors that install the system themselves are supported by our team for a couple of hours until we are sure that they will be able to install it correctly. During the past 3 months, almost 90% of our products were installed by our sub-contractor.

3. **Are your products SABS/SANS or ISO accredited?**
   We design and manufacture the products according to these standards, but we are not accredited by these standards. The cost involved to be accredited is not worth it because it is not a requirement in South Africa.

4. **How are the products made - is it with labour-intensive methods or machinised methods?**
   We have labourers inside the factory that are responsible for bending and welding of the steel to the appropriate shapes and sizes for the ribs. We used to employ 28 factory labourers, but due to the low season we are down to 6 workers. Factory workers have a overhead crane to transport the reinforcement or other heavy materials throughout the factory. The concrete is not made on site.

5. **Is there any training provided to the labourers?**
   We make use of in-house training programmes. The labourers are trained in a 7 months. The training includes the reading of drawings, process understanding, manufacturing processes and installation processes. No out-of-house training is provided to the labourers and therefore no certificate of compliance can be awarded to them for their training. Training is an ongoing process and we spend numerous hours training these labourers to ensure they understand their duties. The labourers find it encouraging to gain experience of the process and elements.

6. **What health and safety precautions are in place to protect the workers within the factory?**
   Signs and posters are visible throughout the factory to constantly remind the labourers of their personal-protective-equipment (PPE). All the machines that are used are imported from Italy and are equipped with emergency "STOP" and protective covers over the moving parts.

   Our company has been in operation since 1993. To this day, we did not have any critical injuries or fatalities.

7. **Are your accredited at any environmental organisation such as Green Building Council?**
   No, we are not registered at any of these organisations. Again, the financial cost involved with the accreditation process does not make it feasible.

8. **Do you believe you have "green" products?**
   Our systems work on the basis of using less concrete. Compared to normal in-situ construction, we use 50% less concrete. We require no shuttering on site, only propping resulting in less timber to be used. Inside our factory, we make use of steel shutters that can be used for several years without replacement. Due to the foamalite void filler, our systems require less concrete and thus less transportation is necessary.

9. **Do you have any limitations regarding delivery distances?**
   No, we deliver our products to any destination. The distance that must be traveled will be allowed for within the price per unit when we provide a quote for our systems.

E-mail correspondence

Date: 16 March 2011 @ 16:59

Paul van Rooyen

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1. **You are manufacturing different elements than the traditional panels or slabs. Can you elaborate on the elements that you are able to construct?**
   SPE (NMS Specialised Precast Elements cc) is not a very big company, but we do have two factories. The one manufacture and install the façade panels for high rise buildings while the other factory manufacture and install other structural elements. We also manufacture more traditional elements such as channels, cappings, window-sills etcetera.

2. **Is there a market in South Africa for different elements such as façades, beams or columns?**
   The market for façade panels have decreased over the years due to alternative façade materials that became quite popular for architects. The construction market for new buildings has decreased over the years. I believe that the future of pre-fabricated elements lies in the design, manufacture and installation of structural elements.

   Unfortunately a lack of skilled artisans to produce in-situ elements within the required tolerances are becoming a major issue when pre-fabrication of concrete elements are considered. Elements such as staircases are known as typical traditional elements and can easily be manufactured in a factory, although additional effort is required to manufacture it on-site.

3. **Many contractors would rather manufacture the special elements themselves. One reason may be because contractors believe that manufacturers do not have the resources to manufacture such elements. What inspired SPE to invest in the required resources (machinery or carpenters)to be able to manufacture such a wide range of elements? Is SPE subsidised by a construction company or the government?**
   SPE is renowned for making *special* elements that are not easily obtained. We mainly work with the larger construction companies that approach us with queries about strange precast concrete elements. We design and manufacture the moulds internally. We are an independent company and no shares belong to external institutions.

4. **Is SPE a design-and-install company or can engineers supply you with the drawings to manufacture the elements while the contractors install the elements?**
   We do our own designs, but we do manufacture elements from provided designs and specifications. We install the elements if it is required, but we prefer it if the elements are installed by a different contractors.

South Africa has a problem with traditional methods where the professional team of architect and engineers design buildings and then it is constructed by a contractor. At that time, it is usually to late to consider precast alternatives. The only method to change this process is to develop a *design-manufacture-install-manage-project* for structural buildings. The process is similar to a contract management projects where a consortium manage the whole project. This does amount to high capital investment to obtain the right professional team to operate the business or consortium until it is self-sustainable. The large investment may be the reason why it is not used in South Africa.

5. **Elements such as lintels are sold in bulk from the shelf. Will SPE manufacture standard structural elements such as beams or columns for contractors to purchase? If so/not, for what reason?**
   My experience has shown that there is not something such as a *standard* beam or column. The cost of the moulds on these elements is not that expensive and can easily be adjusted without additional costs. For this reason it is easy to manufacture the elements for the specific purpose and thus additional storage or marketing is not required.

6. **A benefit of precast concrete is that it requires less labour on site. Unfortunately in South Africa, labour-intensive projects are promoted. What is your opinion on the process of promoting precast concrete and minimising labour on a project?**
   This is an extremely sensitive issue in South Africa. Many local authorities has given orders not to use precast concrete because it is not labour-intensive. Nothing can be as wrong. Pre-fabricated concrete requires just as many if not more labour within the factories. These labourers need to be trained to obtain higher skills levels than on sites.

7. **What type of training is provided to the labourers at SPE?**
   We employ the following labourforce that are trained both internally and externally:

   (a) Mouldmakers - they must be able to read drawings and be able to manufacture moulds with timber, steel, gypsum, concrete, fiberglass or silicone.

   (b) Operators for tower cranes, mobile cranes, gantry cranes and crane trucks as well as the banksmen that accompany the operators during construction.

   (c) Steel fixers

   (d) Concrete mixing, casting and finishing labourers

   (e) Dispatch clerks

   (f) Truck drivers

   (g) Contract and project managers

   (h) Factory managers

   (i) Storekeepers

8. **Is SPE accredited according to ISO or SABS standards?**
   No, throughout the 30 years that I have been in the pre-fabrication industry, not one project pre-requested these standards. This accreditation may become more important in the future.

9. **Due to patent rights, manufacturers cannot produce similar elements as their rival companies. This cause for slower movement towards a transformed construction industry. What is SPE's opinion on patent rights (if applicable)?**
   I was involved with the development of a patent for a window- and doorframe. If I am required to undergo the same process, I would not go through the effort and costs to patent a product in this industry. The solution would be to manufacture a more effective and cost efficient product to obtain the competitive advantage in the market.

Date: 11 May 2011 @ 19:00

Inba Thumbiran

Company: Construction Industry Development Board
Profile: Programme manager: Procurement and delivery management
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Sent E-mail: 11 May 2011

Good afternoon Dr Marx and Ms Thumbiran

I have recently read the "CIDB construction industry indicators" for 2010 and the "CIDB Procurement and Delivery Mandate" as part of my thesis research. What I found while reading many of these CIDB surveys was many instances where training was promoted (for both contractors and private and public clients). I realise that Sirs Latham and Egan promote it as well especially for the clients.

What I would like to know is: Do you know of any research/surveys/reports that illustrate the amount of recurring clients in the private sector?

I thought that you might be of assistance due to your involvement in these and similar surveys.

The concept that I would try and portray is a method to improve or train public sector recurring clients in terms of procurement or construction as a whole rather than to invest in the private sector that is constantly changing. For my thesis, I am focussing on increasing the use of hybrid concrete construction in South African - one barrier is the lack of training of the clients and the project team.

I would really appreciate some feedback or references from you.

Thank you very much
Regards

Rojean Hanekom
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Received E-mail: 15 May 2011

Hello Mr Hanekom

Although the CIDB Act extends to the private sector, we have not focused on this sector, only because of the magnitude of the problem we face in the public sector. You will find that our regulations and "Standard for Uniformity" are geared to public sector reform.

We have commenced with an arduous campaign to get client compliance on track (see attached gazette notice). This is a huge task, and an expensive one too! The campaign will initially focus on public sector and then begin a focus on the private sector. However, there is much work to be done with private sector stakeholders before we commence that phase.

A short answer to your question below is "No". We do not as yet have list of private sector clients.

I would be appreciated it if you kept in contact with my office, should you have any information to share in this regard.

Kind regards

Ms Inba Thumbiran
Programme Manager: Procurement & Delivery Management
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Date: 11 August 2011 @ 14:34

Jarrod Lewin

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1. **What is the benefit of being accredited according to the star rating?**
   There are numerous benefits that arise from both building (and retro-fitting) a "green" building and achieving a Green Star South African certification. Please see below for some of the benefits Green Star SA certified projects have the potential to enjoy:
   - Lower energy consumption
   - Reduced water consumption
   - Lower operating costs
   - Vastly improved indoor environmental quality - which has been intrinsically linked to long-term productivity, increases and staff retention, as well as general increases in wellbeing.
   - Improved building management structures
   - Industry leaders are acknowledging that "non-green" buildings will suffer from a loss of a competitive advantage in coming months and years. This will transpire through to both directly and non-directly held assets.
   - Marketability - Marketing leverage has been a highly acclaimed benefit for Green Star South African certified buildings.
2. **To date, no regulations enforce a builder owner to be accredited according to your accreditation, is that maybe something that will be enforced in coming years? If accreditation is enforced, I would think that the project team and builder owner will investigate and implement more "greener" building methods**
   Green Building Council of South Africa (GBCSA) is a completely voluntary system and will continue as such into the foreseeable future. The GBCSA prefers to influence the market by illustrating the virtues of "best practice" rather than making GBCSA a mandatory certification process. Should sectors of the market decide to make GBCSA certification mandatory within their own spheres however; the GBCSA will wholly support them.
3. **Are there any developments for an "operation-toolkit" for industrial factories?**
   GBCSA is a base-building tool (for now, interior and performance tools will follow in time) and as such is not equipped to certify or assess processes or operations. The GBCSA isn't equipped to deal with this matter, even though we agree with the sentiment that the South African market will benefit from such a service.
4. **For clarification, the accreditation is never audited by means of reports, except for the mandatory annual report that must be provided at the end of the first year of operation?**
   Any awarded GBCSA certification is not audited. The GBCSA trusts that project teams will continue with

the sustainable interventions they have initiated and continue to reap the benefits therefrom. With all the benefits that are had from retaining efficient designs and operation, why would a project team choose to discontinue this?

That said, the GBCSA is contemplating reviewing how certifications are managed going into the future.

5. **Can you be awarded points for activities that occur off-site that will be transported and used on the project? An example would be of precast construction that does not make use of timber shuttering. If a precast supplier can manufacture slabs without timber and deliver the products to site, you can be accredited according to MAT-10**
   For MAT-10, and dependant on the resource in question - projects either to need to establish a reference case (to illustrate a reduction in resource usage) or convey a dual use. The circumstance you point out would not adequately meet the credit criteria for MAT-10.

6. **Can you achieve double points where some of benefits overlap different rating criteria?**
   GBCSA takes this into careful consideration and as such, no, projects are not eligible to be awarded more than once for one initiative. Do take note of the fact that various Green Star credits are intrinsically linked and a certain amount of inter-relatedness do exist. This relationship can bring about both positive and negative point feedbacks. The occurrence of this however, is largely project dependant.

7. **Points are awarded for contractors being ISO 14001 accredited (MAN-6) - does this include sub-contractors or suppliers as well or only the main contractor?**
   ISO 14001 accreditation is prescribed for the Main Contractor only, but it is expected that sub-contractors adhere to the principles set up therein. Again one would question why they would not? GBCSA Technical Manuals do set up the ability for projects to make use of ISO 14001 alternatives, where appropriate.

8. **What is the GBCSA's opinion on items that do affect the "greenness" of a project that are not accounted for within the toolkits? Items such as emissions of material delivery and transportation or less waste generation during construction are not accounted for within the toolkit.**
   As mentioned before, GBCSA is a base-building tool in its current form and does not provide a "silver bullet" solution to all sustainable or building concerns. The GBCSA acknowledges, that there are indeed factors that need addressing, but these currently fall outside of the scope of GBCSA rating tools and need to be dealt with by future endeavours and/or through other channels in the property or construction sector.

9. **Can you think of any other items that precast construction can be awarded points for?**
   Project teams need to consult the GBCSA rating tools and technical manuals for guidance and assistance in where and how their desired design initiatives may be rewarded. The GBCSA is careful to not endorse nor promote the use of any particular product or service, instead we allow project teams to design and construct at their own will and GBCSA will reward them where they have met (or exceeded) the benchmarks prescribed by the tools.

Appendix B

Interviews and correspondence with project team members - United Kingdom

Interviews

The following persons were interviewed (only interviews and e-mail correspondence are displayed in this Appendix):

Prof. Alistair Gibb and Chris Goodier	*Loughborough University*
Charles Goodchild	*The Concrete Centre*
Colin Nessfield, Dr Hafiz Elhag and James Fudge	*British Precast Organisation*
Dr Jacqui Glass	*Loughborough University*
Janet Campbell	*ACT UK Simulation Centre*
Dr Kamel Bensalem	*Bison Manufacturers*
Dr Kim Elliott and Sarakot A. Hasan	*University of Nottingham*
Dr Simon Bailey	*Andrews Associates*

Date: 16 March 2011 @ 15:00

Dr Simon Bailey

Company: Andrews Associates

Profile: Consulting Engineer

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1. **What precast systems are you using?**
   We make use of floor systems. There are no standard sizes for beams, therefore it is not being used. We do make use of rib-and-block (beam-and-block) on ground levels because of the suspended floor principal that is required in United Kingdom. Reinforced slabs and hollow-core slabs are frequently used with steel frame buildings.

2. **What type of projects are you focussed on?**
   The company is mostly involved with small jobs that consists of school extensions, residential buildings etcetera.

3. **Do you make use of design-and-build?**
   No

4. **Do you have any governmental projects?**
   All the projects are for private clients. We do not have any governmental projects.

5. **Who is responsible for installing the pre-fabricated elements on site?**
   The supplier installs the elements and it is priced for the supply and installation as well. The panels are from Ireland but they do have mobile installation teams that assist during installations.

6. **How does the consultant ensure that minimal changes occur within the project?**
   The projects that are applicable for the company is not really undergoing many changes. The extensions are mainly for private schools. Because we build small buildings, the changes are minimal.

7. **Do you make use of public-private-partnership?**
   In the United Kingdom, it is called a "private-finance-initiatives" (PFI). It is being used, but we are not too familiar with it. We do make use of "cost plus" contracts where a performance specification is provided to the client. The contractor has to provide the client with an initial price. When items are used that are not

covered in the bill, the contractor needs to provide competitive pricing on the items (at least 3 competitive prices) for the client to approve.

8. **What contract document do you use?**
   We make use of the NEC document. It is chosen by the quantity surveyor.

9. **Do consultants design for in-situ or pre-fabricated systems?**
   It is preferred to design for precast instead of in-situ. The consultant designs for precast based on the loading tables. The final design is still done by the precast manufacturer. It is always cheaper with precast, then rib-and-block (1^{st} floor) and only then in-situ.

Date: 17 March 2011 @ 14:51

Charles Goodchild

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1. **What is the history of HCC in the United Kingdom?**
   HCC was used for a very long time especially for the construction of housing projects after the World Wars. Unfortunately it was used without the right security and with "cowboy" building methods. In 1968, the multi-storey "Ronan Point" building collapsed. This caused for an intense investigation in the building codes and pre-fabricated construction. Ever since the "Latham" report, it was used again, but with much better regulations and precautionary measures.

2. **Why is the use of HCC so limited for instance with façades?**
   Architects use different building materials such as glass for façades.

3. **What is your opinion regarding the Latham and Egan reports and the implementation thereof?**
   Latham made very realistic conclusions while Egan wrote his report from a client's perspective, making it very unrealistic. It did provide for less antagonism - in the past, clients were pressured for money due to variation orders, but it has been limited now.

4. **What contract procurement strategies are used throughout the United Kingdom?**
   The tendering process is slow and is only used on $^{1}/_{3}$ of all works. Most projects are done by a construction management team. Clients consult a construction management group or consortium that consist of specialist companies. The client is provided a fixed price before the contract for all the work. The main contractor must ensure that the project is constructed within the given tender value. An issue is raised though - during a project (around 30 years) the client does not have to attend to any maintenance work. After the contract, the client needs to set actions in place to continue the maintenance of the project. The government prefers this method of contracts in the United Kingdom.

5. **What are the main adjudication criteria used during the project procurement process?**
   Private clients just look at cost and time, while public clients can pay for sustainability as well. The project must be politically correct as well (in line with governmental targets - green projects). Eventually projects

are procured according to cost and time while sustainability has become more prominent.

6. **Why are you so pro-design-and-build?**
   The prelim design is 90% complete before it goes to tender. For this reason, late changes are minimal. Design-and-build allows for early involvement from the whole project team, allowing contractors to assist with the design process.

Date: 18 March @ 10:00

Janet Campbell

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1. **Explain ACT-UK?**
   It is a training institute that forms part of Coventry University, but it's operation is completely on its own. The training centre was constructed with financial assistance from both private and public resources and amounted to £8.7 million. *ACT-UK Simulation Centre* is the United Kingdom's first virtual reality training facility for the construction industry - and only the second of its kind in the world. Engineers and builders are now making use of the training centre to improve their leadership skills. The institute is supported by the United Kingdom's construction industry.

   The facility includes an enhanced form of simulation training method that makes use of highly-skilled actors and a virtual reality auditorium comprising of a 12-meter panoramic screen and realistic site conditions. A 4-D simulation projection on the screen enables trainees to navigate through every aspect of a building project recorded from real projects.

2. **Please explain the training process?**
   The trainees go through 3 processes. 1^{st} - The briefing where the trainees are briefed of their assignments, 2^{nd} - they are place in a simulation location with a 4-D modeling system, 3^{rd} - post simulation feedback is provided to assist the trainees with improved methods of working.

3. **Is the centre a successful training institute?**
   The companies that provided funding to construct the facility make extensive use of the centre, but because it is quite an expensive method of training, it is unsuitable for all companies. Companies that do make use of it provides very positive feedback.

4. **Who makes use of the facility?**
   Universities - Birmingham, Coventry, UWE (Bristol); Contractors - more for site manager level of training.

Date: 21 March 2011 @ 10:00

Dr Hafiz Elhag, James Fudge, Colin Nessfield

Company: The British Precast organisation

Profile: Research Institute

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1. **What are the types of systems you find in the UK?**
   We are frequently making use of steel and precast systems. Designers are very well educated in this regard. The steel industry has developed sufficient training tools to improve the use of steel construction.

2. **Are design-and-build frequently used?**
   It is mostly used for housing projects and other mass production projects. Construction management are used for more complicated projects.

3. **Do you have any involvement with the training in the construction industry?**
   A precast design course is set up and will hopefully be implemented at universities consisting of 12 classes. The *Construction Plant Competence Scheme* (CPCS) provides for skills development in line with the ISO 9000 series. The *Construction Design and Management 2007*(CDM) regulations provide for a code of practice for the installation of precast elements, crane operation etcetera. We have established the *Construction Targets 2015* originally launched in 2001 to support the government led *Revitalising Health and Safety* initiative.

4. **What is your involvement with the health and safety of the construction industry?**
   RIDDOR is a health and safety scheme. It is implemented by means of monthly meetings with all registered companies (registered with *The British Precast* organisation). The meetings are arranged for the sharing of information with representatives of the government and *The British Precast* organisation. Companies provide health and safety statistics for a construction database. In the process of sharing, the company is rewarded by means of a rating system if it is aligned with the *RIDDOR* targets. Companies are required to confirm their obedience to the health and safety standards that are applicable to all construction companies.

   We have found through these meetings that during the recession periods people try harder to perform and become a hazard on site due to faster and longer working hours. With the economy improving, new workers are employed and the untrained labour cause more accidents. Figure B.1 is a typical curve that illustrates this behaviour.

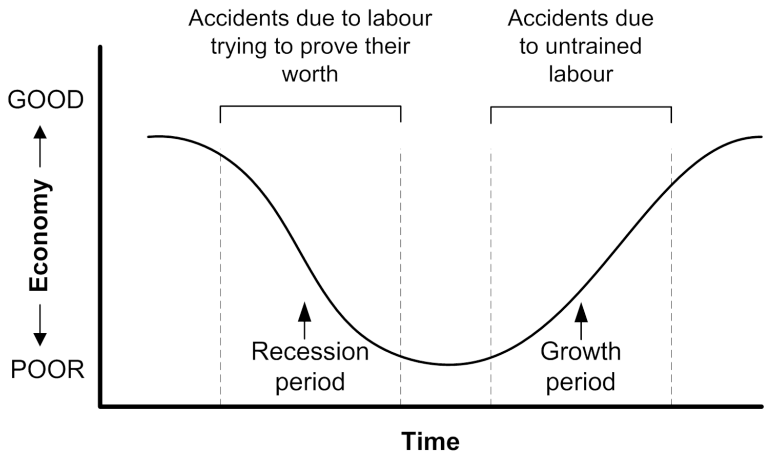

Figure B.1: The occurrence of accidents during recession periods

CHARGE is another initiative across all industries that aims for industry improvement through peer meetings.

5. **How did you initiate these initiatives?**
   It was important to get the health and safety representatives of companies involved in these meetings. It was difficult for the industry representatives to discuss their health and safety problems with *The British Precast* organisation. At first it was very competitive that resulted in the representatives to be hesitant to provide feedback of their experiences. Later, the health and safety statistics of the companies improved and the benefits of the sharing of knowledge was realised. Minutes of all the situations and examples mentioned in the meetings are distributed to all of the registered companies. Some sensitive cases remained anonymous even on the minutes. The sharing of information has proven to improve the health and safety on sites and it ensures that the industry does not work in isolation.

6. **We were told that precast construction was always cheaper than other construction methods. How is that possible?** When the cost of precast is evaluated, it must be a holistic analysis to other construction materials and methods. Usually, the industry only compares element cost which is incorrect. Several items such as a reduction of waste, rejection of material or installation processes must also be analysed to ensure a holistic comparison.

7. **What are some of the selling points for the government?**
   Local material and labour is used for the manufacturing of the precast elements. Through the use of pre-fabricated elements, less waste is generated.

8. **Very positive statistics were provided regarding your construction industry, does the Olympic Games 2012 influence your statistics?**
   No, all the infrastructure is already in place in the country resulting in limited large construction projects to be built.

9. **What has the United Kingdom done to ensure greener construction projects?**
   The *Green Guide* forms part of *LEED* but it is focused on construction products.

10. **What is the government's involvement with The British Precast organisation?**
    The government set targets and *The British Precast* organisation ensures that these targets are achieved. This is obtained through different schemes, regulations or research. Some of the methods are the *Modern Methods of Construction* programme or thermal protection and sound insulation regulations. *The British Precast* organisation is the conduit between the government and the industry.

Date: 22 March 2011 @ 10:00

Dr Kim Elliott and Sarakot A. Hasan

Company: University of Nottingham

Profile: Ex-lecturer and researcher at the university

Address:

Department of Civil Engineering

University Park

University of Nottingham

NG7 2RD

1. **Do you provide any courses that improve pre-fabrication and what are the expected outcome of these courses?**
   The current courses to the industry are more focussed on hybrid structures. The courses consist of steel frames with concrete claddings and floors because of the huge market for steel structures in the United Kingdom. Training courses are provided for the graduate students on precast design and construction. The industry does not provide the means to provide training to the established markets.

   One course that is presented by *Kim Elliott* comprises of design, manufacturing and construction, stability, connections, progressive collapse as well as a practical design exercise. The course is for young engineers that start their careers or are in their mid 20's.

2. **What are the concerning issues regarding the design of precast construction?**
   The main aspects to take into account are the structural stability, connections and sequence of construction. For precast construction there is no standard connections. The shortage of standard designs make precast design similar to that of steel connection design. For steel connection design, software packages are available to assist during the designs. For the precast design, such software packages do not exist. *Tekla* is planning on making 6 general connections for precast systems and will hopefully be able to implement the design into a software package.

3. **Is there a market for the hybrid concrete construction regardless of these design difficulties?**
   There is a market for hollow-core slabs on steel structures or rib-and-block systems with brickwork. A market is available for the projects that require architectural features.

4. **What are the technical aspects that need to be thought of during designs?**
   The main aspects are:

   - Rather use long spans precast floor panels spanning onto shorter spanning beams.
   - Precast will give a smaller carbon footprint and is especially useful with tall buildings.
   - With column to column design, make the connection halfway between the two floors where the column's moment is zero.

5. **Why does the industry need to know how to design for precast if a supplier is responsible for the final design before it is presented to the contractor?**
   Designers usually design to establish the size of the elements that need to be used. This is necessary to predict the loads on other structural members.

6. **Who is responsible for the installation of the pre-fabricated elements?**
   In Italy they make use of buy-and-install and buy-to-install methods. The supplier can be responsible for the elements as well as the installation or only for the supply of the elements if the contractor installs the elements.

7. **You have written a book on precast design, can you elaborate?**
   The book is called "Precast Concrete Structures" by Kim S.Elliott. It is published by "Butterworth Heineman".

8. **Any other useful information?**
   During my research I made a study of the labour compared to the precast use. A C-factor was created:

$$C_{factor} = \frac{£of labour/day}{£of 1m^3 concrete/day}$$

   Although the results were not scientific, it showed that two trend lines exist in the world. The more expensive labour is on sites, the more precast is used in the industry.

Date: 23 March 2011 @ 11:00

Dr Kamel Bensalem

Company: Bison Manufacturers

Profile: Design engineer at manufacturing plant

E-mail: concrete@bison.co.uk

Address:

Gresley Park

William Nadin Way

Swadlincote

Derbyshire

DE11 0BB

1. **What is your turnover time - from receiving a project to installation of the elements?**
   During low seasons we are able to install within 3 weeks, while in the high season we usually complete the work within 8 weeks. The times include the approval of drawings, manufacturing and installation of elements.

2. **Bison makes use of several connections between elements. Are these connections patented to Bison or is it a general connection?**
   The connections and interlocking mechanisms are all standard and specified by the designer.

3. **As a leader in the pre-fabrication industry, do you have any competition in the country?**
   The four major pre-fabrication companies in the United Kingdom are Bison, Hanson, Tarmac and Milbank.

4. **What is Bison's history?**
   Bison use to have 4 factories. During the recession 2 factories closed down and a construction company called *Laing o'Rourke* bought the company. *Laing o'Rourke* has a vision to implement precast concrete in as many of their projects as possible.

5. **What is your responsibility towards insurances of your products?**
   It is stated in contracts that Bison is only responsible for their products and not the connections or the installation thereof - if the contractor prefers to install it themselves.

6. **Does Bison make elements in advance for possible incoming projects?**
   No, Bison works with the just-in-time (JIT) principals and therefore does not manufacture any elements to be stored on site.

7. **What do you do to ensure effective production or delivery?**
   The elements are loaded onto the loading crate that is placed directly on the delivery truck. This cause for less time wastage to stack the elements one by one onto the truck. This does result in the truck to be

loaded with the additional loading.

8. **What are the other services provided by Bison?**
   All holes, service ducts or openings are cut and installed into the elements by the supplier.

9. **What does Bison do to ensure that they remain a green manufacturer?**
   Waste material are crushed and reused as aggregate or road building material. Water is recycled causing for a company that is 100% recycling on all waste.

10. **Explain the manufacturing process (labour, hours etcetera)?**
    The whole factory is mechanised and is fully automated. The labour in the factory work 24 hours per day in 3 shifts. The labour is responsible to ensure the machines are working and to custom moulds.

11. **What elements are you able to supply?**
    We make anything from specialised products (curved shapes), pre-stressed beams and slabs, normal reinforced elements, staircases or landings.

12. **For Bison to have the resources that it has today there must have been some stage where they decided to invest in additional equipment. How did you make that large financial decision to invest in additional resources regardless of the changing market?**
    It is al about the building of relationships with the project teams. By having a good relationship, understanding and trust in the designers, contractors and clients, the risk is minimised because of their continuous support.

13. **Are there any regulations that do not allow for precast use within the United Kingdom?**
    The regulation regarding sound insulation cause for rib-and-block systems only to be used for ground floors except if additional insulation is installed. Precast hollow-core slabs provide more sound insulation due to the hollow cores and can be used without additional insulation.

Date: 24 March 2011 @ 11:30

Prof. Alistair Gibb and Chris Goodier

Company: Loughborough University

Profile: Lecturer and researcher at university

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Address:

Department of Civil and Building Engineering

Loughborough University

Leicestershire

LE11 3TU

1. **How do you see the precast construction industry?**
   It was destroyed throughout Europe during the 1970's. During the recession, clients started to revert to the concept of the cheapest option. Time became an applicable consideration but only if it is applicable to the specific project. In the United Kingdom, the weather is more variable than in South Africa, for that reason precast is used more frequently. The Netherlands make even more use of precast for similar reasons. In the United Kingdom, they promote precast due to the sustainability benefits it provides.

2. **Are there any issues regarding precast when it is prescribed?**
   Quantity surveyors hide the cost aspect of pre-fabrication. On paper, it looks to be more expensive than in-situ, but the comparison is false. Items such as rework, electricity on site, labour on site etcetera are never quantified. Most contractors do not know the real cost of the elements (including all the other quantifications as well), instead they only know the price of the elements.

3. **How do you combat late changes to a design which influences the flexibility of the precast elements?**
   Precast needs to be decided on in advance. With in-situ, the variations are applied at a late stage and provide for additional costs for the client. With partnering (design-and-build or private-finance-initiatives) you can save on rework because the price that are provided to the client will be the final price, causing hesitance to apply variations. Due to a lazy attitude, design issues are dealt with on site and not in the office. The concept of a given deadline for information is important to control last-minute changes. In the past, projects were tendered for zero profit, because the contractor expected an income from variation orders.

4. **Do you have a decision-making model for in-situ and precast construction?**
   Immprest LA (http://imprest.lboro.ac.uk) is an Excel based program that a project team can use. This is a decision support tool. Based on the advantages and disadvantages of building methods, the program asks a range of questions. A final printout is provided that advises the user on the most appropriate construction method.

5. **What is your concept on the health and safety between sites and factories?**

The sites are 5 – 6x more dangerous than the factories. By taking the bulk of labour off-the site and into a controlled environment will be a safe way to move forward. By making the factories labour-intensive in South Africa, they must be trained according to standards they must uphold.

E-mail correspondence

Date: 1 July 2010 @ 18:06

Dr Jacqueline Glass

Company: Loughborough University

Profile: Lecturer and Researcher at University

E-mail: J.Glass@lboro.ac.uk

1. **What infrastructure must be in place for hybrid concrete construction to be successful in a country?**
   You certainly need a level of knowledge of hybrid concrete construciton (HCC) in structural engineers and construction companies. Here in the United Kingdom, there were a few leaders from these two groups who really championed the use of shall we say the more complex forms of HCC. They used HCC to overcome particular project challenges such as time or access constraints, by developing clever design solutions to make the frame construction possible. Apart from knowledge, you need precast manufacturers who are prepared to make time to understand the engineering drawings and "panelise" bespoke solutions to achieve an economic solution. Understandably, precasters need repetition to get the value out of mould materials and setting up time and costs, so there can be a challenge in getting a precaster to give a competitive quote for a HCC project if they do not understand how to re-design the concrete interfaces, joints, panels etcetera to make commercial sense. So, I think the infrastructure you need is knowledge, early involvement and willingness to re-design. Notwithstanding all that, architects also need to be involved - they can help champion HCC to the client by reinforcing the benefits it brings from an aesthetic point of view.

2. **Besides the Latham report (1994), how did the United Kingdom's clients, engineers and contractors get to be so interested and involved in using precast elements - In South Africa it is mainly used for slabs, beams and stairs. What made the United Kingdom's project teams stray from the normal in-situ designs and construction?**
   In-situ is still used, but it centred in London and the South East, where the majority of the in-situ contractors are based. Precasters tend to be based in the Midlands and North, so they can have a better command of the market. That said, there has been a big push to get wet trades off-site as they are seen as old-fashioned and dangerous. If you look up the term *Modern Methods of Construction* you will see significant use of that term because the Government was pushing all forms of pre-fabrication in the late 1990's to try and get the construction industry a bit more up to date - search for the *Barker Report*, written by Kate Barker of HM-Treasury. Clearly the popularity of precast rose at that time. However, in comparison to other European countries the United Kingdom has a very low rate use of precast. The Scandinavian countries and Italy are the highest per capita consumers of precast. It is also important to note that the steel industry made it easy for people to use precast floors with steel frames, and since steel has a massive majority of the frame market in the United Kingdom, this also helped the precast sector.

3. **How must the contract procurement within the industry change to accommodate the use of HCC? The Best practice guidance for HCC is only applicable to countries that are currently enthusiastic about HCC, making it slightly irrelavant for a country such as South Africa.**
   This is a critical point. In the *Best practice guidance for HCC* we talk about this on many occasions because it seems that some conditions of contract are prohibitive to HCC (and innovation generally). We found that

design-and-build contracts were preferable, and importantly you need early involvement from the contractors and precasters to make the most of a HCC solution. You also need open book accounting to ensure that the client, project manager and quantity surveyor fully see the value that HCC brings - but the open book needs to account for time as well as cost. The most commonly cited benefit of HCC is time benefits, such as the ability to reduce the construction programme and sadly all too often clients are not made aware of the true impact of construction decisions on programme.

Date: 8 July 2011 @ 12:36

Prof. Alistair Gibb

Company: Loughborough University

Profile: Lecturer and researcher at university

E-mail: A.G.Gibb@lboro.ac.uk

1. **How did the United Kingdom's construction industry change towards "thinking precast"? In the beginning there must have been scepticism towards precast construction. How was it overcome?**
   I think for the United Kingdom we need to be careful about the term precast - we tend to use OFF-SITE as a more generic term - I am not sure that the United Kingdom does 'think precast', but some sectors and some decision makers are now moving towards more "thinking off-site".

   We can trace a recent history back over the last few years in terms of our own involvement that resulted in the industry to overcome. It is probably fair to say that, parallel to our work and initiatives, there were some other initiatives - we wouldn't claim that we created or caused these other efforts, but I would argue that we influenced them.

2. **What measures were set in place before precast really took off in the United Kingdom to ensure good acceptance of the "new construction method" - whether procurement methods, manufacturers, regulations etcetera?**
   I am not aware of any particular PRIOR measures. Much of our legislation and codes have responded to issues (e.g. Ronan Point led to the laws to prevent progressive collapse).

3. **What are the ongoing processes that ensure an interest in precast?**
   There have been various attempts by people such as *Buildoffsite* to provide better warranties for off-site products (for example the *Buildoffsite Lloyds* warranty scheme). Encouragement to use off-site is often included in documents from governments - although the current coalition Government is less likely to be as proactive, not because they do not believe that off-site is a good idea but rather that the conservatives tend to let the market decide.

4. **You mentioned that the contractor is the greatest roll player towards the use of precast in projects. What if the project's procurement is not according to design-and-build, private-finance-initiative or other partnering methods (thus traditional tendering methods)? How can the contractor influence the design?**
   Contractors can not influence the design unless they are invited and even then, some are not particularly good at it anyway.

5. **The client's role in the design is inevitable - how did the United Kingdom train the clients to ensure more frequent use of precast in construction?**

We did some extensive research. Egan was also aiming at clients. The *CIRIA* toolkits explicitly aims at clients.

6. **Would you say that the United Kingdom's construction industry has undergone an "industry change"? Who forced or drived such a change?**
   I am somewhat sceptical of claiming a step change. Off-site is still a relatively small part of the overall sector - influencers are covered in question 1.

Appendix C

Additional tables

Table C.1: Hybrid concrete construction programms at the South African tertiary institutions

Tertiary Institution	Telephone	Undergraduate final year civil engineering			Course	Post-Graduate 1^{st} year structural engineering			Course	Contact Person
		2008	2009	2010		2009	2010	2011		
Stellenbosch University	+2721 808 4404	58	67	87	No	8	15	16	No (except 2008)	Prof J. Wium & Ms A. de Wet
University of Pretoria	+2712 420 2925	49	53	85	Yes	19	17	17	No (except 2010)	Prof E. Kearsley & Prof N. Dekker
Durban University of Technology	+2731 373 2224	54	122	136	No	2	0	0	No	Mr G. Parrott
Nelson Mandela Metropolitan University	+2741 504 3297	77	96	95	No	N/A	N/A	N/A	N/A	Mr J. Barnard
University of Johannesburg	+2711 559 6415	51	42	44	No	14	18	20	No	Mr J. De Koker
Tshwane University of Technology	+2721 382 5250	203	199	219	No	2	5	2	No	Ms D. Ngoma
University of Kwazulu-Natal	+2731 260 3055	80	100	100	No	2	2	2	No	Ms P. Bhagwandin
University of the Witwatersrand	+2711 717 7121	21	30	37	No	21	9	20	No	Ms T. Mtsela
	Total	**593**	**709**	**803**	**2105**	**68**	**66**	**77**	**211**	
		Exposure			**9%**	**Exposure**			**8%**	

Table C.2: External companies that provide training for the building construction industry

Institute	Reference	Date	Target	Course	Precast concrete courses
Institute of Municipal Engineers of Southern Africa	IMESA website	23/06/2011	Managers	Procurement procedures and documentation, management skills	-
South African Association of Consulting Engineers	CESA website	23/06/2011	Managers	Procurement procedures and documentation, management skills	-
South African Institution of Civil Engineering	SAICE website	29/06/2011		Courses offline	-
Construction Education and Training Authority	CETA website	29/06/2011	-	-	-
Engineering Council of South Africa			-	-	-
Construction Industry Development Board	CIDB website	26/05/2011	Construction staff and labour	Properties of concrete, concrete manufacturing and placing	Concrete practice incl precast elements
Cement and Concrete Institute	Petrus Jooste	10/03/2011	Designers	Pre-stressed concrete design, concrete technology	Concrete technology incl precast
Concrete Society of Southern Africa	website	28/06/2011	Manufacturers	Properties of concrete	Practical Applications and manufacturing of elements
Concrete Manufacturers Association	CMA response	26/05/2011	Designers	-	Hollowcore floors seminar
South African Federation of Civil Engineering Contractors	SAFCEC links - (eg Tjeka)	29/06/2011	Construction staff and labour	Construction opperations and procedures and skill developement	Installation of precast elements, Building with precast elements

Table C.3: Accreditations according to the *Office toolkit* obtained from the *Green Building Council of South Africa* (Green Building Council of South Africa 2011)

Ref no.	Title	Aim of credit	Credit criteria summary	No. of points Available
Mat-5	Concrete	To encourage and recognise the reduction of embodied energyand resource depletion occurring through use of concrete.	Three points are available as follows: Up to two points are available where the project has reduced the absolute quantity of Portland cement, as an average across all concrete mixes, by substituting it with industrial waste product(s) or oversized aggregate as follows: - For 1 point, 30% for in-situ concrete, 20% for precast concrete and 15% for stressed concrete; or - For 2 points, 60% for in-situ concrete, 40% for precast concrete and 30% for stressed concrete.	2
			An additional point is awarded where: - At least one of the above points is achieved; AND - 10% of all aggregate used for structural purposes is recycled (Class 1 RCA in accordance with HB155-2002) or slag aggregate; AND - No natural aggregates are used in non-structural uses (e.g. building base course, sub-grade to any car parks and footpaths, backfilling to service trenches, kerb and gutter) unless they are being reused.	1
Mat-8	Sustainable Timber	To encourage and recognise the specification of reused timber products or timber that has certified environmentally-responsible forest	Two points are available as follows: One point is awarded where 50% (by cost) of all timber products used in the building and construction works have been sourced from any combination of the following: - Reused timber; - Post-consumer recycled timber; or - Forest Stewardship Council (FSC) Certified Timber. An additional point is awarded where 95% (by cost) of all timber	2

Continued on next page

Table C.3 – continued from previous page

Ref no.	Title	Aim of credit	Credit criteria aummary	No. of points Available
		management practices.	products used in the building and construction works satisfy the above mentioned sourcing criteria.	
Mat-10	Dematerial-isation	To encourage and recognise designs that produce a net reduction in the total amount of material used.	One point is available where a substantial reduction in materials consumption occurs as follows: Where it is demonstrated that the building's structural requirements and integrity have been achieved using 20% less structural steel (by mass) OR 20% less concrete and reinforcing/stressing steel (by mass), OR 20% less timber (by volume) than in a structure with conventional steel, concrete or timber framing, without changing the load path to other structural components OR.	1
			Where any two of the initiatives below are demonstrated: Structure criteria Ductwork criteria Building Efficiency criteria Finishes criteria Piping criteria Cladding criteria	

Appendix D

Questionnaire

UNIVERSITEIT STELLENBOSCH UNIVERSITY

Research questionnaire on Hybrid Concrete Construction in South Africa - Clients

OVERVIEW:

Hybrid concrete construction (HCC) is a technique that makes use of a combination of in-situ concrete and pre-fabricated concrete elements, to achieve the superior quality, flexibility and workability of each product in one project.

1. PERSONAL INFORMATION:

In order to create an accurate database of hybrid concrete construction projects in the industry, details of the company are important.

1.1 Company name:
(Governmental organization must please state their specific institution and/or department)?

1.3 Contact person:

1.4 Contact phone no:

1.5 Company physical address:

2. PROJECT AND HCC INFORMATION

Certain divisions of civil engineering appear to make more frequent use of pre-fabricated concrete elements than other divisions. One reason is due to certain standardized elements that are made by specialist suppliers on a large scale. The building industry in South Africa is starting to use more pre-fabricated concrete elements than in the past, but it is not comparable to the quantities used in other countries.

2.1 **Client's project portfolio:**
Please allocate a percentage value for the client's project portfolio

Civil works (roads)		High quality finish buildings (hotels, spa's etc)	
Bridge		Civil projects (no finishes) (dams, quay,etc)	
Industrial building		Other (specify)	
Office blocks		Total	100%

2.2 **Tendering Methods:**

It has been found in the UK that a specific contracting method (design and construct) is the best method to accommodate HCC. By using the design and construct concept, the contractor has sole responsibility on the design and construction of the project, which eliminates any confusion of risk responsibilities. These questions are based on the method of tender which the client is most accustomed to and comfortable with.

Which contracting/tendering method has the client used for HCC project? (Please allocate a percentage value for the specific tender method)

Single stage tendering (traditional)	
Two-stage tendering*	
Design and build	
Other (specify)	
Total	100%

* Two stage tendering is the process by which a contractor is contracted for a broad spectrum design purposes. After completion of the design, the project is on tender for construction purposes

		Yes	No	Some-times
2.3	Does the client have representatives besides the project team to overlook the project?			
2.4	Does the client have sufficient knowledge of engineering to evaluate and query the structural designs and construction method presented by the project design team?			
2.5	Is the client obliged by regulations to follow a traditional tendering method and what are these obligations?			
2.6	Will the client attempt the process of design and construct if this method is better understood and seen in more projects?			

2.7 What information needs to be known to the client before attempting a design and construct project – please list the required information?

_____

_____

3. PRE-FABRICATED ELEMENTS

These questions focus specifically on the use of HCC technology and the information that was discussed during tender procedures. In other countries, pre-fabricated elements are used for columns, floors, beams, staircases etc.

		Yes	No	Some-times
3.1	Did the architect and/or engineer propose different possibilities of construction to the client			
3.2	Were the advantages and disadvantages about the proposed project concept by the architect and/or structural/civil engineer discussed with the client?			
3.3	Is the client aware of HCC and the advantages it brings to a project?			
3.4.1	If a HCC method is introduced by the design team: a) will the client support in this method?			
3.4.2	b) Will the client request a traditional in-situ approach?			
3.5	If the client do insist on using pre-fabricated elements, does the project team object to use these elements			

4. General

4.1 What can the construction industry do to promote the use of HCC or increase the use of different pre-fabricated elements (eg columns)?

After completion of this questionnaire, please send it via:

Fax: 021 808 4947 (attention: Rojean Hanekom S216)

E-mail: rhanekom@sun.ac.za (please remember to attach the questionnaire)

Thank you very much for your time and co-operation.

Rojean Hanekom
cell: 082 472 3020

UNIVERSITEIT STELLENBOSCH UNIVERSITY

Research questionnaire on Hybrid Concrete Construction in South Africa - Consultants

OVERVIEW:

Hybrid concrete construction (HCC) is a technique that makes use of a combination of in-situ concrete and pre-fabricated concrete elements, to achieve the superior quality, flexibility and workability of each product in one project.

1. PERSONAL INFORMATION:

In order to create an accurate database of hybrid concrete construction projects in the industry, details of the company are important.

1.1	Company name:	
1.2	Company registration no:	
1.3	Contact person:	
1.4	Contact phone no:	
1.5	Company physical address:	

2. PROJECT INFORMATION

Certain divisions of civil engineering appear to make more frequent use of pre-fabricated concrete elements than other divisions. One reason is due to certain standardized elements that are made by specialist suppliers on a large scale. The building industry in South Africa is starting to use more pre-fabricated concrete elements than in the past, but it is not comparable to the quantities used in other countries.

2.1 **Consultant's project portfolio:**

Please allocate a percentage value for the consultant's project portfolio

Civil works (roads)		High quality finish buildings (hotels, spa's etc)	
Bridge		Civil projects (no finishes) (dams, quay,etc)	
Industrial building		Other (specify)	
Office blocks		Total	100%

2.2 **HCC project portfolio:**

In which project type does the consultant have the most experience with HCC? (Please allocate a percentage value for the contractors HCC project portfolio)

Civil works (roads)		High quality finish buildings (hotels, spa's etc)	
Bridge		Civil projects (no finishes) (dams, quay,etc)	
Industrial building		Other (specify)	
Office blocks			

2.3 **Tendering Methods:**

Which contracting/tendering method has the contractor used for HCC project? (Please allocate a percentage value for the specific tender method)

Single stage tendering (traditional)		
Two-stage tendering*		
Design and build		
Other (specify)		
	Total	100%

* Two stage tendering is the process by which a contractor is contracted for a broad spectrum design purposes. After completion of the design, the project is on tender for construction purposes

2.4 **Tendering Documentation:**

Which conditions of contract was used for the HCC projects? (Please allocate a percentage value for the specific standard documention)

GCC		
JBCC		
NEC		
FIDIC		
Other (specify)		
	Total	100%

2.5 **Tendering Documentation Preference:**

Why is the above mentioned tendering conditions of contract preferred?

2.5 **Project issues:**

Please indicated the main causes of contracts not being completed within the specified required time:

Project specification change by client		
Variation orders		
Weather ralated issues		
Unforeseen holidays		
Late delivery of products by suppliers		
Health and safety related issues		
Claims and disputes		
Late submission of information/drawings to the contractor		
Other (specify)		
	Total	100%

3. PRE-FABRICATED ELEMENTS

These questions focus specifically on the use of HCC technology and the information that was discussed during tender procedures. In other countries, pre-fabricated elements are used for columns, floors, beams, staircases etc.

3.1 Which pre-fabricated elements has the consultant used during designing (please choose the appropriate boxes):

	Regularly	Sometimes	Never
Pre-stressed floor/wall panel			
Reinforced floor/wall panel			
Beams for bridge construction (T-beam, U-beams etc)			
Reinforced beams			
Pre-stressed beams			
Staircases			
Columns			
Culverts (incl. bases, spills etc)			
Specialist elements (kiosks, toilets, shelters etc)			
Other (specify):			

3.2 Please indicate by ticking where the statements below apply most, in your opinion:

		Always	Often	Rarely	Never
a)	Does the consultant meet with the project team (contractors, suppliers, QS, architect and clients) before a project to discuss different construction methods and elements to be used?				
b)	Will the consultant insist on using pre-fabricated elements if it is not prescribed by architect or client?				
		Always	Often	Rarely	Never
c)	Does the consultant encounter elements that suppliers or contractor do not want to supply? (if applicable, list items below) …… …… ……				
			Regularly	Seldom	Never
d)	Does the consultant send their designers on training courses to increase the design skill with pre-fabricated elements?				

3.3 Are there elements that the consultants prefer not to use during construction? For what reason does the consultant prefer not to use these elements? (eg not to use precast staircases in projects)

_____

_____

_____

3.4 (Consultants that do not make use of pre-fabricated elements) Why does the consultant not make use of pre-fabricated products?

4. General

4.1 What can the construction industry do to promote the use of HCC or increase the use of different pre-fabricated elements (eg columns)?

After completion of this questionnaire, please send it via:

Fax: 021 808 4947 (attention: Rojean Hanekom S216)
E-mail: rhanekom@sun.ac.za (please remember to attach the questionnaire)

Thank you very much for your time and co-operation.

Rojean Hanekom
cell: 082 472 3020

UNIVERSITEIT STELLENBOSCH UNIVERSITY

Research questionnaire on Hybrid Concrete Construction in South Africa - Contractors

OVERVIEW:

Hybrid concrete construction (HCC) is a technique that makes use of a combination of in-situ concrete and pre-fabricated concrete elements, to achieve the superior quality, flexibility and workability of each product in one project.

1. PERSONAL INFORMATION:

In order to create an accurate database of hybrid concrete construction projects in the industry, details of the company are important.

1.1	Company name:	
1.2	Company registration no:	
1.3	Contact person:	
1.4	Contact phone no:	
1.5	Company physical address:	

2. PROJECT INFORMATION

Certain divisions of civil engineering appear to make more frequent use of pre-fabricated concrete elements than other divisions. One reason is due to certain standardized elements that are made by specialist suppliers on a large scale. The building industry in South Africa is starting to use more pre-fabricated concrete elements than in the past, but it is not comparable to the quantities used in other countries.

2.1 **Contractor's project portfolio:**

Please allocate a percentage value for the contractor's project portfolio

Civil works (roads)		High quality finish buildings (hotels, spa's etc)	
Bridge		Civil projects (no finishes) (dams, quay,etc)	
Industrial building		Other (specify)	
Office blocks		Total	100%

2.2 **HCC project portfolio:**

In which project type does the contractor have the most experience with HCC? (Please allocate a percentage value for the contractors HCC project portfolio)

Civil works (roads)		High quality finish buildings (hotels, spa's etc)	
Bridge		Civil projects (no finishes) (dams, quay,etc)	
Industrial building		Other (specify)	
Office blocks			

2.3 **Tendering Methods:**

Which contracting/tendering method has the contractor used for HCC project? (Please allocate a percentage value for the specific tender method)

Single stage tendering (traditional)		
Two-stage tendering*		
Design and build		
Other (specify)		
	Total	100%

* Two stage tendering is the process by which a contractor is contracted for a broad spectrum design purposes. After completion of the design, the project is on tender for construction purposes

2.4 **Tendering Documentation:**

Which conditions of contract was used for the HCC projects? (Please allocate a percentage value for the specific standard documention)

GCC		
JBCC		
NEC		
FIDIC		
Other (specify)		
	Total	100%

2.5 **Design and build:**

2.5.1 If the contractor was involved with design and build or turnkey project (Please indicate by ticking where the statements below apply most, in your opinion)

		Always	Often	Rarely	Never
a)	Were there any amendments to the standard conditions of contract?				
b)	Did the contractor find the conditions of contract adequate for the design and build project?				

2.5.2 If question 2.5.1 is applicable - list some of the inadequacies that the contractor found with standard conditions of contract that was used?

2.5.3 If the contractor has not been involved with design and build project, why does the contractor prefer not to ingage in such projects?

3. PRE-FABRICATED INFORMATION

These questions focus specifically on the use of HCC technology and the information that was discussed during tender procedures. South Africa is using floor panels and in some cases, beams. In other countries, pre-fabricated elements are used for columns, floors, beams, staircases etc.

3.1 Which pre-fabricated elements has the contractor used during construction (please choose the appropriate boxes):

	Regularly	Sometimes	Never
Pre-stressed floor/wall panel			
Reinforced floor/wall panel			
Beams for bridge construction (T-beam, U-beams etc)			
Reinforced beams			
Pre-stressed beams			
Staircases			
Columns			
Culverts (incl. bases, spills etc)			
Specialist elements (kiosks, toilets, shelters etc)			
Other (specify):			

3.2 Please indicate by ticking where the statements below apply most, in your opinion:

		Always	Often	Rarely	Never
a)	Does the contractor meet with the design team before a project to discuss different construction methods for the different elements to be requested?				
b)	Will the contractor insist on using pre-fabricated elements if it is not prescribed?				
c)	Does the contractor encounter some elements that suppliers do not want to supply? (if applicable, list items below) …… …… ……				
d)	Does the contractor install the pre-fabricated elements?				
e)	Does the contractor find the installation of pre-fabricated elements dangerous?				
f)	Does the contractor make use of specialist suppliers to supply pre-fabricated elements?				
			Regularly	Seldom	Never
g)	Does the contractor provide training programs to increase the skills of labourers regarding the use of pre-fabricated elements				

3.3 If contractors do not make use of suppliers to supply the pre-fabricated elements, does the contractor experience any difficuties fabricating and installing the elements? List the difficulties the contractor experienced.

3.4 Are there elements that the contractor prefer not to use during construction? For what reason does the contractor prefer not to use these elements?

3.5 (Contractors that do not make use of pre-fabricated elements) Why does the contractor not make use of pre-fabricated products? (eg not to use precast staircases in projects)

4. General

4.1 What can the construction industry do to promote the use of HCC or increase the use of different pre-fabricated elements (eg columns)?

4.2 Can you please provide details of projects that the contractor was part of that made use of HCC? (Project name, location, pre-fabricated elements used, structure cost, % pre-fabricated elements used in structure etc)

4.3 Can you please provide details of projects that the contractor was allowed to make use of design and build tendering methods? (Project name, location, pre-fabricated elements used, structure cost, % pre-fabricated elements used in structure etc)

After completion of this questionnaire, please send it via:

Fax: 021 808 4947 (attention: Rojean Hanekom S216)

E-mail: rhanekom@sun.ac.za (please remember to attach the questionnaire)

Thank you very much for your time and co-operation.

Rojean Hanekom
cell: 082 472 3020

Questionnaire response summary

Questionnaire response information

Figure D.1 illustrates that a total of 22 questionnaires were returned. Of the 22, 3 were unusable because they were either partially completed or received from a project team member that does not work with structural precast elements. From the remaining questionnaires, 10 were from contractors, 7 were from consultants and 2 were from clients.

When the project teams' portfolios were analysed, it was found that 29% were involved with building construction. A total of 31% were from the transportation industry and 20% were working on major infrastructure projects that refer to dam walls or similar structures. The remaining 4% worked on building structures where pre-fabricated construction was not applicable such as bridge designs (not applicable to this study).

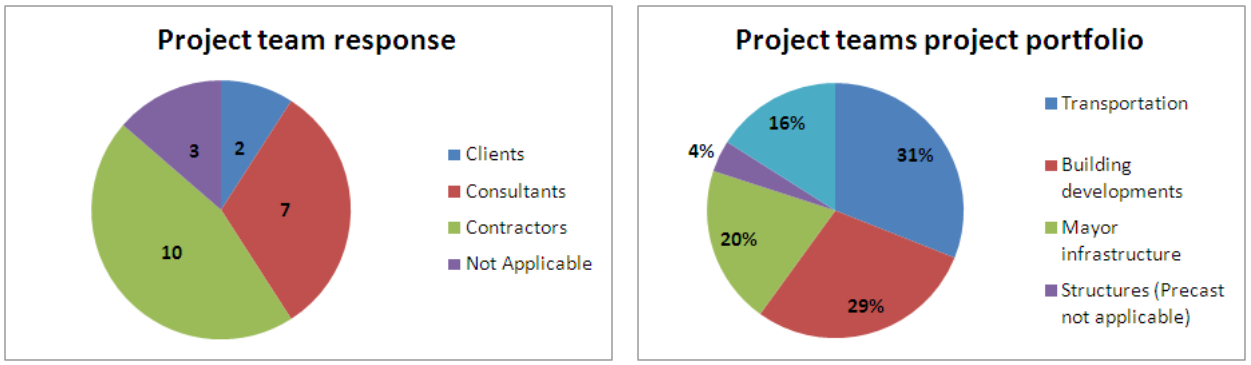

Figure D.1: Questionnaire distribution: left - Display of the distribution between project team members, right - the specific project portfolio of the participants

Procurement documentation

Figure D.2 illustrates the distribution of contract documentation in projects. The *International Federation of Consulting Engineers* (FIDIC) contract was most dominant with 38% utilisation and the *General Conditions of Contract 2004* (GCC) was used on 22% of projects. The *Joint Building Contracts Committee* (JBCC) was used on 21% of projects and the *New Engineering Contract 3* (NEC) was only utilised on 16% of projects. The remaining 3% were other contracts that included the *Committee of Land Transport Officials* (COLTO) specifications that are normally used in combination with the GCC on transportation projects.

Figure D.3 shows the utilisation of each contract document according to the different criteria of the respondents' projects. Of these figures, the structural figure is most appropriate for this document. In structural projects, the FIDIC and GCC dominated the distribution with 48% and 27% of projects respectively. The high GCC distribution can be falsely interpreted because it can be due to transportation projects where precast culverts are used and not building projects. The JBCC were expected to be dominant, although only 14% were used while the NEC was used on only 11% of projects.

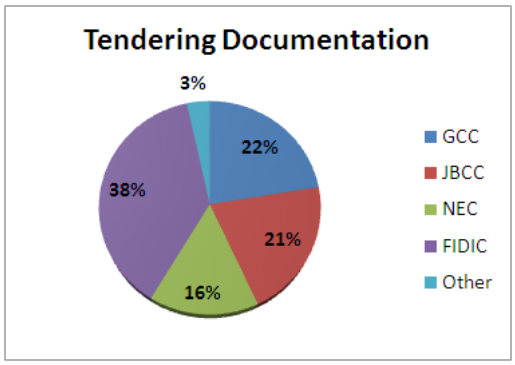

Figure D.2: The distribution of the respondents different contract documentation

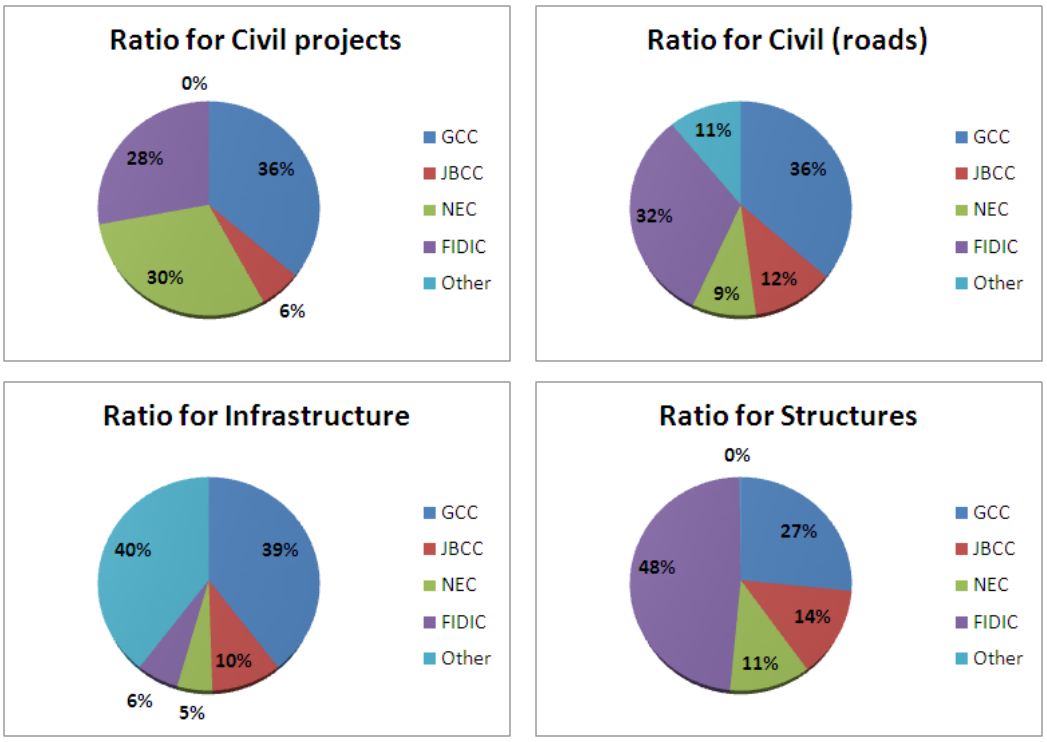

Figure D.3: The distribution of the contract documents within the respondent's specific discipline

Procurement methods

Figure D.4 shows the procurement strategies that were used on the respondents' projects. As expected, single-stage tendering was used on 70% of projects and design-and-build was used on 17% of the projects. Unexpectedly, two-stage tendering equated to 9% of projects while other procurement methods (such as public-private-partnerships, contract management etc.) were used on the remaining 4% of the projects.

Figure D.5 illustrates the distribution of the different procurement strategies and the percentage that these strategy were used within their company. For single-stage procurement methods, a total of 75–100% of the company's projects were procured according to this strategy by 78% of the respondents. Similarly, 50–75% of the company's projects were procured according to single-stage methods by 11% of the respondents. When

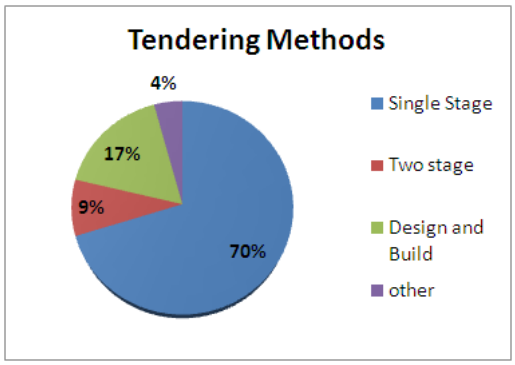

Figure D.4: The distribution of the respondents with the different contract procurement strategies

the design-and-build figure is analysed, 60% of companies procure according to this method on 0–25% of their projects. When it is taken into account that only 17% of all projects were procured according to the design-and-build method (Table D.4), it is evident that the exposure and experience with this strategy is limited.

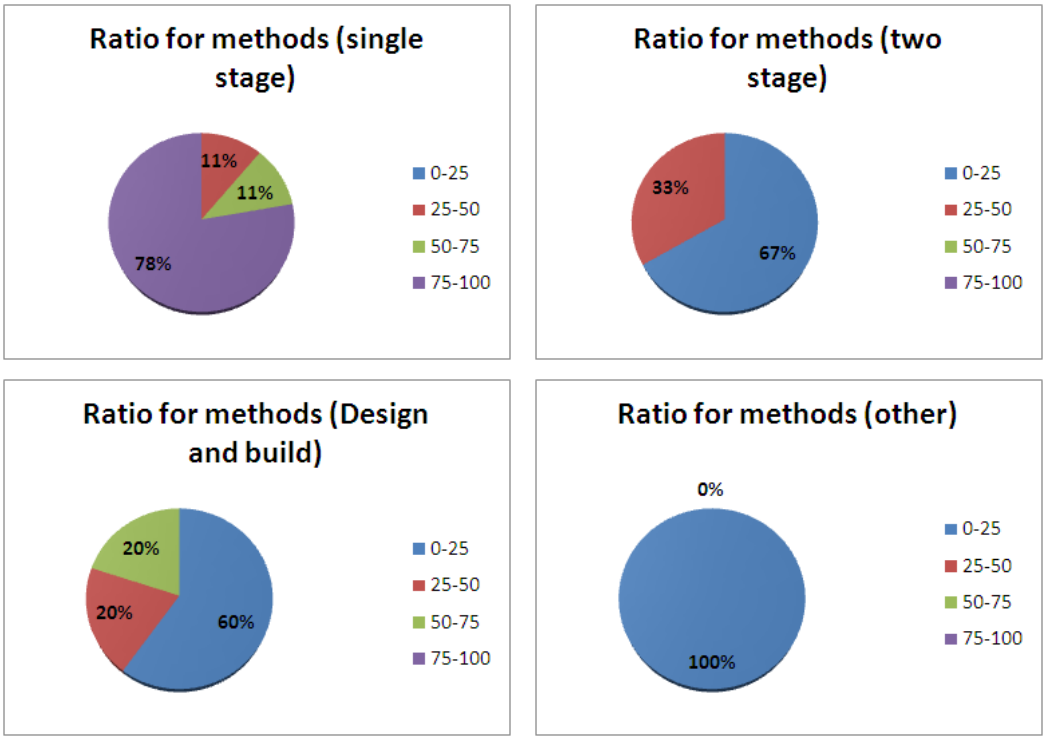

Figure D.5: The percentage that each procurement strategy is utilised within a company