A Market Review on the Use of Structural Precast Concrete in South Africa

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ACCREDITED TECHNICAL PAPER

A Market Review on the use of Structural Precast Concrete in South Africa

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ABSTRACT: Structural precast concrete is applied extensively in European and North American construction industries and the trend to use precast technology is generally growing. There are many benefits associated with precast construction including speed of construction, quality assurance, reduction in on-site labour and design freedom, all of which relate to an underlying economical benefit. However, in comparison to most European and North American countries, structural precast construction contributes only a small percentage to the construction industry in South Africa.

The local structural precast market is dominated by precast flooring systems and there is generally an absence of frame components such as beams and columns. A market review was carried out with the objective of identifying the extent of use of structural precast concrete in South Africa, and to acertain the mindset of the industry. The review indicated that engineers and architects are generally reluctant to specify precast construction methods for structural applications, which is partly based on a lack of knowledge of the subject.

Further, lack of planning of construction projects seems to hinder acceptance of precast technology. However, despite the current lack of structural precast technology in South Africa, there is large interest in the subject in the local industry. Recommendations to increase the use of structural precast concrete in the South African industry are provided.

KEYWORDS:

Precast concrete, structural design, construction techniques, frame structures, market review

1. INTRODUCTION

Some regions in North America and Europe make use of precast concrete technology as the favoured method of construction for large structural frames. Precast components used include various types of columns, beams, slabs and shear walls. In contrast, structural applications of precast concrete products in South Africa are mainly limited to hollow core slab systems and rib and block systems.

Based on detailed planning from the beginning of the project and proper communication between all parties involved, precast technology offers a great relief from the characteristic time pressures on clients and designers that are associated with in-situ concrete construction and can significantly increase the speed of construction.

Another important advantage includes design freedom, which however is not always acknowledged by individuals who favour in-situ construction techniques. From an architectural point of view, precast prestressed technology offers the possibility to use more slender members and longer spans, while precast concrete generally results in higher quality fair faced surfaces, compared to in-situ concrete. Site complications and labour requirements are generally reduced with the application of precast construction techniques, which is often overlooked by design engineers who are not directly involved in the construction.

The choice of an appropriate construction technique generally depends on economical considerations. Whether precast technology is economically beneficial depends on the particular project as the cost per volume of concrete is generally significantly higher, compared to in-situ concrete construction. A cost comparison needs to take all the above aspects into account, (where relevant), to decide on the most appropriate construction technique.

This paper investigates the precast concrete industry and how it has been applied in past developments both locally and globally. With a notorious shortage of skills and problems in quality assurance, precast concrete technology holds significant potential in local application. However, there are numerous issues that hinder the acceptance of structural precast technology by the South African market, which were investigated in this project through a market review in the local construction industry.

2. BRIEF REVIEW OF THE CHARACTERISTICS OF STRUCTURAL PRECAST CONCRETE

General advantages of precast construction

Construction methods employing precast technology have numerous advantages, compared to in-situ concrete construction (Hegger 2006). It is however difficult to rate the various advantages as each application has to be considered on its merits in specific circumstances. Advantages inherent in precasting are factory-controlled production methods, increased tolerances and improved standards of finish, reduction in site labour requirements, and the removal of large sections of work from the critical path determining overall contract duration (Richardson 1991).

The many advantages of precast concrete are described in most literature on the subject, however the majority relate to an economical advantage. The following advantages are prevailing: Design freedom for occupational floor area; Reduced on-site complications provided the connection details are good; High product quality; Reduced on-site labour; and High speed of construction.

Precast concrete provides the same advantages as in-situ concrete with respect to the freedom in design of occupational floor area. European systems follow an open construction technique where the trend is to design a layout with free open spaces created by long spans between load bearing walls. This allows for the layout of the internal walls or partitioning, which serve no load bearing function, to be changed at a

later stage during service. Furthermore, structural integrity can be achieved through a variety of layouts and structural compositions, making use of various frame and floor slab systems (Elliot 1996).

Constructing concrete members on site requires considerable skill in formwork erection, reinforcing steel placement, concrete placement and curing. If the concrete is mixed on-site, quality control becomes a further issue during the batching and mixing process. As a result of time constraints and lack of skilled workforce, the finished product may not be of acceptable quality, a problem, which is often encountered in the South African industry.

Another issue is the frequent application of complex geometric configurations, requiring the use of intricate formwork. If designed and implemented correctly, precast concrete allows for economical and easy installation and hence reduces the work load on the contractor (Yee 2001). This makes it considerably easier to meet the required quality standards. Noise pollution and waste disposal linked to concrete manufacturing are eliminated from site. Another advantage is that factory-controlled production reduces on-site dependency towards adverse weather conditions such as extreme heat, cold, or rain.

Precast concrete components are cast in a manufacturing plant under controlled conditions, resulting in generally higher quality, compared to in-situ concrete. This is of growing concern to the construction industry, in South Africa and worldwide, as concrete durability issues are increasingly being considered in the design of structures.

Precast concrete construction techniques require significantly less on-site labour compared to in-situ concrete construction. Despite the savings in on-site labour costs, total cost of construction may however be higher. The manufactured products are often more expensive compared to their in-situ counterparts, which may result in an increase in the total cost of the project. In North America and Europe, designers often favour precast construction as it can significantly speed up construction, allow early occupancy of the structure or building and therefore reduce total project costs.

Generally, the cost-effectiveness of precast construction needs to be established by considering construction time savings and improved product quality. However, transport costs may also play a role in cost-effectiveness and this will depend on how far from the site the precast plant is located.

Common applications and systems of structural precast concrete in Europe and North America

Precast technology is applied in many regions of the world. As an example, the precast industries in Europe and North America, being relatively well developed, were investigated in more detail. Even though precast technology is generally well accepted in these regions, the application of various precast systems and construction methods, as well as the percentage of construction being carried out using precast concrete members differ significantly between different countries. It is therefore difficult to give a general overview on the application precast technology overseas. However, a few important principles and developments in the application of precast technology were identified and are briefly discussed in this section.

Housing projects

Precast concrete can be incorporated into both low-income housing projects as well as upmarket residential developments covering the entire range of residential applications.

In Europe, there are two main systems used in housing development. The first is known as the cross-wall system. The configuration is such that a number of precast walls are load-bearing and are positioned perpendicular to the front façade. The exterior cladding and front façade can be of any suitable material - from brickwork to manufactured precast panels (Van Acker 2007). Another system incorporated by European designers is the envelope system. This makes use of precast concrete elements to envelop the building, i.e. to construct exterior walls. The internal walls are non load-bearing and are commonly made of materials other than precast concrete such as masonry or cement blocks however precast panels can be used. This means that the roof and floors span the entire width of the house or apartment (Van Acker 2007).

The authors consider it unlikely that vertical load-bearing members would currently be employed in individual housing projects in South Africa. However, the above construction principles may be useful in the low income housing market and township upgrading projects, where the speed of construction is of importance.

Office Buildings

In Europe, office buildings are often designed as frame structures made up of a configuration of precast beams, columns, slabs and façades. Hollow core slabs span between load bearing precast concrete façades to create large open spaces (figure 1). For designs which require longer spans, internal columns can be used to provide intermediate supports (figure 2) (Van Acker 2007). In South Africa, equivalent buildings are often constructed in-situ using frames made from concrete columns and beams in connection with post-tensioned flat slabs. →

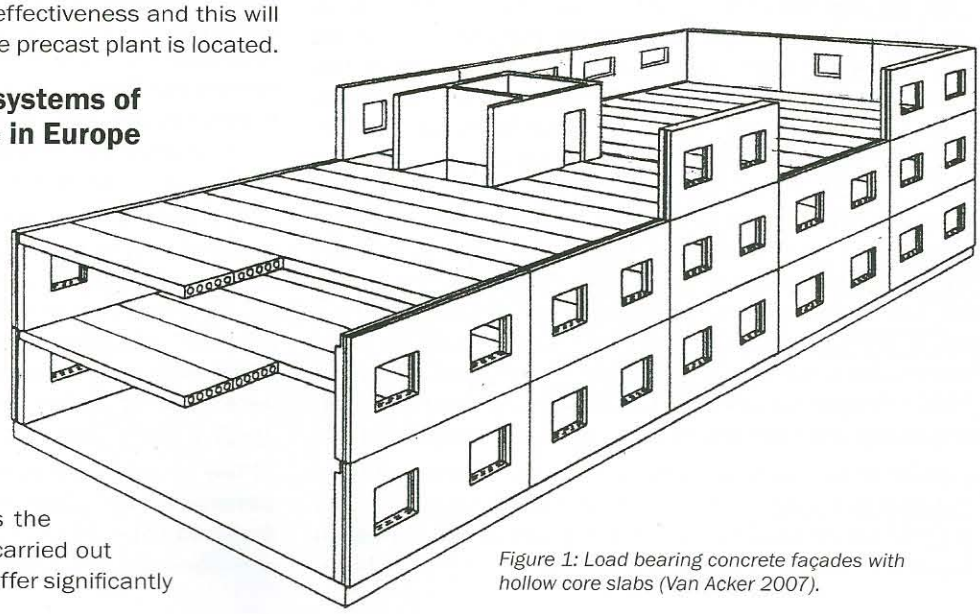


Figure 1: Load bearing concrete façades with hollow core slabs (Van Acker 2007).

Figure 2: Skeletal frame design with internal columns (Van Acker 2007).

Figure 3: Example of skeletal frame design with internal columns (Spancrete, USA).

Industrial Buildings

It is common practice in South Africa for industrial warehouses to consist of a portal frame of structural steel with brickwork enclosing the rest of the structure. On a number of building projects in South Africa, tilt-up precast concrete columns have also been used. European designers have made the use of precast concrete in two different systems for industrial application. The first system is the portal frame system. The basic components of a portal frame include two columns and a roof beam or rafter (Van Acker 2007). The vertical forces are transferred into the rafter and further into moment resisting columns on which the beam/rafter is simply supported. The connection between column and beam is assumed to be pinned, however a clamped or moment resisting connection is necessary between the column and foundation so as to allow for a moment distribution within the column (Elliot 2002). Precast façades can be connected to a portal frame of columns and edge beams to support the horizontal panels.

In another European application, load bearing façades are used to support saddle roof elements. The roof elements are precast double T slabs, which are light in weight and are capable of spanning large lengths.

Parking Structures

In Europe and North America precast concrete is often the most popular material in the construction of multi-level parking structures. The most common design of such structures is a skeletal frame system made of precast columns, beams and slabs (Van Acker 2007). In skeletal structures, vertical loads are transferred into the foundations through a network of beams and columns, and the horizontal loads by columns, elevator shafts, stairwells and shear walls.

Structural Stability and connection between elements

Structural stability is one of the most important considerations of structural precast concrete design as it involves both the design of the members as well as the connections between them. The transfer of forces through the components of a precast structure is vastly different to that of a continuous monolithic structure which is especially true at the connections (Elliot 2002).

The design of joints and connections is therefore of great importance and represents the single largest difference between the design of in-situ and precast structural frames. Educating structural engineers in the design of precast frame structures, emphasis has to be placed on connections. Design guidelines for connection types and details are provided in the literature (Van Acker 2007).

3. REVIEW ON THE SOUTH AFRICAN MARKET CONDITIONS FOR PRECAST CONCRETE

The first introduction of structural precast technology to South Africa occurred in the early 1960s, with much North American and European influence. During the past few decades, a sustainable trend towards structural precast could however not be established, and a number of precast facilities had to close following the recession in the mid 1990s (Beushausen 2004). The use of precast technology as a time-efficient method for erecting residential and industrial buildings should be encouraged by architects and engineers. However, despite the obvious advantages of precast construction for the local industry it is still far from being used to its full potential.

Market reviews in the form of questionnaires and personal interviews were undertaken in an attempt to investigate the current status of the structural precast concrete industry in South Africa. The objectives were to identify differences between the local and global applications of precast concrete, to investigate the mindset of the local industry towards precast technology, to identify the extent to which precast concrete applications were being used and to investigate the sustainability of the local precast industry.

The first part of the market review, the questionnaires, served mainly to identify application fields of structural precast components in South Africa and to establish whether the individuals taking part in the survey, acknowledge the various advantages of precast construction and design. A total of 20 questionnaires were sent out country-wide, of which 14 were returned by five architects, four consulting engineers and five contractors.

The second part of the market review involved discussions with 14 selected individuals from different regions in South Africa, in addition to those who had responded to the questionnaire, who are actively involved in the South African

precast industry. This included for example manufacturers of precast components and representatives of official industry bodies such as the Cement and Concrete Institute and the Concrete Manufacturers Association.

Detailed discussions on possible reasons for the apparent reluctance of the South African market to adopt a sustainable and effective precast manufacturing industry were held. The most important information gathered and the main conclusions drawn from the market review are discussed in the following sections.

Questionnaire responses

General awareness of advantages of precast construction

All of the respondents claimed to be familiar with the benefits of structural precast concrete. The advantages that were listed are summarised in relevant categories, as shown in table 1.

Table 1: The advantages of structural precast construction as acknowledged by various professions in the industry.

Advantage	Contractors (5)	Consulting engineers (4)	Architects (5)	Total
Quality of products (durability)	4	3	4	11
Reduction of on-site labour	4	3	4	11
Increased speed of construction	4	3	3	10
Cost benefits	4	1	1	6
Reduced on-site complications	4	0	2	6
Variety of surface finishes	0	2	1	3

Most of the respondents (11 out of 14) acknowledged the high product quality that can be achieved through precast construction methods and linked this to superior durability of the structure. The same number of individuals stated that the reduction of on-site labour is a major advantage of precast construction, while increased construction speed was recognised by 10 respondents. It is interesting to observe that despite the awareness of the above advantages only six respondents linked these advantages to economical benefits.

Generally, the list of responses covered most of the advantages commonly ascribed to precast concrete, however only two people listed more than three advantages, which indicates a limited knowledge on the subject.

Another advantage generally attributed to precast concrete technology is freedom in architectural design of concrete surfaces, which local architects seem to be largely ignorant towards. It was found that both architects and consulting engineers are unaware of design flexibility and diversity offered by precast technology, which could possibly be attributed to a lack of interest on the subject.

As can be seen from Table 1, the advantages of precast technology are predominantly experienced by the contractor, who profits from reduced on-site complications and increased construction speed and links these advantages to economical benefits.

Awareness about economical advantages of precast construction

Most benefits commonly associated with precast technology relate to a direct or indirect economical advantage. Indirect economical benefits can, for example, result from high speed of construction in connection with early occupation of the structure and hence early return on investments.

Improved quality standards reduce repair and maintenance work and may result in considerable cost savings already during the construction period. In addition, the repetition in manufacturing standard elements can result in cost savings during fabrication.

In an attempt to explore the mindsets of the respondents in view of the economical advantages of precast concrete they were asked to state which of the following two general statements they would rather agree with:

Precast construction is economical as it reduces the cost of on-site labour, speeds up construction and ensures high quality surface finishes.

or

Precast concrete components are expensive which renders in-situ concrete construction a more economical option.

It should be noted that the 'correct' choice between the above two statements depends on the particular project under consideration. In the scope of this general review, the two statements were used to identify the general mindset of the industry.

In response, the majority of the respondents felt that precast concrete components were uneconomical in comparison to in-situ concrete (figure 4). Two individuals chose not to reply to the question. All of the four individuals who agreed with (a) were contractors, which suggests that the contractors are more accepting of precast construction as the advantages of the technology are experienced by them the most. This also suggests that the lack of structural precast in local construction is related to the mindsets of the designers and project leaders. →

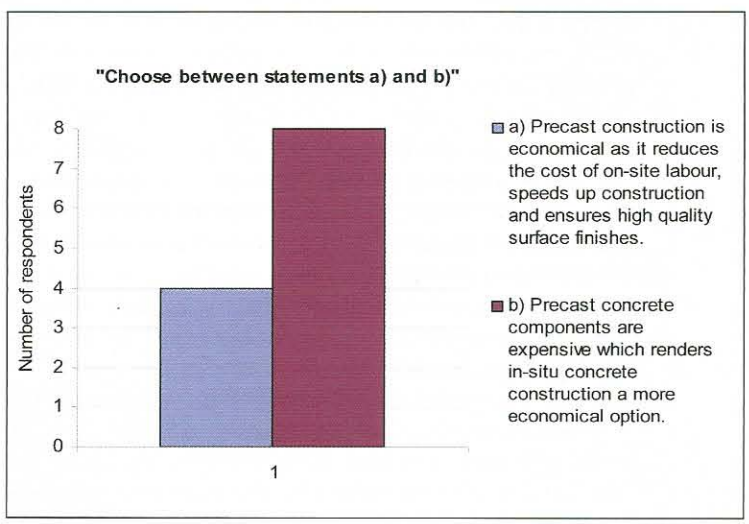


Figure 4: Graphic illustration of the number of responses to the question whether precast construction had economical advantages or disadvantages towards in-situ construction.

The use of structural precast components in South Africa

Most of the respondents had made use of precast components in some of their projects. Table 2 lists the applications, for which precast components have been used. As indicated, structural precast is mostly used in residential applications followed by commercial and industrial buildings.

The most commonly used elements are precast floor slab systems, such as hollow core or rib and block. Precast beams are used mainly in commercial applications where long spans are required. Other applications included non-structural components and precast products such as paving blocks, roof tiles and gutters as well as infrastructural elements in the form of bridge beams and storm water pipes, which are not discussed in the scope of this paper.

The responses, unfortunately, do not indicate to what extent or how often precast technology was applied for the various elements. However, they show a general trend on which types of elements have found a certain degree of acceptance in the local industry.

All of the respondents who had made use of structural precast technology for various applications agreed that they in fact had benefited from the use of precast concrete.

Table 2: Questionnaire response: Applications of structural precast components in South Africa (14 respondents).

	Type of building structure		
Component	**Residential**	**Commercial**	**Industrial**
Suspended slabs	10	8	7
Beams	5	7	2
Columns	1	4	3
Walls	2	0	2
Load bearing façades	5	4	3
Non-load bearing façades	6	4	2

Acceptance of precast technology

The South African structural precast industry is small in comparison to European and North American standards, with only a very limited number of precast yards countrywide being equipped to produce structural elements such as columns, beams and slabs other than hollow core (e.g. double-T slabs).

In order for the precast industry to expand its facilities, there needs to be a demand for precast components and a willingness to consider precast concrete as a design alternative. The current lack of structural precast concrete in South Africa seems to be resulting mainly from the mindset of the industry, favouring traditional in-situ methods of construction for various reasons. However, almost all of the questionnaire respondents were willing to expand their knowledge and gain further insight into the use of structural precast concrete (figure 5). This reveals that the mindsets of engineers, architects and contractors can be altered through the development and expansion of the existing precast industry. Of the 14 respondents, 12 indicated a willingness to consider incorporating structural precast more frequently if a sustainable precast industry was to be established (figure 6).

It appears that professionals in the construction industry would accept structural precast more readily if a greater range of systems and components were available to them.

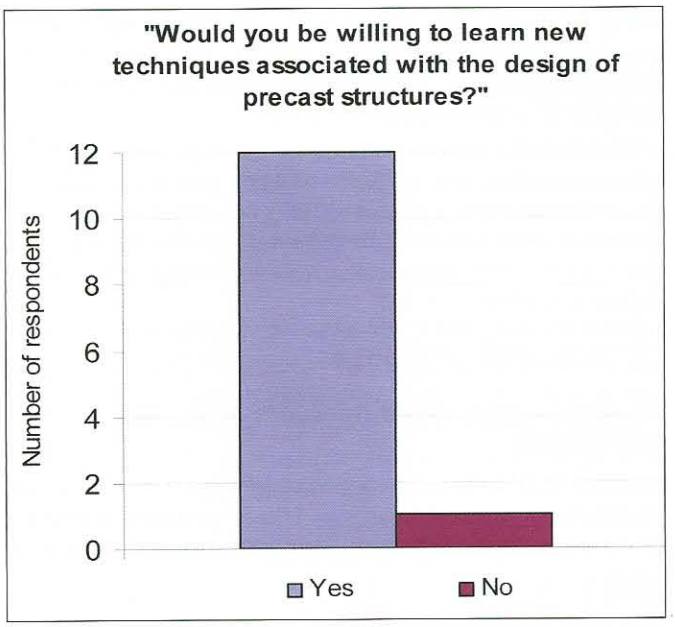


Figure 5: Number of respondents interested in learning more about the use of structural precast concrete. (One individual did not reply to the question).

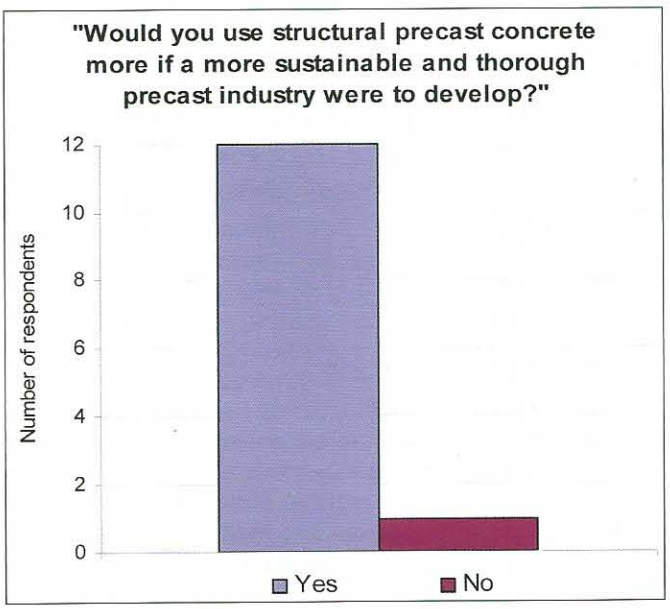


Figure 6: Number of respondents willing to apply precast concrete construction more frequently. (One individual did not reply to the question).

Individual interviews with selected experts

Reasons for the lack of structural precast concrete in South Africa

In the discussions it was discovered that the lack of precast concrete technology in South Africa can be attributed mainly to the following reasons: Conservative industry mindset; Lack of technical skills of construction workers; Lack of engineering knowledge in precast design; Lack of planning in the design phase; and Lack of diversity in precast components and limited design alternatives.

Conservative industry

The bulk of interviewees felt that the consulting engineering fraternity in South Africa is conservative and slow to adapt to new ideas. Seven individuals agreed that mindset is a major

detrimental factor to precast in this country and they gave examples of projects where precast technology could have successfully been used in the design, but in-situ was preferred because the engineer was reluctant to look into alternative design and construction methods.

As a possible reason for this mindset it was identified that precast technology is generally not taught in the civil engineering programmes of the South African universities.

Lack of engineering knowledge in precast design

The absence of precast frame structures in South Africa was related to the lack of engineering knowledge required to manage complex connection details both in the design and construction phases.

Lack of technical skills among construction workers

Ten of the interviewees agreed that South Africa lacks the technical skills required for precast technology and related this to the shortage of skilled artisans and construction workers. It was felt that the degree of accuracy and precision necessary for precast component installation could not be achieved in South Africa.

Lack of planning in the design phase

For a project to incorporate precast successfully, interaction between the precast manufacturer, the contractor and the design engineer is vital at the earliest possible stage.

It was mentioned by three interviewees that insufficient planning in many South African construction projects is restricting the market from adopting structural precast technology.

In Europe, for example, it is common practice to commence site work only once the design has been finalised and completed. In contrast, in South Africa the design and construction stages are often carried out simultaneously, which does not suit precast construction.

Lack of diversity in precast components and limited design alternatives

Five individuals felt that the repetition of elements and the modular nature of precast construction restrict designs to standard layouts, which limits architectural diversity. In addition it was stated that design engineers generally favour in-situ construction as precast concrete limits the amount of design changes that can be made once construction has begun.

Methods for the promotion of structural precast in South Africa

Most of the interviewees were of the opinion that structural precast should be promoted in South Africa as the inherent advantages of precast construction would benefit the local industry. Changing the mindset of design engineers and architect seems to be one of the biggest challenges in developing a sustainable precast industry in South Africa. Suggestions were made to incorporate precast design in engineering education at universities and to regularly hold seminars and workshops on the subject. A number of interviewees felt that suitable marketing and awareness strategies should be implemented to improve the customers' perceptions of structural precast. Another suggestion was to promote a combination of precast and in-situ construction techniques. This could increase the acceptance of precast technology as it would gradually blend into the market and allow design engineers and architects to familiarise themselves with the technology.

A precast frame structure (columns, beams, slabs, shear walls) in Europe (Arnold van Acker, Belgium).

Three interviewees felt that precast framed structures would be more prominent if the structure of the contracts would allow for it. It was recommended that the design be carried out in cooperation with the contractor or project manager and that communication between different parties should commence at early stages of the design process.

Opinions on the future of the South African structural precast industry were both negative and positive. Three individuals felt that no future exists for structural precast manufacturers within South Africa, with the exception of precast floor systems. In contrast, other interviewees supported a positive outlook and suggested that efforts to promote precast technology may well increase its acceptance and application in South Africa.

4. DISCUSSION AND CONCLUSIONS

Structural precast concrete has various advantages that can be exploited to a great extent in the South African construction industry. Precast technology offers users the benefits of speed of construction and assured quality in products.

Furthermore, the use of precast components reduces both the amount of labour and complications present on site. The benefits associated with the use of structural precast concrete all filter through to an economical advantage, which results in precast technology being successful in the European and North American construction industries.

The South African construction industry is growing continuously and the ability of the precast industry to participate equally in this growth is hindered by various inter-related factors that make this country unique to Europe and North America.

It is found that the mindset of the local industry is somewhat conservative towards new technology. Further, there is a large shortage of skilled labour in South Africa and this has resulted in a general lack of quality in building, which does not suit the precision of precast construction especially with regard to the complex connection details the technology entails. Local engineers are not educated on precast design principles at the universities, which leads to a lack of technical expertise associated with the subject. This has resulted in precast technology generally not being considered in the →

design phase of a project. Another issue that hinders application of precast technology is that the South African industry has developed a culture whereby construction commences prior to the completion of the final design, which is not conducive to precast construction as designs cannot be changed once the components have been ordered.

The results of the market survey further suggest that the perceived benefits of precast construction are, by and large, only experienced by the contractor.

Architects seem to be reluctant to consider precast in design due to the lack of diversity offered as only a limited range of elements and systems are currently available to the local market.

The mindset of the industry assumes precast components to be expensive but it has been found that the speed of construction and the early occupancy for the client, can offset this cost. Clients are further benefited in that the life cycle cost of the building is improved through the enhanced durability of precast concrete which reduces overall maintenance work.

A limited range of products exists in the local structural precast industry as it is dominated by floor manufacturers that supply hollow core and beam and block systems mostly for residential applications.

Other precast systems that are used in South Africa include tilt-up construction and hybrid construction. The latter marries the advantages of both precast and in-situ construction with significant benefits, which include solving the structural stability problems with purely precast construction and reducing the complexity of design of joints and connections.

In order for design engineers and architects to increasingly specify the use of precast components, a more diverse precast industry needs to be developed to ensure that designs can be realised in practice. This translates into the requirement to establish more precast facilities and produce a larger range of structural components.

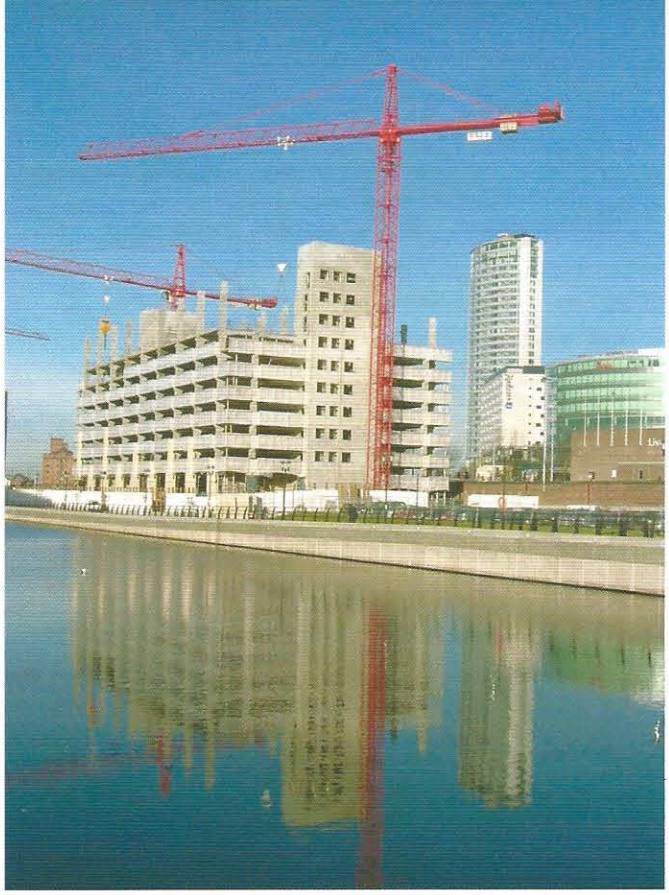
However, facilities will not be established, or upgraded, to produce structural components unless there is a clear demand. To disrupt this vicious cycle, the different members of the industry, i.e. engineers, architects, contractors and precast manufacturers, need to cooperate to establish and sustain structural precast technology in South Africa and eventually profit from the potential advantages.

5. RECOMMENDATIONS

It is clear that the acceptance of structural precast concrete in South Africa is dependent on the ability to change the traditional mindset of the industry, which is largely due to the factors included in the conclusion. The following recommendations are aimed at altering the perceptions of the South African construction industry in respect to the use of structural precast concrete technology.

In an attempt to increase the level of skills within the industry it is recommended that both designers and contractors be educated on the design and applications of structural precast concrete. Universities need to include a course on the use of structural precast concrete (with specific attention given to connection details) within their curriculums.

Training programmes aimed at addressing the poor standard of building must be initiated by precast manufacturers, who are also encouraged to create awareness amongst the



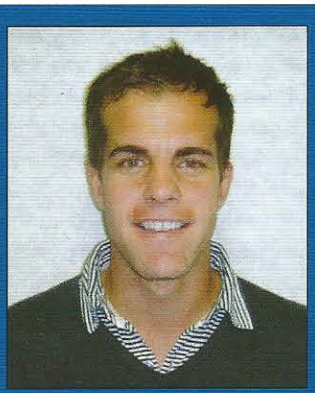
A fully precast structure in England (Martin Clarke, UK).

engineers, architects and contractors on the use and design of their products. It is recommended that suppliers send out educational software to engineers and architects informing them of the advantages and applications of the various systems as this will familiarise the industry with the technology and hence increase its acceptance.

Increasing the level of technical skills through these recommendations will enable a more sophisticated industry to develop through which projects can be planned and finalised before the contractor starts on site.

It is also recommended that manufacturers are viewed as partners in the design and construction of the entire project and get involved at the earliest possible stage.

The authors feel the acceptance of precast will be a slow process of gradual change. Therefore, it is recommended that structural precast technology be blended into the market whereby composite construction is promoted. This will allow the industry to get used to the idea of structural precast concrete in various applications. Also, existing precast facilities extend the capacity of their plants incrementally through the introduction of precast components that work in collaboration with the systems that are currently being produced.



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