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THE ASPECT OF LABOUR IN HYBRID AND IN-SITU CONCRETE CONSTRUCTION IN SOUTH AFRICA

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Abstract
In this research programme labour has been identified as one of the aspects of the decision-making process between in-situ and hybrid concrete construction (HCC). The construction industry is ranked as the employer with the fifth highest number of employees in South Africa, which is currently experiencing a 25.4% unemployment rate. This highlights the importance of the construction industry as an employer in South Africa. Labour is considered as one of the areas of highest concern in the South African construction industry. This concern is intensified when the shortage of skilled labour in the industry is taken into account. A labour hour comparison between an in-situ and HCC project were conducted to provide information regarding the amounts and types of labour used in both construction techniques. The comparison showed that HCC employs low-skilled labour more effectively and in larger percentages of total labour than the in-situ alternative. However, the in-situ alternative is better for job-creation considering the total number of employment opportunities. Nevertheless, the HCC alternative has a quicker return rate due to shorter construction periods, therefore labourers are available at an earlier stage for employment on subsequent projects. It is recommended that the use of HCC be promoted to employ larger percentages of low skilled workers and to improve product delivery durations.

Keywords: Hybrid concrete construction, Labour, In-situ concrete

1 Introduction

Hybrid concrete construction (HCC) is a construction technique combining precast concrete elements and in-situ concrete by making use of the best attributes of each to construct buildings and other structures. Several factors can play a role when a decision is required for the most appropriate construction technique to be used on a project. Projects teams need to consider the effect of time and cost, construction safety and quality, technical capability of the designers and contractors, aesthetics, sustainability and labour related issues. This research investigated specifically the aspects of labour and how this would be impacted by a choice for a construction method. The objectives of the study were thus to make a comparison between the two construction methods by considering the types of labour and labour hours spent on each.

2 Literature Review

Precast elements are manufactured in a controlled environment, enabling the production of higher quality products than in the in-situ environment (Elliott, 2002). The controlled environment enables project parties to provide a safer environment for the workforce and to give them better job security (Lombard, 2011). South Africa strives to create 11 million jobs by 2030 (National Planning Commission, 2013). These job creation schemes are described by the *National Development* Plan (NDP). This programme has a direct influence on the

construction industry as it is expected from construction companies and other labour-based industries to provide job opportunities to the unskilled and unemployed labour market. Civil construction projects are ranked amongst the best areas to promote good economic growth and to create job opportunities since it is considered as a labour-intensive environment (National Planning Commission, 2013). Interviews with individuals from the South African construction industry concluded that job creation is considered as one of the barriers for the implementation of HCC in South Africa (Schreuder, 2015). Considering the NDP, in-situ construction may provide more employment opportunities, but it is of a more temporary nature than that of HCC projects. Also, according to (Piek, 2014), in-situ concrete construction requires skilled labour, making the use of unskilled temporary labourers a concern for meeting quality requirements.

The *Expanded Public Works Programme* (EPWP) provides a platform to carry out the projected milestones of the NDP. This programme also strives to promote skills development at a sub-programme level, as they are familiar with the current low skills of labourers in South Africa (Department of Public Works, 2013). Considering the objectives of the NDP and EPWP regarding job creation and skills development, HCC does not seem as the ideal solution upfront as it is often postulated to utilize fewer labourers and also for a shorter period (Irish Concrete Federation, 2014). Information on the extent and type of labourers used in this environment will provide relevant support regarding the validity of this opinion. For this reason an investigation was carried out to investigate these aspects of labour by means of a case study.

3 Research Methodology

3.1 Techniques

This study made use of several techniques to satisfy the required research objectives. It was decided to divide the study into two sub-divisions. These were:

Socio-economic aspects of labour in both construction techniques.

Labour productivity and its effect on both construction techniques.

The research process of this study is based on triangulation, which is defined as the use of two or more points of reference to enhance the accuracy of findings. The following paragraphs give a brief description of the research methods applied.

A literature study was first conducted, combining international and local information regarding this investigation to gain background knowledge and to guide the remainder of this study. Semi-structured interviews were also performed involving representatives from various organisations in the South African construction industry. These interviews served as the primary data source regarding socio economic aspects of labour in both construction techniques. It also served as guideline for the set-up of the case study. Ten individuals were interviewed and were asked similar questions. Asking similar questions to various people provides a good point of reference and gives a better understanding of the topic.

Site visits were conducted to enrich the researcher's practical knowledge regarding the two construction methods under consideration. These visits were conducted at the following construction sites:

- In-situ construction sites: New Panorama hospital building - (NMC)
- Hybrid Concrete Construction sites: CPUT hostel building - (NMC)
- Prefabricated elements manufacturing plants: Cobute, Concrete Units, Portland Hollowcore

In a case study a labour hour comparison between an in-situ and hybrid concrete construction project was done to investigate job creation in both the considered construction methods. According to the *Fundamentals of quantitative research*, quantitative methods are normally

used to test hypothesis and theories (Sukamolson, 2012). This labour hour comparison compares the labour hours of an in-situ building with a similar HCC building. The labour hours spent to manufacture the precast concrete elements used at the HCC project were also considered. The case study was conducted to help with the setup of the research. The interviews were mainly conducted with individuals from the construction companies providing the labour execution rates. A representative from the precast manufacturing industry was also interviewed to obtain labour hour rates regarding the precast concrete element manufacturing process.

Previous similar (construction related) qualitative and quantitative studies by Jin and Ling (2006) and Lam, Chan and Chan (2007) made use of surveys to successfully answer research questions (Jin and Ling, 2006; Lam, Chan and Chan, 2007). Furthermore, Chan and Chan (2004) also used semi-structured interviews to assist with primary data collection (Chan and Chan, 2004). In addition, research by Ogunlana (2010) determined how various participants on large-scale construction projects perceive performance on projects, by using both semi-structured interviews (a total of 35 interviewees) and a survey questionnaire (a total of 76 respondents).

3.2 Case study

The following paragraphs provide information on the case study.

3.2.1 Structural systems and projects used in this comparison

The structural systems used in the case study were a function of the availability of data from the individuals interviewed for this case study. The construction company which provided the researcher with the labour hour rates of execution predominantly use hollow core floor slabs on loadbearing brick walls in their HCC projects. In their in-situ projects they predominantly use the first two techniques shown in Figure 1.

Project-specific labour hours of activities for post-tensioned flat slabs and conventional flat slabs on in-situ concrete columns as shown in Figure 1 were obtained through site visits and through meetings with the project manager and quantity surveyor of an example project. Information regarding the labour hours of a hybrid concrete construction project was also gathered through meetings with the on-site project manager and quantity surveyor and through a meeting with the director of an anonymous precast manufacturer in South Africa.

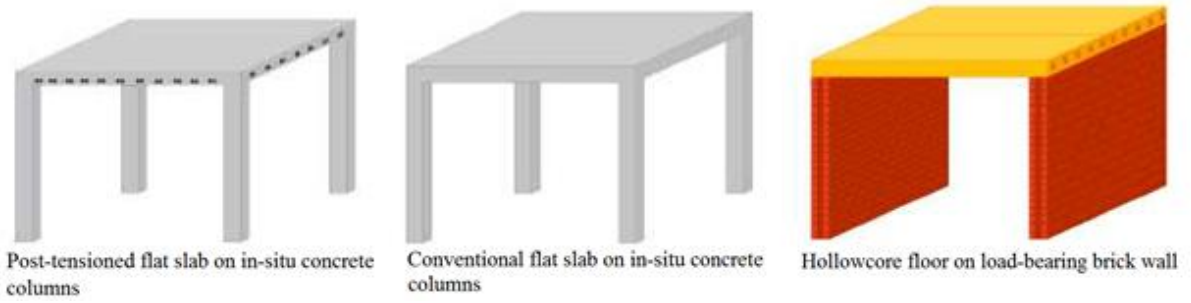

Figure 1. Structural systems used in this case study (Lombard, 2011)

In order to enable a labour hour comparison between the two construction methods, similar in-situ and HCC projects had to be compared. Information for a HCC project was available, but an in-situ replica of the HCC project was not.

A construction company was able to provide the rates of an HCC four storey student residence building. The building was constructed using loadbearing masonry walls with hollow core floor slabs, as shown by the third concept in Figure 1. The floor plan of the student residence building is shown in Figure2.

For the in-situ building improvisation was required. This was done using the available in-situ construction rates from the construction of a multi-storey hospital building. The project manager of the in-situ project was able to provide the construction rates of execution for the two in-situ structural systems shown in Figure 1**Error! Reference source not found.**. It was decided to use these rates as basis for the in-situ project and to apply them to an in-situ concept of the HCC example project. This was possible, as the spans between supports of the in-situ design could be applied to the HCC design.

By conceptually placing columns in the residence building as shown in Figure 3, a floor span configuration reasonably similar to that of the hospital building could be obtained. Also, the floor loadings of imposed load and masonry walls would be reasonably similar. By applying the in-situ execution rates (from the hospital building) to the configured residence building (Figure2), it provided an in-situ alternative for comparison with the HCC example building.

Due to the symmetrical design of the residence building, Figure2 only shows one half of the in-situ structural concept of the residence building. It is important to note that the masonry walls for the in-situ design of the residence building is non-loadbearing and all the inner walls are single-layered, which is similar to the hospital concept from where the in-situ execution rates were obtained. On the other hand, the outer brick walls of the HCC design are loadbearing together with the thicker inner walls which are also double-layered loadbearing walls.

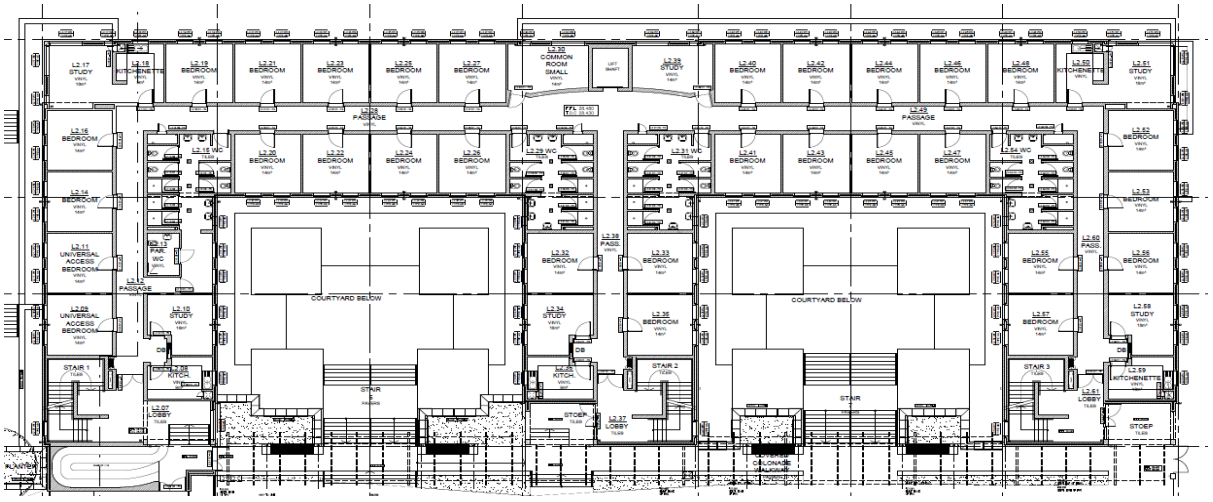

Figure 2. Original floor plan of the HCC student residence building

Both projects were constructed by the same construction company in the same year. This ensured minimal labour execution rate fluctuations between the two considered projects. The precast floor slabs used in the HCC project were manufactured using the extrusion process which is a highly mechanized manufacturing process. The precast manufacturer who provided the precast element manufacturing rates is a well-recognised hollow core floor slab manufacturer in South Africa, which contributes to the reliability of the rates.

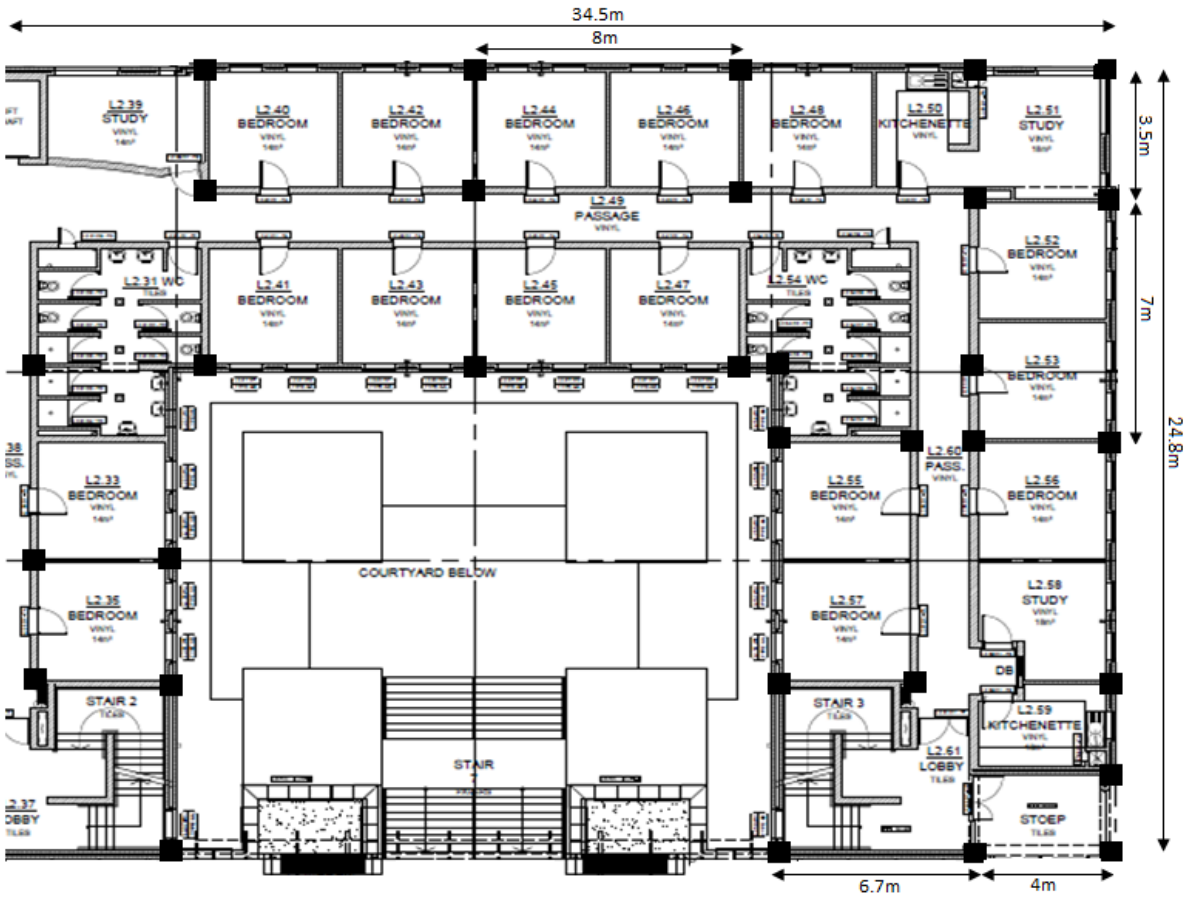

Figure 3. In-situ structural concept of student residence building

4 Findings and Discussions

The labour hour case study was carried out on a project in the structural building industry, and conclusions drawn are therefore only applicable to this industry. The comparison provides relevant information on the construction technique which best promote job creation according to the EPWP as well as the technique which best suit the current labour environment of the South African construction industry.

4.1 Labour rate estimates

The labour rates of execution as received from the project managers of both projects were a function of the labour teams used. These execution rates were simplified to units per hour for a corresponding labour team, where the unit is a function of the type of activity.

The in-situ construction unit rates from the hospital project, with the corresponding labour teams as obtained from the project managers, are shown in Table. Table2 shows the HCC rates of the student residence building with the corresponding labour teams.

The execution rates of the precast manufacturing plant and related labour teams are shown in Table3. This information was obtained from an interview with the director of a precast manufacturing plant.

Table 1. In-situ construction labour rates with corresponding labour teams (Hospital building project)

	Unit rates for each activity			Related labour teams				
	Activity	**Rate of execution**	**Production Unit**	**Supervisor**	**Operator**	**Skilled**	**Semi-skilled**	**General labour**
Columns	Erect formwork	24.19	m^2/h	1	-	-	2	4
	Re-bar	1.57	m^3/h**	1	-	-	3	-
	Cast concrete	4.18	m^3/h	1	-	-	1	2
	Dismantle formwork	30.24	m^2/h	1	-	-	-	4
Deck (Flat slab-250mm)	Erect formwork	15.63	m^2/h	1	-	-	5	8
	Stop-ends	50.00	m^2/h	-	-	-	2	-
	Re-bar	20.83	m^2/h	1	-	-	10	-
	*Install post-tensioned cables	2.63	cables/h	1	-	-	6	-
	Concrete placement	25.00	m^3/h	1	-	-	2	6
	Powerfloating (concrete)	83.33	m^2/h	-	-	3	-	-
	Curing compound (concrete)	166.67	m^2/h	-	-	-	-	2
	Remove stop-ends	62.50	m^2/h	-	-	-	-	4
	*Stressing of post-tensioned cables	4.20	cables/h	1	-	-	3	-
	Strip formwork	20.83	m^2/h	1	-	-	-	6
Masonry Walls	Single layer	14.42	m^2/h	1	-	-	10	6
	Double layer	7.21	m^2/h	1	-	-	10	6

Note: For the deck, the rates for the stop-ends and the re-bar are given as per the area of the floor

* Activities only related to the post-tensioned (PT) flat slab alternative

** The rebar for the column is given as the volume of concrete reinforced per hour

4.2 Employment opportunities in both environments

4.2.1 Legislation requirements

HCC does not seem as an ideal construction method in South Africa due to the reduced labour requirements as shown in Table 4. However, programmes such as the EPWP and NDP do not restrict the use of HCC in the structural building environment.

In the case where a project in this environment is subject to the EPWP, the only activities required to be done using labour intensive techniques are the excavation of foundation trenches by hand and the manufacturing of masonry elements on site (Department of Public Works, 2012). Both these activities can thus be done in a labour intensive manner, even when using HCC as a construction alternative.

Table 2. HCC on-site labour rates with corresponding labour terms (Student residence project)

Unit rates for each activity				Related labour teams				
	Activity	**Rate of execution**	**Production Unit**	**Supervisor**	**Operator**	**Skilled**	**Semi-skilled**	**General labour**
Deck (Structural topping -60mm)	Precast element placement	31.25	m^2/h	1	1	-	-	4
	Formwork to edges	50.00	m^2/h	1	-	-	2	4
	Props	62.50	m^2/h	-	-	-	2	2
	Mesh instalment	20.58	m^2/h	-	-	-	-	4
	Concrete placement	12.43	m^3/h	1	-	-	2	6
	Powerfloating (concrete)	83.33	m^2/h	-	-	3	-	-
	Curing compound (concrete)	166.67	m^2/h	-	-	-	-	2
	Strip formwork	2.25	m^2/h	1	-	-	-	4
	Strip props	62.50	m^2/h	-	-	-	-	4
Masonry Walls	Single layer	14.42	m^2/h	1	-	-	10	6
	Double layer	7.21	m^2/h	1	-	-	10	6

Note: The rates for the formwork to the edges and for the props are given as per the area of the floor

Table 3. Labour manufacturing rates at precast plant

Unit rates for each activity				Labour teams			
	Activity	**Rate of execution**	**Production Unit**	**Supervisor**	**Operator**	**Semi-skilled**	**General labour**
Production	Cable placement and stressing	86.67	m^2/h	-	1	2	-
	Casting	130.00	m^2/h	1	4	-	4
Stripping	Measure and cutting	130.00	m^2/h	1	2	4	-
	Removal from cast bed	65.00	m^2/h	-	1	-	4
	Move from stockyard onto truck	65.00	m^2/h	-	1	-	4

Note: All the rates in Table 3 are given per area of the floor

4.2.2 Labour hour comparison

A labour hour comparison between the three alternatives shown in Figure 1 was conducted. The comparison relies on the labour hour rates as received from the project managers and the quantity surveyors.

The floor slab is the only structural element constructed using precast elements in the HCC alternative. Therefore, this activity will be compared in isolation. The labour requirements for the HCC alternative are 1385.6 hours (1030.3 + 355.3), while the conventional method requires 3117.3 hours. This indicates a 55.6% reduction in labour for the construction of the floor slab when using HCC. However, in the structural building industry, all the components are rarely constructed using only precast elements, therefore considering the construction of all the components will provide a better indication of the labour requirements for both techniques.

Table 4. Labour requirements in different construction alternatives

Labour requirements, in man hours per floor level			
Activities group	In-situ concrete construction		Hybrid concrete construction
	Post-tensioned floor slab	**Conventional floor slab**	**Precast floor slabs and bearing walls**
Walls	1898.3	1898.3	2397.3
Columns	377.4	377.4	-
Floor slabs (on-site)	2805.7	3117.3	1030.3
Floor slabs (plant)	-	-	355.3
Total	5081.5	5393.1	3782.9

Considering the total labour requirements as shown in Table 4, it is evident that HCC only requires between 70.1% and 74.4% of the labour force used in the two in-situ alternatives. This comparison includes the floor system, floor supports and supporting walls. Thus, considering the labour requirement reduction of the HCC alternative, it follows that this alternative is more labour effective since it uses less labour to construct the same building (Table 5). However, referring to these values, the use of HCC implies loss of employment opportunities which is considered as a disadvantage considering the current unemployment rate of South Africa. Although HCC utilizes less labour, it has a faster turnover, which means that labourers are available for new employment opportunities at an earlier stage. Another important factor to consider is the type of labour used in each alternative.

Table 5. Man hours required per square meter

Floor slab	Rate (Man hours/m^2)
In-situ (conventional)	4.68
HCC	3.28

4.3 Types of labourers used in both environments

The comparison of the types of on-site labour used in the in-situ and hybrid concrete construction projects, as provided by the project managers, will address the validity of the HCC technique to serve as solution for the current shortage of skills of South African labourers.

Table 6 shows the on-site labour skills breakdown of the construction of the floor systems shown in Figure 1 for the two construction types (In-situ and HCC). These values were compiled from the information obtained from Tables 1, 2 and 3. The labour information of the in-situ conventional floor system (Figure 1) were used for the in-situ construction type shown

in Tables 5 and 6, as this technique is more commonly used in South Africa than the post-tensioned (PT) flat slab system.

Table 6. On-site labour skills breakdown for the construction of the floor slab

Construction type	Labour skills						Total
	General		Semi-skilled		Skilled		
	Number	**% of total**	**Number**	**% of total**	**Number**	**% of total**	
In-situ	26	45.6	28	49.1	3	5.3	57
HCC	30*	75.0	6**	15.0	4	10.0	40

*Example - General labour (Table) 4+4+2+4+6+2+4+4 = 30

**Example – Semi-skilled (Table) 2+2+2 = 6

Note: Machine operators are considered as skilled

Note that supervision was not considered in this comparison as they were not considered as part of the workforce in the research. Also, the number of supervisors used in the considered techniques was relatively similar.

Table 7 shows the on-site labour hour breakdown of the various types of labourers. This comparison should be read together with the on-site labour skills breakdown shown in Table 6.

Table 7. On-site labour hours per type of worker

Construction type	Labour skills						Total
	General		Semi-skilled		Skilled		
	Hours	% of total	Hours	% of total	Hours	% of total	
In-situ	1004.5	36.2	1728.0	62.3	41.5	1.5	2774.0
HCC	713.5	80.5	94.1	10.6	78.3	8.8	885.9

Note: Supervisors were not considered in this comparison, therefore the total hours is less than that of Table .

The in-situ labour breakdown shown in Table 6 consists of 45.6% *general* and 49.1% *semi-skilled labourers*. Whilst for the HCC alternative, 75% of the labour consists of *general labourers*. Thus, the majority of HCC's labour force is low-skilled labour.

Table 7 shows that *general labour* conduct 80.5% of the work in the HCC alternative, whilst in the in-situ alternative, *general labour* only conduct 36.2% of the work. Also, important to note is that *semi-skilled labour* conduct 62.3% of the work in the in-situ alternative. Thus, the HCC alternative requires limited skilled and semi-skilled work on-site compared to the in-situ alternative.

Thus from the comparisons presented in Tables 5 and 6 HCC comes across as the ideal solution to the current low skills of labour in South Africa, as it largely relies on *general labour* to conduct the majority of the work.

5 Conclusion and Further Research

From the comparisons conducted in this case study it is concluded that HCC utilizes unskilled labour (conduct 80.5% of concrete work) to greater effect than how the in-situ alternative utilizes semi-skilled and skilled labour (conduct 63.8% of concrete work) considering the

productivity of each alternative as shown in Table 5. Thus, considering the effective use of unskilled labour in the HCC environment, this alternative can serve as the ideal solution for the current shortage work for un-skilled labour in South Africa.

It should be kept in mind that HCC creates less job opportunities considering the number of labour hours required for each alternative. However, more job opportunities can be promoted in the local communities as HCC utilizes higher percentages of unskilled labourers than the in-situ alternative. Nevertheless, considering the project as a whole, the HCC alternative would create less job opportunities in total. HCC would not be penalised for creating less job-opportunities as tender requirements usually primarily encourage percentages of job creation amongst local communities. By promoting HCC more projects can be completed at a shorter delivery time providing higher percentages of low skilled employment opportunities.

6 Acknowledgements

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