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Plastic Concrete Transportation Techniques on Construction Sites: A Comparative Productivity Study

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Abstract
Target outputs on construction operations are of paramount importance to productivity studies in the built environment. The objective of this study therefore was to determine the target outputs of various methods of placing plastic concrete on construction sites as information for benchmarking concreting productivity in the Nigeria built environment. Using Lagos state as the study area, concreting operations were examined in 64 building construction sites spanning large-sized, medium-sized and small-sized construction companies with 8,34 and 22 projects respectively. Using stratified random sampling, 25 of the 64 sites were selected for investigation and were made up of 5, 10, 10 sites for the respective large, medium and small-sized construction firms. The study was limited to bungalows and single storey residential, commercial and office building sites managed by construction companies registered with the Federal or Lagos State Ministry of Works only. A total of 167 daily concrete pours was observed on the 25 construction sites at an average of 6 days per site. Data collected included placing method, location/type of concrete pours, quantity of concrete placed, overall pour time, number of operatives engaged, and actual duration of concreting, distance to pour location, weather and delay time. The results showed that the four main concrete placing techniques used in Lagos State were cranes, dumpers, wheelbarrows, and head pans. The mean overall concreting productivity of cranes was 11.24 m^3/hr compared to 8.53 m^3/hr by dumpers, 6.69 m^3/hr by wheelbarrows and 3.21 m^3/hr by head pans. The labour productivity for concreting by cranes was 4.09 whr/m^3 as against 5.13 whr/m^3 for dumpers, 9.74 whr/m^3 for wheelbarrows and 12.11 whr/m^3 for head pans. The productivities were in the ratio of 4:3:2:1 for cranes, dumpers, wheelbarrows, and head pans respectively. The results have significant bearing for contractor's method statement and tend to guide construction clients in adjudicating tenders for selecting the contractor who can best manage the technical risk associated with the construction project.
Keywords: Plastic concrete, transportation techniques, construction sites, productivity.

1. Introduction

Some studies have submitted that the output of the construction industry is about 3-8% of the Gross Domestic Product (GDP) in most countries and that the European construction investments estimated at some 690 billion ECU, representing approximately 12% of European GDP employs more than 7 % of Europe's work force and is the largest industrial employing sector in the continent (Proverbs, Holt and Olomolaiye, 1999a; Ameh and Odusami, 2003).

Concreting is one of the most common operations in today's construction industry and concrete operations including batching, transporting and placing are familiar in many construction sites throughout the world. Furthermore, the operational productivity of equipment and labour in concrete placing is an essential, intrinsic parameter influencing the construction industry (Chan and Kumaraswamy, 1995), (Wang Ofori and Teo, 2001) and (Dunlop and Smith, 2003). In addition, Graham, Smith and Tommelein (2005) submit that globally, the construction industry is a major consumer of mixed concrete and the trend that the production rates of the material are on the increase signifies a continuous reliance by the construction industry on it.

According to Wang and Anson (1994), the production of concrete in Hong Kong was estimated at over 10 million m^3 per year or 1.6m^3 per person per year while Wang Ofori and Teo (2001), reports that in Singapore, the demand for ready-mixed concrete (RMC) rose steadily from 4.7 million m^3 in 1991 to 10.7 million m^3 in 1998. Although in Nigeria there is shortage of data and information on the overall demand and production of concrete, there is no doubt that concreting and concrete placing also play important supportive roles in the growth of the Nigerian construction industry. In a typical Nigerian building, for example, there is concreting in virtually all elements of the building-foundation, wall strips and bases, columns and beams including lintels, ground and superstructure floors, roof gutters and roof beams.

It has since been established that productivity rates rank amongst the most essential data needed in the study of construction productivity because planning engineers require these rates to estimate and schedule pours, resource levels as well as accounting control and often maintain a large databank of basic productivity rates which they adjust for individual projects taking into account specific site factors and conditions which may influence productivity rates (Dunlop and Smith, 2003). While several studies have been conducted on factors that affect labour productivity in the Nigerian construction industry, there has not been any detailed study or published information on the on-site management factors that affect overall productivity in construction operations. These factors have been found to be of more potential value than motivational influences and without them being addressed, it is fruitless pursuing any other productivity drive (Olomolaiye and Ogunlana (1989). In order to fulfill this requirement, this research has investigated the productivity of the different concrete placing methods and the influence of these methods on concreting productivity rates. Previous findings by Anson and Wang and Anson (1994,), Chan and Kumaraswamy (1995), Wang Ofori and Teo (2001), Lu and Anson (2004) and Dunlop and Smith (2003), have indicated the effects of placing method on concrete placing productivity in the countries of Europe, Hong Kong and Singapore. This paper builds and expands on these pervious works by identifying the concrete placing methods prevalent in and peculiar to Nigeria and focusing on the examination of the productivity rates in these placing methods.

The previous findings referred above indicate the impact of concrete placing method on the productivity of concreting operations Based on these findings, this study examined many concreting operations on selected building construction sites in the Lagos metropolis to obtain concreting productivity data which can be analyzed to enable project managers predict productivity rates given the type of placing method adopted in any concreting operation.

2. Concreting Productivity Rates

Productivity can be defined in different ways depending on the purpose of measurement. In construction, trade productivity is usually defined for conceptual and analytical simplification as the ratio of the output in a particular trade as related to the tradesman's inputs and can be expressed in quantitative terms as physical productivity. Wang (1995) further submits that it is important to specify the input and output to be measured when calculating productivity because there are many inputs such as labour, materials, equipment, tools, capital and design to the construction system while the conversion process from input to outputs associated with construction operations is also complex, being influenced by the technology used and by many externalities such as government regulations, weather, unions, economic conditions and management and by various environmental components. Even for an operation like concreting, with well known equipment and work methods, construction productivity estimation can be challenging, owing to the unique work requirements and changeable environment of each construction project as well as the complexity of the influences of job and management factors on operational productivity (Ok and Sinha, 2006).

Different yardsticks are usually employed for measuring the productivity of concrete placing by giving the placing labour or equipment productivity as the ratio between the quantity of concrete placed to the man-hours (mh) or equipment hours (eh) committed by the placing gang or equipment respectively, the mixer productivity as the ratio between the quantity of concrete placed to the mixer-hours spent on site (Anson, Wang and Wang, 1996). Concreting productivity consequently entails relating a single input(worker-hour or equipment-hour) to a single output (concrete volume in m^3) and the simple productivity ratio of this input and output is calculated assuming a closed system with all other factors held constant except for the desired input and output (Wang, 1995). Such productivity measures relating output separately to each major class of input proportions reflect changes in these input proportions as well as changes in productive efficiency and allow organizations to analyze the changing costs of the inputs when combined or when separated in terms of both their prices and quantities. The overall productivity for an entire concreting operation which is the placing rate is thus appropriately measured as the ratio of the quantity of concrete placed to the total time of the operation in m^3 /hr. However, in this study the convention of measuring labour productivity as input divided by output or operative hours per unit of work, (wh/m^3 of concrete) has been adopted, since it has been found more appropriate for planning purposes (Proverbs, Holt and Olomolaiye,1999b), Dunlop and Smith, 2003).

3. Methodology

For the purpose of this study, all the bungalow and single-storey building sites in Lagos metropolis where considerable in-situ concreting was being carried out were visited between January and March 2006 to identify 64 building sites manned by contractors duly registered with the Nigerian Federal Ministry of Works because only such contractors are formally adjudged capable of concreting to acceptable standards. Lagos was selected for the study because it is a typical mega city with the largest concentration of construction sites and workers in Nigeria (Olaoluwa and Adeyemi, 2009). Out of the 64 building construction sites visited, 25 were selected through stratified random sampling method for detailed productivity study of their concreting operations as follows:

- 5 building construction sites manned by large sized construction firms registered in category A with the Federal Ministry of Works.
- 10 building sites manned by medium sized construction firms registered in categories B and C with the Federal Ministry of Works and
- 10 building sites manned by small sized construction firms registered in category D with the Federal Ministry of Works.

On these 25 project sites, a total of 167 separate concrete operations were observed between April and October 2006.from beginning to end comprising 35 pours placed by crane and skip, 26 pours placed by dumper, 58 pours placed by wheelbarrow,37 pours placed by head pan and 11 pours placed jointly by pump, wheelbarrow and/or head pan.

4. Results

Table 1 summarizes the data and productivity characteristics that were observed and calculated for the 167 concreting operations. The observed data includes the transportation and placing method employed; the types of pour, the pour size or quantity of concrete placed, the total duration of the pour or overall pour time from the beginning of each operation to the end and the total time of delay. The calculated quantities are the fractional delay as well as the productivity (overall and labour) values indicated in the table.

Table 1: Overall pour and productivity characteristics for each transportation techniques

Transportation Technique	Pour Size (m^3)	Delay (Hours)	Duration (Hours)	Number of Operatives	Overall Productivity (m^3/hr)	Worker-hour/m^3
Pumping*	11	515.600	470.00	235	134.63	37.26
Crane &Skip	35	1455.648	1746.17	611	393.43	143.23
Dumper	26	446.430	228.38	381	221.86	133.35
Wheel Barrow	58	2780.368	3031.03	1027	388.16	564.86
Head Pan	37	980.850	17.39.07	644	118.78	448.05
Total	167	6188.896	8241.65	2898	1256.86	1326.76

*Data is a combination of pump, wheelbarrow and head pan.

Table 2 shows the summary of all the mean data and characteristics for the 167 concrete pours for each placing method and for all pours. The mean pour size for all the 167 pours in the sample was 37m^3. The biggest mean pour size was 48m^3 placed by wheelbarrows followed by about 42m^3 for cranes. The mean pour size for concrete placed with head pans (26.5m^3) is about half the size placed by wheelbarrows while the mean pour size for dumpers was the smallest at 17.2m^3 showing that head pans and dumpers were generally used when the quantities of concrete placed were least. This is expected since the head pan is the smallest and most primitive and labour intensive of the placing methods while dumpers are generally restricted to ground floor and pavement pours only.

Table 2: Mean pour and productivity characteristics for each transportation techniques

Transportation Technique	Pour Size (m^3)	Delay (Hours)	Duration (Hours)	Number of Operatives	Overall Productivity (m^3/hr)	Worker-hour/m^3
Pumping*	46.873	0.712	4.8485	21.36	12.2392	3.3873
Crane &Skip	41.590	0.832	3.6229	17.46	11.2409	4.0924
Dumper	17.170	0.787	3.6534	14.65	8.5331	5.1290
Wheel Barrow	48.110	0.871	6.8004	17.71	6.6924	9.7390
Head Pan	26.509	0.783	7.1304	17.41	3.2103	12.1095
Total	37.059	0.82	5.5890	17.35	7.5261	7.9447

*Data is a combination of pump, wheelbarrow and head pan.

The mean duration of all pours was found to be approximately $5^1/_2$ hours. The longest mean duration of about 7 hours was for pours placed by head pans and wheelbarrows while the mean duration for pours placed by cranes and dumpers were almost equal at about $3^1/_2$ hours or about half the duration for pours placed by head pans and wheelbarrows. This is also reasonable because concreting with cranes and dumpers is more mechanized and faster and therefore expected to take shorter time.

The mean number of operatives for all the concrete operations was 17 and was about the same as the mean number of operatives for pours placed by cranes, wheelbarrows and head pans. Only the mean number of operatives employed for pours placed by dumpers was slightly lower at 15 implying that there might not have been proper planning or work scheduling effort to synchronize the number of operatives required with the placing method and ensure optimal utilization of labour.

Delays observed in all the operations were within the range of 50 ± 3 minutes for all the placing methods suggesting that these overall delays may not have much to do with the placing method but rather are materials- and labour-related delays likely due to poor co-ordination, improper planning and lack of adequate control of site activities (Majid and McCaffer,1998).

For all pours, the mean distance between the mixing/batching point and the pour location was about 14.5 meters. This distance was longest for pours placed by dumpers (about 30 meters), shortest for pours placed by cranes (8 meters) and about the same for pours placed by wheelbarrows and head pans(about 12 meters). This is reasonable as dumpers are usually required for transporting concrete over long horizontal distances where head pans and wheelbarrows are at disadvantage while cranes are used mainly for their advantage in slewing over vertical distances.

4.1 Productivities Achieved

For all the pours, the overall and labour productivities were monitored and calculated in m^3/hour and worker hour/m^3 respectively for each type of pour and for each placing method as shown in Table 1.

The productivity achieved overall for each placing method is the ratio of pour size to the total duration excluding all delays. For labour productivity, it is the ratio between the times committed by the concreting operatives to the pour size. It should be noted that no wholly pumped pours were observed in this study. The data classified as pumped pours in the tables are asterisked because they were actually obtained when the combination of pumps, wheelbarrows and head pans was used to place the concrete. In such pours, the concrete was pumped foremost into wheelbarrows and/or head pans which were used for placing the concrete subsequently into the first floor levels of the buildings. The analysis and discussions on individual placing methods in this paper are therefore restricted to each of the remaining four concrete placing methods (cranes, dumpers, wheelbarrows and head pans) for which exclusive productivity data were obtained.

4.2 Concrete Placing Technology and Productivity Values

In this study, it has been found that the most prevalent concrete placing methods used by contractors in Lagos State, Nigeria, in descending order of frequency of usage were head pans, wheelbarrows, dumpers and cranes. This contrasts sharply with the results of other studies, where the concrete placing methods were pumps (Anson, Wang and Wang, 1998), pumps, and cranes and skips (Chan and Kumaraswamy, 1995), pumps, cranes and skips, hoist and barrow, and tremies (Anson and Wang, 1998 and Lu and Anson,2004) pumps, cranes and skips, and tremies (Wang, Ofori, and Teo, 2001).

4.3 Overall Productivity

The mean overall productivity or placing rate obtained for all the 167 concrete pours observed in this study(Table 2) was 7.53m^3/hr for a mean pour size of 37.1 m^3.whereas the mean productivities or placing rates observed in the other comparative studies highlighted in the Literature were:

- 15.5m^3/hr for 70 pumped pours of 29m^3 mean pour size in the UK (Anson and Wang, 1998) 20.5m^3/hr for 32 pumped pours of 170m^3 mean pour size in West Germany (Anson and Wang, 1998) 17.4m^3/hr for 154 pumped, craned, hoist and barrowed, and tremied pours of 120m^3 mean pour size in Hong Kong (Anson and Wang, 1998).
- 15.5m^3/hr for 32 pumped, craned and tremied pours of 61.9m^3 mean pour size in Singapore (Wang, Ofori and Teo, 2001).
- 15.23m^3/hr for 462 pumped, craned, hoist and barrowed, direct tipped and tremied pours of 98.16m^3 mean pour size in Hong Kong (Lu and Anson, 2004).

Obviously, the low mean overall productivity in this study, compared to those obtained in other studies, must be due to the poor concrete placing methods used in this survey as against the more sophisticated methods employed in the highlighted studies.

4.4 Labour Productivity

For all the 167 concrete pours in this study, the mean labour productivity observed was 7.94 wh/m^3 as compared to:

- 0.49wh/m^3 observed in 154 pours in Hong Kong (Anson, and Wang, 1998).
- 0.53wh/m^3 observed in 32 pours in Singapore (Wang Ofori and Teo 2001)
- 9.58wh/m^3 observed in 18 construction sites in Lagos (Ameh and Odusami, 2003)

Again, the very low mean labour productivity observed in this study, which is about 15 – 16 times less than those obtained in Hong Kong and Singapore must, among other reasons, be due to the more sophisticated concrete placing methods adopted in these other places.

4.5 Influence of Transportation and Placing Technology

From the study, it was observed that for all the pours, the transportation and placing method is a major determinant of productivity. For example, the craned pours were the fastest at a mean productivity rate of 11.24m^3/hr for the 35 pours of 41.6m^3 mean pour size. This compares well with the figures obtained in other similar studies, which are:

- 12.2m^3/hr for 43 craned pours in Hong Kong with a mean pour size of 89m^3 (Anson and Wang, 1998).

- 11.3m^3/hr for 10 craned pours in Hong Kong with a mean pour size of 49m^3 (Chan and Kumaraswamy, 1995**),** and confirm the earlier observation that the low mean overall productivity must be due to the other poor concrete placing methods adopted in this study.

Next to craned pours were pours placed by dumper at a productivity rate of 8.53m^3/hr followed by wheel barrowed pours at 6.69m^3/hr, i.e. about half of the productivity rate for craned pours. The slowest were pours placed by head pans at 3.21m^3/hr, about half the productivity rate for pours placed by wheelbarrows.

Similarly, the labour productivity was found to increase (i.e. less worker hours are required to place 1m^3 of concrete) with decrease in the mechanization of the placing method as the following productivities indicate:

- 4.09wh/m^3 for crane
- 5.13wh/m^3 for dumper
- 9.74wh/m^3 for wheelbarrow and
- 12.11 wh/m^3 for head pan

The labour productivity of 4.09wh/m^3 for crane and skip observed in this study is however nearly five times lower than the figure of 0.81wh/m^3 obtained in Anson, Wang and Wang's (1998) study of craned pours in Hong Kong buildings showing that for the same concrete placing method, labour productivity in this study is comparatively lower than in Europe or Asia.. The labour productivity of 9.74wh/m^3 for wheelbarrow, on the other hand, agrees fairly well with the figure of 9.58wh/m^3 obtained by Ameh and Odusami (2003) in their output study of in-situ concreting operations in Lagos State.

5. Conclusion

This study revealed that the transportation and placing technique employed during construction on site is a major determinant of concreting productivity and that productivity increases with increased mechanization of technique. Concrete placing by crane and skip is the least labour intensive of the placing methods and gets the job completed most quickly, being about twice as fast as wheelbarrow and nearly four times faster than head pan. Labour productivity using crane and skip is similarly over twice that of wheelbarrow and about thrice that of head pan. While the overall productivity of craned pours compares favorably with international standards, labour productivity for craned pours in Nigeria is nearly five times lower than those obtainable in Hong Kong and Singapore. This might be due to poor professional site management, including the improper planning and scheduling of site labour, as it was observed that virtually the same numbers of operatives were employed in all the concreting operations irrespective of the concrete placing method adopted or the duration of operation.

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Biography

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