PART 1 Pre-cast Concrete for Low Cost Housing: *State of the Art*

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This project is aimed at surveying the state of the art modern construction methods used in pre-cast concrete systems to suit today's low cost housing needs worldwide. The following review will provide a basis for design formulation that will be included as Part 2 of this submission.

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Executive Summary

This project is aimed at surveying the state of the art modern construction methods used in pre-cast concrete systems to suit today's low cost housing needs worldwide. The following review provides a basis for design formulation that is included as Part 2 of this submission. A survey of literature has allowed determination of the current housing needs and appropriate technologies have been identified for low cost applications.

The current housing situation in developing countries is unsustainable and existing low cost housing systems are not economically viable for governments and their populations. Solutions have been proposed by various literature sources with the most common being a return to conventional building practices and utilisation of the informal construction sector. These two practices increase the link that any scheme would have with its owners and environment whilst reducing project costs.

Consideration of the above housing solutions has led to a selection of feasible pre-cast concrete technologies being analysed. The techniques discussed are low density concretes, recycled aggregates, appropriate connections and flexible construction practices. These technologies can potentially be used together to drastically reduce the cost of building and simplify building processes to make use of informal construction sectors. The combination of technologies used would depend largely on availability of materials within the vicinity of the works. Literature resources reviewed highlight the importance of using local and readily available materials. Many recycled aggregates can be locally sourced and concerns over their material properties can be offset with other mix constituents such as crushed class or polyethylene terephthalat (PET).

This report summaries pertinent literature on state of the art technology associated with pre-cast concrete. It was found that there are many such techniques suitable for low cost housing. An ideal system would utilise recycled and local aggregates to create a low density concrete. Porosity issues associated with recycled aggregates could be offset by the introduction of crushed glass or PET aggregates. This concrete would be reinforced using short fibre reinforcement and cast in a fabric formwork. Pre-cast slab construction would allow the centralisation of skill sets, alleviating labour shortages and allow on site erection to be carried out by the informal construction sector.

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1.0 Introduction

Food and shelter are the basic requirements to sustain life. As such, shortages of low cost housing are becoming a major focus for governments and aid organisations all around the world. An increased need for low cost housing specifically exists within third world countries. These countries are those which are underdeveloped or developing in terms of their economy or infrastructure. Third world countries are predominately located within Asia, Africa and Latin America. The economic and political climates in these countries are largely unstable and this severely limits both the governments' capacities to invest in housing infrastructure and the ability of households to save with the view to buying a house. In recent times, this has been further accentuated by natural disasters in such areas and a lack of resources or planning to provide an immediate response.

Current housing systems within underdeveloped and developing nations have traditionally used the formal building sector for construction (Ikejifor, 1999). These systems have been largely unaffordable for the target demographic of low income constituents and have regularly been purchased by wealthier individuals, drug lords and prostitution rings (Lizarralde & Root, 2008). In recent times housing programs have started to look towards the informal construction sector and traditional housing methods to solve these problems. Traditional housing provides a greater connection between house and environment but is also the most effective solution for satisfying the occupant's lifestyle requirements and sociological needs.

Pre-cast concrete provides an opportunity to streamline construction within the informal sector and incorporate traditional housing requirements into low cost housing. Concrete can be made using local aggregates and shaped to create housing that successfully integrates with established dwellings. Increasing the speed of construction and decreasing the costs of materials are pivotal to providing affordable housing for the homeless. Pre-cast concrete structures have always been quick to install but recent advances in technology have meant that a wide variety of aggregates can be used at decreased volumes.

It is the purpose of this project to survey pertinent literature on state of the art pre-cast concrete techniques that have a possible application in providing a solution for housing shortages. Existing housing systems will be explored and with this exploration as a context, appropriate technologies identified for application in future low cost housing systems. The technologies identified by this literature review centre on the use of low density concretes, recycled aggregates and the reinforcement of pre-cast concrete members. These technologies have exciting applications for low cost housing when teamed with appropriate connections and construction practices.

1.1 Evolution of Pre-cast Concrete Technologies

Pre-cast concrete is concrete that has been cast in a place other than its final position. Pre-cast concrete is concrete that has been cast in a place other than its final position. It is a movable material that can be cast either on or off site, potentially within a factory. In cases where construction is carried out on site pre-cast concrete can alleviate issues associated with site access. The popularity of pre-cast concrete members over the last century has seen it used in numerous structural and architectural applications. The reason for this widespread use is that it offers increased accuracies, quality finishes, fast construction and low maintenance (Richardson, 2003). Labour costs are a major component of any project budget and pre-cast panels can reduce these costs dramatically. Utilising tilt up construction techniques, a building can be completed in days not weeks.

Pre-cast concrete offers tested solutions for specific geometries and provides the perfect solution to skill shortages in the construction industry. A major component of pre-cast concretes appeal was that panels and members could be cast off site and a less skilled crew used for onsite erection. Only one group of workers needed to be trained in the slab casting techniques.

The new trend with pre-cast concrete members is to use admixtures and different aggregates to create lower density concretes. These concretes use much fewer materials and have high insulating properties due to their comparatively high void ratio. Advances in low density pre-cast concrete panels have centred on non-structural members but work is now being done to create low density structural members with the aid of reinforcement. This is a revolutionary step in the design of pre-cast concrete.

Advances in technologies are not limited to low density concretes. The provision for the use of recycled aggregates in precast construction and flexible construction techniques are now being explored. It is these technologies, along with low density concretes, that constitute the state of the art techniques discussed in the body of this report.

1.2 Current Technologies and Their Potential Use in Context

Current pre-cast concrete technologies provide an opportunity to solve the costing problems associated with the low cost housing sector in many different environments. This literature review has identified the relevant techniques for use in third world countries. These techniques consist of; low density concretes, recycled aggregates, short fibre reinforcements, shallow embedded connections, tilt up construction and fabric formwork.

These technologies have been selected because they are applicable to construction to be carried out by the informal sector of the industry, they can be adapted to provide housing that assimilates with traditional housing structures and provide cost reduction opportunities for low cost housing construction. The relevant literature specific to each of these technologies will be analysed and cited in the following body of work.

2.0 Current Housing Systems

The prevailing view throughout almost all the literature analysed is that current low cost housing systems are unsustainable. Lizarralde et al. provides anecdotal evidence of government housing being purchased by organised crime due to its financial inaccessibility. This perception of existing low cost housing as out of reach from its target populace is widespread throughout the literature surveyed. The other problems identified with current low cost housing include thermal efficiency (Matthews, Richards, Rousseau & van Wyk, 1994) and lack of context among traditional structures (Ikejiofor, 1999).

Contrast exists within the body of literature examined, in that; each source provides a different solution to the viability problems encountered by low cost housing schemes. Uche Ikejiofor of the Nigerian Federal Ministry for Works and Housing, highlights the importance of utilising existing architectural designs and materials to increase the connection between people, structure and environment. This stance makes financial sense too as these materials would be in greater abundance and require less transportation to site. Recommendations are made by Ikejiofor regarding multiple family units being housed within one dwelling and central walled courtyards to provide a secured outdoor space. These are both characteristics of traditional Nigerian housing. The need for housing in Nigeria is estimated at 200,000 new units per year just to cope with the population growth in urban areas (Ikejiofor, 1999).

The second avenue for improvement of low cost housing systems is through the informal construction sector. Lizarralde & Root outline the importance of utilising the community as a labour resource in increasing efficiency of housing erection. In many third world countries skill shortages mean that supply of housing infrastructure is much lower than demand. This is the reason for high prices and the unaffordable nature of housing in these areas. The solution provided by Lizarralde et al is to enlist prospective home owners as labour in constructing their own homes. This form of informal construction industry alleviates labour shortages and means that supply is much closer aligned with demand. In doing this, emphasis must be placed on centralising skill sets and simplifying housing designs for easy construction.

Literature on low cost housing schemes provides a general consensus that current systems are too expensive. They differ however in their solution to this problem. All solutions emphasise the importance of increasing the connection of the structures to the surrounding environment. This may be done through utilising informal construction sectors and/or traditional designs. Any future schemes or designs must incorporate these ideas if they hope to be successful in addressing the growing demand for new housing throughout developing nations.

3.0 Pre-cast Concrete Technologies

Any technology to be applied to low cost housing must satisfy the requirements of the market it is targeting. The above review of literature on existing housing systems provided the basis for selecting pre-cast concrete technologies to survey. Technologies identified provide savings in gross material consumption and simplify the construction process. In many instances they would also allow for the use of local materials and each can be applied in a manner sensitive to existing traditional urbanised environments.

3.1 Low Density Concretes

The advent of low density concrete has drastically decreased the raw materials required to cast concrete members. Insulating properties of these members are also extremely high due to the increase in void ratio. The mode by which this low density concrete is produced differs between literature sources. Those modes appropriate for use in developing countries are limited to low cost solutions. Of the literature surveyed the systems selected for further review were those utilising polystyrene aggregates, fly ashes and animal protein air entraining admixtures. It is these same literature sources that also debate the suitability of such low density concretes for structural applications.

Demirboga and Kan's 2009 work on concrete composites suggests that expanded polystyrene foams (EPS) provide an unconventional method for reducing concrete density. Traditionally, EPS aggregate has not been used in structural concrete due to low strength but the literature suggests that thermal modification can dramatically increase the strength of concrete produced with these aggregates. This process requires the waste foam to be exposed to 130 ° C temperatures for 15 minutes. Testing carried out by Demirboga et al used EPS aggregate replacement rates ranging between 0% to 100% at 25% intervals. The results of testing on EPS aggregate concrete have shown that even at high levels of replacement it is still has sufficient strength to be utilised in semi-structural members. Compressive strengths of 12.58Mpa have been achieved for 100% replacement (Demirboga & Kan, 2009). The test results for various mix compositions can be seen below with mix type C1 containing the highest proportion of modified expanded polystyrene foams.

Table 1: Density, UPV, compressive and splitting tensile strength of MEPS concrete
(from Demirbog et al, 2009, pp.491)

Mix type	Density (kg/m³)	UPV (m/s)			Splitting-tensile str. (MPa)f_a			Comp. Str. (MPa)f_c		
		7 days	28 days	90 days	7 days	28 days	90 days	7 days	28 days	90 days
C1	980	1980	2190	2270	1.70	1.82	1.85	11.17	12.58	13.39
C2	1377	2500	2620	2750	2.23	2.34	2.40	12.55	13.08	15.62
C3	1692	2940	3060	3190	1.72	2.07	2.15	11.37	13.93	14.31
C4	1734	2820	3010	3180	2.13	2.38	2.39	13.44	17.65	18.92
C5	1741	3020	3150	3230	1.75	2.16	2.56	12.75	17.85	19.14
C6	2025	3420	3600	3670	2.47	3.00	3.01	19.22	23.34	27.78

Even less conventional than polystyrene aggregates are animal protein foaming agents. These admixtures are less expensive than traditional chemical agents whose cost and limited availability preclude them from use in developing countries. Effectively dried, atomised cows' blood, the use of atomised bovine haemoglobin is explored by Dheilly, Laidoudi, Queneudec & Remadnia's paper from Construction and Building Materials journal. The positives associated with such an agent are not only in aggregate savings due to low density but also in the increase of flowability and workability they exhibit. Haemoglobin to cement ratios (H/C) up to 2% have been trialled with density reductions of approximately 30% (Dheilly et al, 2009).

Table 2: Evolution of bulk density(kg/m³)of the composites as a function of H/C and mixing time used after haemoglobin introduction as regard of the bulk density of a mortar without haemoglobin (1865.39 kg/m³)
(Dheilly et al, 2009, pp.3121)

		Mixing time after hemoglobin introduction (min)		
		1	2	3
H/C ratio (%)	0.5	1540.39	1424.92	1329.84
	1	1447.19	1269.45	1130.23
	2	1421.33	1238.06	1027.58

To maintain concrete strength, mixing must be limited to one minute. Any mixing exceeding one minute in duration results in a dramatic loss in concrete strength as can be seen in Table 2. If one minute of mixing is carried out with a 2% haemoglobin to cement ratio a mix density of 1421kg/m³ with compressive strength of 20MPa can be acheived. This method of producing low density concrete is ideal for third world countries as it decreases the amount of raw materials consumed and utilises food production wastes in the form of animal blood.

The third state of the art method for producing low density concrete with potential applications in third world countries is high volume fly ash mixtures. Eshel, Nisnevich, Schlesinger & Sirotin document testing results with concrete strength of 19MPa corresponding to 1450kg/m^3 density. Fly ash is generated as a result of coal fuelled power plants, which represent the majority of power production in many third world countries. Withstanding the obvious benefits of fly ash based concretes, there have been questions raised in the past regarding its long term strength and subsequent safety for structural members. The work of Carette, Malhorta & Sivasundaram shows the long term strength of concrete prepared with high volumes of fly ash. Their work removes any doubt about the serviceability of fly ash aggregate concrete with no thermal cracking evident and negligible chloride ion permeability exhibited under long term loading.

All low density concretes have increased thermal efficiency and many of the technologies above have benefits in relation to recycling and reuse. Foaming solutions however provide increased workability which is desirable as simple construction techniques are a necessary requirement to utilise the informal construction sector. The literature surveyed identified three possible techniques for producing low density concretes in developing countries. These sources also provided evidence advocating the use of these concretes in structural applications. Of the technologies reviewed the most promising development in pre-cast concrete manufacture must be that of animal protein admixtures. This simple and accessible option for producing a foaming agent provides a recycling and reuse benefit in conjunction with improvements in constructability.

3.2 Recycled Aggregates

Recycled aggregates are often comprised of large proportions of building waste and demolition rubble. The use of this waste is most desirable as it is suited to areas of earthquake activity where housing needs can be severe and immediate. The wide range of literature examined highlighted major shortcomings in the material properties of many recycled aggregates. These deficiencies centre on the heterogeneous nature of the constituent materials. Aggregates that contain large amounts of mortar absorb too much water, adversely affecting mix properties. In addition to this increased porosity, the irregular shape of aggregate particles reduces workability (Lam & Poon, 2008). Literature sources suggest that impermeable recycled aggregates such as crushed glass and Polyethylene terephthalat may provide a solution to these problems (PET).

Recycled aggregates are not limited to those from building or demolition sites. New progress has been made by Carey, Gunning & Hills on the use of industrial waste created as part of Carbon Dioxide (CO_2) Capture and Storage schemes. The large emissions of CO_2 created by many industrialised processes and their contribution to global warming has necessitated the invention of Accelerated Carbon Technology (ACT) to bind carbon into a solid carbonate form using natural reactive materials. This process has led to an industrial waste of low porosity that is perfect for use as aggregate in pre-cast concrete slabs, panels and members. Carey et al outlines the process by which powders are agglomerated using liquid binders to increase grain size. Testing of 28 day strength of concretes made with this aggregate at varying constituencies yielded strengths and densities comparable to standard natural aggregates.

The problems associated with the porosity and subsequent low workability of recycled aggregates are well documented and discussed above. A solution to this problem is provided by in Lam & Poon 2008 and Chan, Lam & Poon 2007. Both papers discuss the properties of recycled crushed glass aggregates and their possible application in reducing porosities of concrete mixes containing traditional recycled building rubbles and wastes. Glass aggregate is almost completely impermeable. Incorporating glass into recycled aggregates for pre-cast concrete offsets any mortar or other permeable impurities in the building rubble or waste. Problems identified with using crushed glass as an aggregate to offset porosity concerns are limited to degradation caused by Alumina Silica Reaction (ASR) within the concrete. These reactions cause the formation of alkali-silica gel that can absorb water, expand and adversely affect mix bonding. This reaction can only occur if; alkalis are present in the system, reactive aggregate is present and there is a ready supply of water. ASR reaction will occur if, and only if, all these conditions are met. Chan et al notes a decrease in tensile splitting strength due to ASR but this can be alleviated through the use of wraps and lateral reinforcement.

Polyethylene terephthalat aggregate offers a viable alternative to the use of recycled crushed glass and avoids any tension cracking problems associated with ASR reactions (Abdel-Azim & Attia, 1995). PET plastics make up a large proportion of plastic bottles sold around the world. It offers similar porosity characteristics to crushed glass, at what is often a lower density. The drawback to PET aggregates is that they must be prepared for use by depolymerisation. This process requires the material to be heated to

approximately 200° C in a nitrogen rich atmosphere for up to seven hours. Depending on the level of infrastructure available in the country targeted for implementation this may preclude PET as a viable porosity offsetting aggregate.

Recycled aggregates are suited to use in developing and undeveloped countries as they reduce the demand on raw materials. This subsequently reduces cost and makes them a viable option for low cost housing applications. There are difficulties associated with porosity that have been identified across various literature sources but they can be offset by carefully designing the mix proportions used.

3.3 Reinforcement

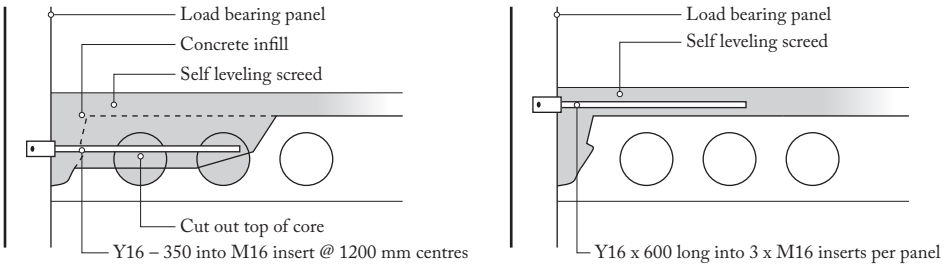
The most cutting edge and cost effective technologies available for reinforcement of pre-cast concrete members involve the use of short fibre reinforcement. Predominate literature trends suggest reinforcement is best provided by Polypropylene (PP) or Polyvinyl Chloride (PVC) fibres. These fibres aid in the transfer stress within the concrete. This form of reinforcement limits cracking caused by freeze thaw cycles and tension cracking. Arisoy & Wu's work likens this technique to the technologies employed in historical building practices. The short strands used provide a bridge within the structure similar to straw and other fibrous materials used in traditional constructions. Concrete with reinforcement can be produced with a density as low as 70% whilst maintaining serviceable compressive strength. The other important consideration with PVC and PP short fibre reinforcement is that upon failure there is no explosive capitulation of or within the structure. Reinforced structures maintain their integrity post failure which in areas of seismic activity is of paramount importance.

Short fibre reinforcement provides increases in tensile strength and, importantly, in bending failure. This increase is sufficient to render this technique appropriate for precast slab and slab track applications (Horiike, Hoshiro, Matsuoka, Sekine & Takahashi, 2008). PVA fibres provide better capacity improvements than PP fibres. Conversely PP fibres provide better workability than PVA fibres. It must be noted that Arisoy et al suggests that short fibre reinforcement used in conjunction with lightweight aggregates and air entraining admixtures produce a concrete mix that exhibits strain hardening and significant increases in flexural strength.

3.4 Connections

Construction joints between pre-cast slab and column elements are pivotal in deciding if a structure is jointed or monolithic in nature. The critical component of pre-cast concrete construction connections is achieving rigidity between members sufficient to resist bending moments, shear, tensile and compressive forces under variable loads (Hamad, Saad & Sherif, 2008). The most notable outcomes of the literature review conducted were the observations of Balendra, Robinson & Wilson regarding the behaviour of jointed structures in areas of low to moderate seismicity. It was determined that in the event of an earthquake, horizontal loading causes rocking of the wall panels resulting in horizontal and vertical shear forces being imposed on both the slab and wall connections. If jointed connections are used with shallow embedment then if failure limits were exceeded the building would retain its integrity at least long enough for people to be evacuated. The difference between shallow and deep embedded connections can be seen below in figure 1.

Figure 1: Wall panel to floor connection details (deep and shallow embedment connections)
(Balendra et al, 2009, pp.1833)



In contrast implementing a system with high rigidity of connections would result in shear deflections dominating and failure being more explosive. The survey of pertinent literature on pre-cast concrete connections completed resulted in a consensus that a jointed structure with shallow embedded connections would be the most suitable solution for any pre-cast system to be deployed in areas of low to medium seismicity.

3.5 Construction Practices

Construction practices in pre-cast concrete consist largely of the process used to form the panels used in erection. The process of completing construction onsite, especially when completing a tilt up building, is quite simple. The literature review completed identified the moulding and formwork used in casting members as a point of great interest. In countries with little to no infrastructure it is important that moulds be simple, cost effective and easily transportable. Robert Schmitz's work on fabric formwork highlights the flexibility of the system and the aesthetic properties of panels created utilising its methodology. Panels of varying size, shape and pattern can be cast. In some cases it has also been possible to transfer patterns using pigment within the textile as described in the Australian Concrete Construction Journal edited by Jack Cleaver. Fabric formwork is the most recent development in pre-cast technologies explored within this literature review. Further research should be forthcoming in the near future and this will be required before any definitive recommendations can be made as to its use in a low cost housing system context. It is this author's opinion that this future research should include the feasibility of fabric formwork being utilised as lateral reinforcement post construction. In instances where the risk of tension cracking is high, this may remove the necessity for auxiliary wrapping of structural members.

4.0 Design Considerations

In any design project the most important stage is that of research and feasibility. The above literature review provides a solid foundation for designing a generic low cost housing system for implementation within third world countries. It is apparent that the most important consideration for designing any such scheme is the context in which it will be implemented.

Availability of materials must be considered in design specification, with preference given to recycled and local aggregates. These design specification must be simple and easily implemented as in many cases construction will be carried out by the informal sector to increase viability.

There are areas within the research topic that there is little to no information. Literature sources fail to provide insight into the best way to make provision for window openings within precast panels. This refers both to their structural implications and in terms of formwork configurations. To include this design feature, more specified research would be required.

5.0 Conclusion

The best solutions provided by current literature on pre-cast concrete technologies for application in third world countries are exciting in the flexibility of their application. Each technique or system has its own merit. Low density concretes reduce the need for raw materials and recycled aggregates further reduce the strain on these natural resources. Different combinations of aggregates make it possible to avoid issues with porosity and material properties.

Uche Ikejiofor explains the concept of Architectural Darwinism as the process by which indigenous buildings are derived as they are those which are most suited to the environment in which they are used. This is why any new building must take on these design features and incorporate, where possible, local materials. The emphasis placed on linking housing to its environment must be incorporated into the method of construction. Emphasis must be placed on utilising the informal sector as this minimizes cost, mitigates labour shortages and maximises the potential inhabitants' connection with the project.

The technologies discussed in the above review are largely complementary and exhibit great scope for implementation in developing countries. Light weight concretes can be created using waste polystyrene, fly ash or animal protein derived foaming agents. The balance of aggregates used would preferably be recycled either from building demolition, waste or carbon capture systems. Any issues relating to porosity of the aggregate mix could be offset with recycled crushed glass or PET plastic. The members cast from the above mix can be formed using fabric formwork to achieve aesthetically appropriate finishes. In fixing the panels, shallow embedded connections are best utilised as under failure conditions they retain their integrity.

State of the art pre-cast concrete technologies have far reaching applications across developing countries. They have the potential to be used in conjunction with one another to produce low cost alternatives to the currently available and ultimately flawed systems. The application of even one such technology in isolation also provides the opportunity for savings in gross material use and energy consumption. In simplifying the construction requirements of the housing systems, the informal construction sector can be better utilised, alleviating the skills shortages currently driving housing costs up.

6.0 Project Management Statement

The extent of analysis required to effectively survey the body of literature available relating to pre-cast concrete technologies for this report required effective time and resource management. The appropriate resources needed to be identified, feasible technologies selected and then analysis of these resources was carried out. Each stage is a time consuming processes and effective progress had to be made each week throughout the academic year.

In retrospect, it is possible to pinpoint shortcomings within my structuring of the project. The majority of these shortcomings were caused by a lack of understanding of the scope of the problem being addressed. This lack of understanding made it impossible to fully comprehend the time requirements of each component. The most positive outcome from the project was the discovery of the resource offered by mentors, faculty and industry contacts. Having this support makes it easier to understand the required concepts and think logically while trying to process all data pertaining to the project. Initial meetings with my supervisor and subsequent follow up meetings were very clear and concise and left me feeling that the methodology I was following was in line with that required to produce a meaningful response to a challenging project topic.

In the early part of the project, too much time was taken in gathering resources and more decisive action was needed to select what technologies were relevant. Although I have met the goals I set out to achieve at the proposal and preliminary stages of the project, the literature review component of the project took too long to complete. If not for time constraints associated with the submission deadline, the design formulation and

construction report that constituted the second component of the submission would not have been completed. This deadline forced me to work longer hours and with renewed focus to complete the report within initial time frames.

In completing this project I have learnt the importance of conducting thorough research and feasibility studies at the outset of any project. Failure to do so leaves unrealistic expectations and leads to unnecessary pressures relating to time constraints. In conjunction with these preparatory measures it has also become apparent that the scope of any project must be flexible enough to allow for any unforeseen events. I believe that this major project has aided me in my preparations for fulltime work and will be of benefit to both me and my employers. I will not only appreciate the importance of thorough preparation but will be able to use my time more efficiently to achieve project milestones and meet deadlines.

7.0 Glossary

Accelerated Carbon Technology (ACT)

The process of binding carbon to solids using reactive materials to form carbonates.

Alumina Silica Reaction (ASR)

The reaction between alkalis and free silica within a structure that produces an alkali-silica gel that can absorb water and expand, damaging the concrete.

Architectural Darwinism

The process by which natural selection results in the most suitable design features being present in a societies traditional housing solutions.

EPS aggregate

Expanded polystyrene foam aggregate.

Fly ash

The waste ash from coal fired powerplants

Formwork

Temporary or permanent moulds used for casting concrete.

Informal Construction Sector

That part of the construction sector whose constituents are not professional construction workers or trained in construction work.

Pre-cast

Any concrete member that is cast in forms at a place other than its final position in use.

PET

Polyethylene terephthalate, commonly found in beverage bottles or scrap textile.

PP

Polypropylene

PVC

Polyvinyl Chloride

Seismicity

The factor of how seismic a region is.

Shallow Embedded Connections

Connections that are cast closer to the surface than to the centreline of a slab.

Short Fibre Reinforcement

Reinforcement of concrete between of approximate length

Third World Country

Those countries which are underdeveloped or developing in terms of their economy or infrastructure.

Tilt Up Construction

Concrete members are cast horizontally adjacent to their final position and tilted into place.

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