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Effect of Pour Size on Concrete Placing Productivity in Nigeria

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Abstract: Pour size as one of the site factors affecting concreting was examined to determine its effects on concreting productivity. A total of 167 separate concrete pours were observed on 25 building construction sites in Lagos, Nigeria,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 head pan. Data collected from the daily concrete pours were analyzed to determine operational productivity rates. The relationship between concreting productivity and pour size was examined using regression analyses to develop a model relating productivity to pour size. The results showed that irrespective of placing method, productivity generally increased by 1.1 m^3/h for every 10 m^3 increase in pour size. It was recommended that the obtained index of productivity increase per pour size be standardised for use in improving on-site productivity in the Nigerian construction industry.

Key words: Concreting, Nigeria, placing method, productivity, volume

INTRODUCTION

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. The operational productivity of equipment and labor in concrete placing has been described by several authors as an essential, intrinsic parameter influencing the construction industry (Chan and Kumaraswamy, 1995; Wang *et al*., 2001; Dunlop and Smith, 2003). In addition, Graham *et al*. (2005) submitted that globally, the construction industry is a major consumer of mixed concrete and the trend is that the production rates of the material would continue to increase, thus signifying a continuous reliance by the construction industry on it.

Anson and Wang (1998) estimated the production of concrete in Hong Kong at over 10 million m^3/year or 1.6 m^3/person/year while Wang *et al*. (2001) reported 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, concreting and concrete placing have always played important supportive roles in the growth of the Nigerian construction industry. In most Nigerian buildings, there is concreting in virtually all elements of the building from foundation to superstructure as the use of alternative materials such as steel structures and prefabricated components is confined to a few prestigious projects. 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 concrete pours, resource levels as well as for accounting control (Dunlop and Smith, 2003). According to Dunlop and Smith (2003), planning engineers often maintain such large databanks of basic productivity rates which they adjust for individual projects taking into account specific site factors and conditions which may influence productivity rates.

While several studies have been conducted on factors that affect labor productivity in the Nigerian construction industry, there has not been any detailed study or published information on these on-site management factors that affect overall productivity in construction operations. Olomolaiye and Ogunlana (1989), submitted that such 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. Similarly, Abd *et al.* (2008) argued that performance measurements and benchmarking of various construction activities and operations are the best methods that may help to develop the productivity of the industry. This research was therefore focused on investigating the influence of pour size, which is one of the site factors and activities, on the productivity of the different concrete placing methods.

LITERATURE REVIEW

Previous findings by Anson and Wang (1994, 1998), Chan and Kumaraswamy (1995), Wang *et al*. (2001), Dunlop and Smith (2003) and Lu and Anson (2004) have indicated that one of the aggregate factors which impact

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Table 1: Influence of pour size on aspects of slab construction for in-situ concrete frame(Source: National structural concrete specification for European Concrete Building Project construction, NSCS, 2000)

	Single pour	Two pours on separate days	Four pours on separate days
Each Pour achievable within a working day	Just	Yes, easily	Yes, easily
Supporting columns required to be complete before slab pour	All	Over half	Over a quarter
Can proceed with next level of columns before slab completed	No	Yes	Yes
Columns (Above) poured at same time as slab (if same specification)	No	Possible	Possible
Formwork required	Full slab area	Two-thirds of slab area	One-third of slab area slab area
Construction joints	None	One	Three
Need for additional safety provisions (e.g.) edge protection	None	Some	Considerable
More even use made of site resources (Plant, operatives, materials etc.)	No	Yes	Yes (closer to a continuous manufacturingprocess

seriously on the productivity of concreting operations in all the placing methods is the concrete pour size. These research results show the effects of the size of concrete pour on concrete placing productivity in the countries of Europe, Hong Kong and Singapore.

The National Structural Concrete Specification (NSCS) for European Concrete Building Project construction, Part 1 (2000) also suggested limits on pour sizes for walls and slabs and advised that generally, a pour should be achievable within a working day. Table 1 is an adapted reproduction of NSCS, Part 1, Table 1, showing the influence of pour size on various aspects of concrete slab construction as provided in the Best Practice Guide for in-situ concrete frame construction by the European Concrete Building Project (ECBP).

Based on Table 1, the Guide stipulates that the size and number of pours for each floor slab of a multi-storey building frame affects the overall progression of construction, particularly the processes related to formwork and reinforcement and therefore the productivity of concreting operation

The Nigerian concreting industry: Construction operations in Nigeria have over the years been subjected to a work environment which has not encouraged a high level of productivity. This according to Ameh and Odusanmi (2002), has led to loss of morale and exodus of traditional craftsmen from the industry as well as the consequent failure to deliver projects timely and within cost limits. Most empirical studies have also revealed that the output of the construction industry in Nigeria is quite low when compared with many developed countries and workers productivity on construction sites has been shown to be very poor (Fagbenle *et al*., 2004). Concreting and the selection of the concrete placing method on construction sites is still largely governed by cost and availability of resources without regard to the economy of location, size of the pour, the rate of progress required and the correct productivity level of the method of placing (Olaoluwa, 2008; Olaoluwa and Adeyemi, 2009). This is in spite of the fact that Nigeria, being the sixth largest oil producing country in the world, had an infrastructural construction investment of about NGN 350bn (approximately US2.8bn dollars) in 2007 and is expected to grow annually by about 11% up till 2013 (Nigeria Infrastructure Report Q2, 2009).

There is therefore a need for overall productivity improvement in the Nigerian construction industry and in view of the important supportive role which concreting plays in the growth of the industry, this study will fullfil a fundamental part of that need.

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 (1999) and Abd *et al*. (2008), however submitted that it is important to specify the input and output to be measured when calculating productivity because there are many inputs like labor, 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. The complexity arises from the fact that the conversion process is influenced by the technology used and by many externalities such as government regulations, weather, union activities, 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 study 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 labor 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 (Wang, 1995; Anson *et al*.,1996). Concreting productivity consequently entails

Table 2: Summary of data and calculated productivity characteristics for each placing method and each type of pour

Placing method	Type of pour		Pour size (m^3)	Delay (min)	Total duration (h)	Fract delay	No. of operatives	Distance to pour location (m)	Overal productivity (m^3/h)	Worker-l hour per m^3
Pumping &wall	beam& slab	Sum	467.6000	470.00	48.66	1.03	194	175.00	112.69	33.62
		Mean	51.955556	52.2222	5.4070	0.1146	21.56	19.4444	12.5212	3.7350
		N	9	9	9	9	9	9	9	9
	column	Sum	48.0000	0.00	4.67	0.00	41	38.00	21.94	3.65
		Mean	24.00000	0.0000	2.3350	0.0000	20.50	19.0000	10.9701	1.8225
		N	2	2	2	2	2	2	2	2
	Total	Sum	515.6000	470.00	53.33	1.03	235	213.00	134.63	37.26
		Mean	46.872727	42.7273	4.8485	0.0938	21.36	19.3636	12.2392	3.3873
		N	11	11	11	11	11	11	11	11
Crane & Skip	beam & slab	Sum	1319.2000	1222.88	92.72	4.31	443	278.00	333.24	55.21
		Mean	59.963636	55.5855	4.2146	0.1958	20.14	12.6364	15.1473	2.5096
		N	22	22	22	22	22	22	22	22
	Column & wall	Sum	136.4480	523.29	34.08	2.35	168	10.00	60.19	88.02
		Mean	10.496000	40.2531	2.6217	0.1804	12.92	0.7692	4.6300	6.7710
		N	13	13	13	13	13	13	13	13
	Total	Sum	1455.6480	1746.17	126.80	6.65	611	288.00	393.43	143.23
		Mean	41.589943	49.8906	3.6229	0.1901	17.46	8.2286	11.2409	4.0924
		N	35	35	35	35	35	35	35	35
Dumper	beam & slab	Sum	411.8000	1048.53	80.73	5.05	334	715.00	212.79	115.02
		Mean	17.904348	45.5883	3.5101	0.2194	14.52	31.0870	9.2519	5.0010
		N	23	23	23	23	23	23	23	23
	column & wall	Sum	34.6300	179.85	14.26	0.58	47	45.00	9.07	18.33
		Mean	11.543333	59.9500	4.7525	0.1937	15.67	15.0000	3.0220	6.1105
		N	3	3	3	3	3	3	3	3
	Total	Sum	446.4300	1228.38	94.99	5.63	381	760.00	221.8	6133.35
		Mean	17.170385	47.2454	3.6534	0.2164	14.65	29.2308	8.5331	5.1290
		N	26	26	26	26	26	26	26	26
Wheel Barrow	beam& slab	Sum	2723.2000	2941.89	354.84	7.24	900	613.80	374.12	364.70
		Mean	55.575510	60.0386	7.2417	0.1477	18.37	12.5265	7.6351	7.4429
		N	49	49	49	49	49	49	49	49
	column & wall	Sum	67.1680	89.14	39.58	0.64	127	68.00	14.04	200.16
		Mean	7.463111	9.9044	4.3973	0.0715	14.11	7.5556	1.5597	22.2400
		N	9	9	9	9	9	9	9	9
	Total	Sum	2790.3680	3031.03	394.42	7.88	1027	681.80	388.16	564.86
		Mean	48.109793	52.2591	6.8004	0.1359	17.71	11.7552	6.6924	9.7390
		N	58	58	58	58	58	58	58	58
Headpan	Beam & slab	Sum	914.9200	1133.18	214.36	3.16	492	379.40	105.58	253.33
		Mean	35.189231	43.5838	8.2445	0.1214	18.92	14.5923	4.0609	9.7436
		N	26	26	26	26	26	26	26	26
	column & wall	Sum	65.9300	605.89	49.47	2.86	152	77.70	13.20	194.72
		Mean	5.993636	55.0809	4.4971	0.2604	13.82	7.0636	1.1997	17.7018
		N	11	11	11	11	11	11	11	11
	Total	Sum	980.8500	1739.07	263.82	6.02	644	457.10	118.78	448.05
		Mean	26.509459	47.0019	7.1304	0.1627	17.41	12.3541	3.2103	12.1095
		N	37	37	37	37	37	37	37	37
Total	Beam & slab	Sum	5836.7200	6816.48	791.32	20.78	2363	2161.20	1138.43	821.88
		Mean	45.245891	52.8409	6.1342	0.1611	18.32	16.7535	8.8251	6.3712
		N	129	129	129	129	129	129	129	129
	column & wall	Sum	352.1760	1398.17	142.05	6.43	535	238.70	118.43	504.88
		Mean	9.267789	36.7939	3.7382	0.1693	14.08	6.2816	3.1166	13.2863
		N	38	38	38	38	38	38	38	38
	Total	Sum	6188.8960	8214.65	933.37	27.21	2898	2399.90	1256.86	1326.76
		Mean	37.059257	49.1895	5.5890	0.1630	17.35	14.3707	7.5261	7.9447
		N	167	167	167	167	167	167	167	167

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, 1999). 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 (total factor) 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/h while the labor productivity is measured as operative hours per unit of work, or wh/m^3 of concrete (Proverbs *et al.*, 1999; Dunlop and Smith, 2003). It is however important to note that while the productivity of each type of resource (factor), such as labor, may be increased, by motivation for example, the overall (total factor) productivity will not be correspondingly enhanced without a proper balance and appropriate synergy (Kumaraswamy and Chan, 1998). As submitted by Kumaraswamy and Chan (1998), such synergy requires effective management of the resources and their interactions within the project, as well as their interactions with the external environment.

METHODOLOGY

A study of concreting operations was conducted on selected building construction sites in the Lagos metropolis to obtain concreting productivity data and ascertain the effect of pour size on concreting productivity in Nigeria.

Observed concrete operations: For the purpose of this study, all the bungalows 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.

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 head pan. Table 2 summarizes the data and productivity characteristics that were observed and calculated for each placing method and type of pour in the 167 concreting operations. The observed data includes 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 total time of delay comprised the idle times encountered during the concreting operation due to poor weather, plant breakdowns, fuel or material shortages and other problems relating to difficulties in mixing and placing the concrete, including inadequate planning or scheduling and poor management which adversely affected the timely

T able 3: Summary of data and calculated productivity characteristics for each placing method.

Placing method		Pour size (m^3)	Delay (min)	Total duration (h)	Fract delay	Overall no. of operair	Distance to pour location (m)	Productivity (m^3/h)	Worker (h/m^3)
Pumping	Sum	515.6000	470.00	53.33	1.03	235	213.00	134.63	37.26
	Mean	46.872727	42.7273	4.848	5.0938	21.36	19.3636	12.2392	3.3873
	N	11	11	11	11	11	11	11	11
Crane & Skip	Sum	1455.6480	1746.17	126.80	6.65	611	288.00	393.43	143.23
	Mean	41.589943	49.8906	3.6229	0.1901	17.46	8.2286	11.2409	4.0924
	N	35	35	35	35	35	35	35	35
Dumper	Sum	446.43001	228.389	4.99	5.63	381	760.00	221.86	133.35
	Mean	17.170385	47.2454	3.6534	0.2164	14.65	29.2308	8.5331	5.1290
	N	26	26	26	26	26	26	26	26
Wheel Barrow	Sum	2790.3680	3031.03	394.42	7.88	1027	681.80	388.16	564.86
	Mean	48.109793	52.2591	6.8004	0.1359	17.71	11.7552	6.6924	9.7390
	N	58	58	58	58	58	58	58	58
Headpan	Sum	980.8500	1739.07	263.82	6.02	644	457.10	118.78	448.05
	Mean	26.509459	47.0019	7.1304	0.1627	17.41	12.3541	3.2103	12.1095
	N	37	37	37	37	37	37	37	37
Total	Sum	6188.8960	8214.65	933.37	27.21	2898	2399.90	1256.86	1326.76
	Mean	37.059257	49.1895	5.5890	0.1630	17.35	14.3707	7.5261	7.9447
	N	167	167	167	167	167	167	167	167

supply of concrete to and from each placing equipment. The calculated quantities are the fractional delay (delay time expressed as a decimal fraction of the pour duration) as well as the productivity (overall and labor) values calculated as indicated below:

Notes: The definitions of all the variables used in Table 2 and 3 as well as in the analysis which follows are:

- Type of pour-either slab&beam or column and slab (coded "1"or "2", respectively in the analysis)
- Pour size-volume of concrete poured (in cubic metres)
- Delay or waiting time in min
- Total duration in h
- Fractional delay-ratio of delay to duration
- Number of operatives-placing crew
- Distance to pour location (dpl)-distance between concrete mixing point and placing location in m.
- Overall productivity or output or quantity of concrete poured in unit time (m^3/h)
- Labor productivity or how many operatives are required to pour 1 m^3 of concrete in worker h/m^3

RESULTS AND DISCUSSION

Table 3 is a summary of all the data and characteristics for each placing method in the 167 concrete pours.

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

The mean duration of all pours was found to be approximately $5^1/_2$ h. The longest mean duration of about 7 h 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 $3^1/_2$ 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 suggesting that there might not have been proper planning or work scheduling effort to correlate the number of operatives required with the placing method and ensure optimal utilization of labor.

Delays observed in all the operations were within the range of 50±3 min for all the placing methods showing that the overall delays are virtually constant and do not correlate with the placing method. They are apparently, mostly materials/equipment- and labor-related delays 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 m. This distance was longest (about 30 m) for pours placed by dumpers, shortest (8 m) for pours placed by cranes and approximately 12 m for pours placed by both wheelbarrows and head pans. This is reasonable because 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.

Productivities achieved: For all the pours, the overall and labor productivities were calculated in m^3/h and worker h/m^3, respectively for each type of pour and for each placing method as shown in Table 2.

The productivity achieved overall for each placing method is the ratio of pour size to the total duration excluding all delays. For labor productivity, it is the ratio between the times committed by the concreting operatives to the pour size. Table 3 summaries these productivities for each placing method in the 167 pours.

From Table 3, it can be observed that the mean productivity for all the 167 pours was 7.52 m^3/h. Craned pours were the fastest at a mean productivity rate of 11.24 m^3/h for the 35 pours of 41.6 m^3 mean pour size. Next to craned pours were pours placed by dumper at a productivity rate of 8.53 m^3/h followed by wheel barrowed pours at 6.69 m^3/h, i.e., about half of the productivity rate for craned pours. The slowest were pours placed by head pans at 3.21 m^3/h, or about half the productivity rate for pours placed by wheelbarrows.

The mean productivity of 11.24m^3/hr for craned pours in this study compares favourably with the figures of 12.2 m^3/h for 43 craned pours in Hong Kong with a mean pour size of 89 m^3 (Anson and Wang, 1998) and 11.3 m^3/h for 10 craned pours in Hong Kong with a mean pour size of 49 m^3 (Chan and Kumaraswamy, 1995).

The mean productivity for all the 167 pours (7.5 m^3/h) is however only about 40% of the mean productivity of 17.4 m^3/h obtained by Anson and Wang (1998) for Hong Kong buildings. This is likely due to the much larger pour size and the use of more mechanised concrete placing methods like hoist and barrow and tremie in the Hong Kong study in place of wheel barrow and head pan in this study. It is particularly interesting to note that the mean pour size of 37 m^3 in this study is about 31% of the mean pour size of 120 m^3 observed by Anson and Wang (1998) for Hong Kong buildings, suggesting that bigger pour size may be mainly responsible for the large difference in productivities obtained in the two studies.

Regression analyses on observed productivity data: Regression analysis was carried out on the observed data to determine the statistical relationship between productivity and the significant explanatory variables and obtain probable models that will estimate productivity rates for the concreting operations. In this regard, the explanatory variables originally identified for variability in concreting productivity were:

- Placing method, coded “1” for pumping, ”2” for crane&skip, ”3” for dumper, ”4” for wheelbarrow and “5” for head pan
- Type of pour, coded “1” for slab and beam and “2” for column and walls
- Pour size, (m^3)
- Total duration (h)
- Delay (min)
- Number of operatives
- Fractional Delay,
- Distance to Pour location (m)
- Weather, coded “1” for Fine weather, “2” for Cloudy weather, “3” for Sunny and “4” for Rainy weather,

For the regression analysis, the in-built functions of SPSS 16.0 for windows was used because it allows one to store the data, perform transformations and analyze and produce charts and graphs of results. In this instance, a regression of productivity was run on all the identified variables for the 167 pours observed. The regression results were then examined in turn to determine the functional relationship among the variables and obtain a model that will predict productivity rates for the concreting operations.

The regression analysis used is stepwise multiple linear regression which began with all the explanatory variables and eliminated the ‘non-significant’ variables for the concrete pours. The output of the regression analysis included the:

- ANOVA table which signified the acceptability or otherwise of the regression results.
- Model summary table, which indicated the strength of the relationship between the model and the variations in the dependent variable.
- Table of correlation coefficients which displayed the values for predicting the dependent variable given the scores of the independent variables and using the ‘Unstandardized Coefficients’ as the values for the constant and the coefficients of the variables.
- Table of correlation coefficients between all pairs of the explanatory variables, including productivity, which indicated the relationships between the variables and confirmed the appropriateness or otherwise of the regression coefficients above.

For the set of stepwise Multiple Regression Analysis performed to explain the effectiveness of the responsive parameters on productivity, the regression was of the form:

$$\text{Productivity, } P = y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6 + b_7x_7 + b_8x_8 + b_9x_9$$

where, $x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9$ are the variables explained previously and a, , b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8, b_9 are constants.

Table 4: ANOVA statistics of regression on actual productivity for all pours-first run

Model	SS	df	MS	F	Sig.
Regression	11888.879	6	1981.480	67.624	0.000[f]
Residual	4688.216	160	29.301		
Total	16577.095	166			

Predictors: (Constant); (m^3): Pour Size; (h): Total duration; Fract delay; typpour; pred4; pred5

Table 5: Coefficients of regression on actual productivity for all pours-sfirst run

	Unstandardized coefficients		Standardized coefficients		
Model	B	SE	β	t	Sig
(Constant)	10.074	1.121		8.984	0.000
Pour size (m3)	0.136	0.008	0.817	17.029	0.000
Total duration (h)	- 1.190	0.126	- 0.487	- 9.426	0.000
Fract delay	- 13.657	2.368	- 0.246	- 5.767	0.000
Typpour	13.794	1.053	0.160	3.603	0.000
Pred4	- 3.184	1.015	- 0.152	- 3.136	0.002
Pred5	- 2.429	1.185	- 0.101	- 2.050	0.042

Table 6: Correlation coefficients between all pairs of variables for all pours-first run

	Overall productivity (m^3/h)	pred1	pred2	pred3	pred4	pred5	typpour1	typour2	Pour Size (m_3)	Delay (min)
Overal Productivity (m^3/h)	1.00	0.13	0.19	0.04	- 0.06	- 0.23	0.24	- 0.24	0.65	-`0.07
pred1	0.13	1.00	- 0.14	- 0.11	- 0.19	- 0.14	0.03	- 0.03	0.04	- 0.03
pred2	0.19	- 0.14	1.00	- 0.22	- 0.38	- 0.28	- 0.18	0.18	0.04	0.01
pred3	0.04	- 0.11	- 0.22	1.00	- 0.31	- 0.23	0.12	- 0.12	- 0.14	- 0.02
pred4	- 0.06	- 0.19	- 0.38	- 0.31	1.00	- 0.39	0.13	- 0.13	0.14	0.04
pred5	- 0.23	- 0.14	- 0.28	- 0.23	- 0.39	1.00	- 0.09	0.09	- 0.09	- 0.02
Typpour1	0.24	0.03	- 0.18	0.12	0.13	- 0.09	1.00	- 1.00	0.25	0.12
Typour2	- 0.24	- 0.03	0.18	- 0.12	- 0.13	0.09	- 1.00	1.00	- 0.25	- 0.12
Pour size (m^3)	0.65	0.04	0.04	- 0.14	0.14	- 0.09	0.25	- 0.25	1.00	0.33
Delay (min)	- 0.07	- 0.03	0.01	- 0.02	0.04	- 0.02	0.12	- 0.12	0.33	1.00
Total duration (h)	- 0.12	- 0.05	- 0.25	- 0.20	0.22	0.20	0.25	- 0.25	0.42	0.461
Fract delay	- 0.21	- 0.10	0.08	0.13	- 0.11	0.00	- 0.02	0.02	- 0.06	0.56
No. of operatives	0.27	0.09	0.00	- 0.10	0.02	0.00	0.15	- 0.15	0.53	0.28
Distance to pour Location (m)	- 0.01	0.08	- 0.18	0.36	- 0.11	- 0.06	0.25	- 0.25	- 0.04	0.00
weath1	- 0.02	- 0.11	0.25	- 0.04	- 0.12	0.00	- 0.17	0.17	0.08	0.15
weath2	- 0.05	0.10	- 0.15	- 0.00	0.02	0.06	0.10	- 0.10	- 0.06	- 0.13
weath3	- 0.06	- 0.04	- 0.07	- 0.06	0.09	0.04	0.07	- 0.07	0.02	- 0.07
weath4	0.08	0.07	- 0.16	0.07	0.10	- 0.05	0.10	- 0.10	- 0.06	- 0.06

	Total duration (h)	Fract delay	No. of operatives	Distance to pour location (m)	weath1	weath2	weath3	weath4
Overal productivity (m^3/h)	- 0.12	-0.21	0.27	- 0.01	- 0.02	- 0.05	- 0.06	0.08
pred1	- 0.05	- 0.10	0.09	0.08	- 0.10	10.1	- 0.04	0.07
pred2	- 0.25	0.08	0.00	- 0.18	0.25	- 0.15	- 0.07	- 0.16
pred3	- 0.20	0.13	- 0.10	0.36	- 0.04	- 0.00	- 0.06	0.07
pred4	0.22	- 0.11	0.02	- 0.11	- 0.12	0.02	0.09	0.10
pred5	0.20	0.00	0.00	- 0.06	0.00	0.06	0.04	- 0.05
Typpour	0.25	- 0.02	0.15	0.25	- 0.17	0.10	0.07	0.10
Typour	- 0.25	0.02	- 0.15	- 0.25	0.17	- 0.10	- 0.07	- 0.10
Pour size (m^3)	0.42	- 0.06	0.53	- 0.04	0.08	- 0.06	0.02	- 0.06
Delay (min)	0.46	0.56	0.28	0.00	0.15	- 0.13	- 0.07	- 0.06
Total duration (h)	1.00	- 0.13	0.43	0.11	- 0.08	0.01	0.31	- 0.02
Fract delay	- 0.13	1.00	- 0.18	- 0.16	0.29	- 0.15	- 0.10	- 0.19
No. of operatives	0.43	- 0.18	1.00	0.02	- 0.03	0.02	- 0.01	0.02
Distance to pour Location (m)	0.11	- 0.16	0.02	1.00	- 0.21	0.00	0.03	0.23
weath1	- 0.08	0.29	- 0.03	- 0.21	1.00	- 0.48	- 0.22	- 0.76
weath2	0.01	- 0.15	0.02	0.00	- 0.48	1.00	- 0.04	- 0.13
weath3	0.31	- 0.10	- 0.01	0.03	- 0.22	- 0.04	1.00	- 0.06
weath4	- 0.02	-`0.19	0.02	0.23	- 0.76	- 0.13	- 0.06	1.00

Regression and ANOVA statistics on actual productivity for all pours: The first stage was to run a regression of productivity on all the identified variables, including concrete placing methods for all the 167 pours. Table 4 is the ANOVA table of Regression on Actual Productivity for all the 167 pours. From the last column titled "Sig" and valued 0.000, it is observed that the model fits the data and the regression results are acceptable.

The computed F-value was 67.624 at 0.000 significance level as seen in Table 4 and from the coefficients in Table 5, the key determinants of concreting productivity for all pours were placing methods 4 and 5 (wheel barrow and head pan) at 0.002 and 0.042 significance levels respectively, pour size, total duration, fractional delay and type of pour 1(beam and slab) all at 0.000 significance level.

Table 6, the correlation coefficients Table however shows that only the variable pour size has a correlation high enough (above 0.250) to be considered to have an important and significant relationship with concreting productivity, its correlation coefficient being 0.65 It was therefore necessary to carry out further runs of regression, eliminating all the other insignificant variables from the regression model to satisfy both the criteria of significance and correlation.

Table 7 is the ANOVA Statistics for the final run regression and the F-ratio is now 122.933 which is much greater than the F-ratio of 67.624 for the first run, showing a greater dependence of productivity on pour size. The coefficients and statistics for this final run multiple regression analysis for all the concrete pours are shown in Table 8 confirming that pour size is the most significant of concreting productivity (at 0.000

Table 7: ANOVA statistics of regression on actual productivity for all pours-final run

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	7077.594	1	7077.594	122.933	0.000[a]
	Residual	9499.501	165	57.573		
	Total	16577.095	166			

Predictors: (Constant), Pour size (m^3); Dependent variable: Overall productivity (m^3/h)

Table 8: Coefficients of regression on actual productivity for all poursfinal run

	Unstandardized coefficients		Standardized coefficients		
Model	B	SE	β	t	Sig.
1 (constant)	3.492	0.691		5.055	0.000
Pour size (m^3)	0.109	0.010	0.653	11.088	0.000

Dependent Variable: Overall productivity (m^3/h)

Table 9: Correlation coefficients between all pairs of variables for all pours-final run

	Overall productivity (m^3/h)	Pour size (m^3)
Pearson correlation overall Productivity (m^3/h)	1.000	0.653
Pour size (m^3)	0.653	1.000

significance level). The final run correlation coefficient shown in Table 9 also implies that this variable has a correlation high enough (0.653) to be considered to have an important relationship with concreting productivity for all pours,

The final run regression equation can be written from Table 8 where the model becomes:

Productivity = 3.5+0.11 (pour size)

From the above model, it is observed that pour size is the only independent variable that is statistically significant in predicting concreting productivity for all pours. Consequently, the relationship between concreting productivity and pour size was examined for further regression analyses to generate a scatter diagram from which the model relating productivity to pour size can be further confirmed and developed, assuming a closed system with other variables held constant (Wang, 1999).

Productivity in relation to pour size for all pours: The scatter plot of productivity, y, against pour size, x_3, for all the 167 pours placed in this study is shown in Fig. 1 and although there is considerable scatter, a linear relationship can reasonably be said to exist as modeled by the regression line because most of the plots cluster close to the line except the outlier cases 118 and 24.

For all the pours, Table 10 shows that pour size has a correlation coefficient of 0.653 with productivity and a significance of 0.000 as before (Table 9), which is strong enough (above 0.250) to be considered an important relationship. The correlation is also significant at 0.01 level.

The linear regression model can be viewed from the Regression Coefficients Table 11 (identical to Table 8) where the model, as before, becomes:

Productivity = 3.5+0.11 (pour size)

A look at Table 6, 8 and 11 shows that both the correlation coefficients and standardised coefficients for pour size with overall productivity are practically the same (0.653), confirming that the removal of the other variables from the regression analysis has not significantly affected the relationship between pour size and productivity and hence this model is statistically valid.

Both models indicate that for all the pours, irrespective of placing method, concreting productivity generally increased by 1.1 m^3 for every 10m^3 increase in pour volume/size.

It is interesting that this model for all the 167 pours in this study is very similar to the model, R = 3.8+0.11S for all 154 concrete pours in Hong Kong buildings obtained by Anson and Wang (1998) where R = placing speed in m^3/h (same as productivity) and S = pour size (m^3).

That large pours are placed at higher productivities may be because contractors pay more attention to site preparation and work planning to ensure that large slab pours are cast monolithically as often as practicable within the limited hours of a single day without 'carry-over' to the next day. This is especially true of Nigeria where most contractors often allocate 'task jobs' to workers to 'finish and go' so that any given pour would

Table 10: Correlation coefficients between productivity and pour size (all pours) vide scatter plot

		Overall productivity (m^3/h)	Pour size (m^3)
Overall (m^3/h)	Productivity pearson correlation	1	0.653**
	Sig. (2-tailed)		0.000
	N	167	167
Pour size (m^3)	Pearson correlation	0.653**	1
	Sig. (2-tailed)	0.000	
	N	167	167

**: Correlation is significant at the 0.01 level (2-tailed)

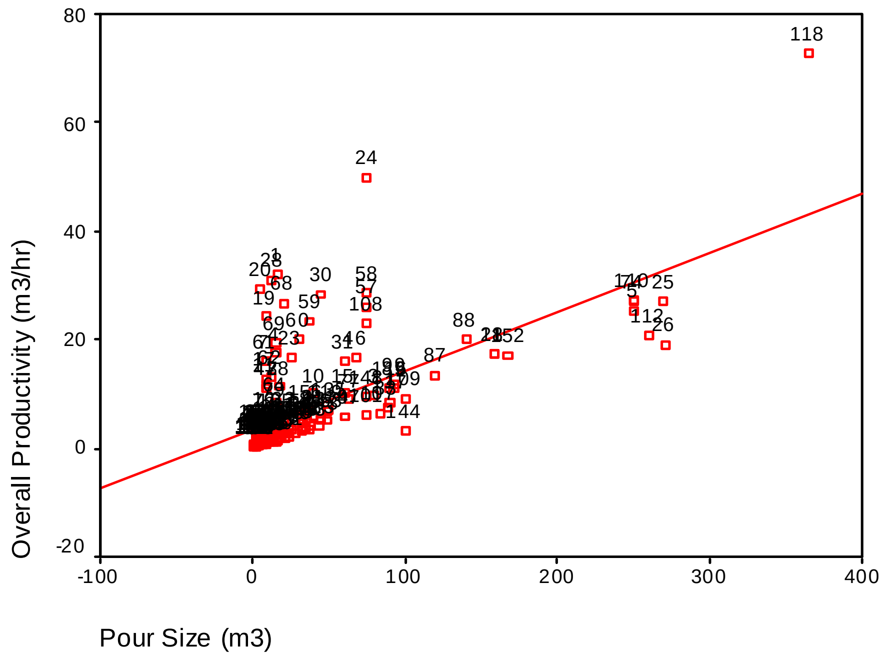

Fig. 1: Plot of productivity against pour size for all pours

Table 11: Coefficients of regression of productivity on pour size for all pours vide scatter plot

	Unstandardized coefficients		Standardized coefficients		
Model	B	SE	β	t	Sig.
1 (Constant)	3.492	0.691		5.055	0.000
Pour size (m^3)	0.019	0.010	0.653	11.088	0.000

be achievable within a working day. On the other hand, smaller pours that require less than a day to execute may be allowed to take longer hours, with less control, provided they are still completed within the single day, thus reducing the overall productivity of smaller pours.

CONCLUSION

A major factor that was found to influence, significantly, the concreting productivity of all pours, irrespective of placing method, in Lagos, Nigeria, is the pour size. The results of the multiple linear regression analysis undertaken to obtain a model for predicting productivity, y, from values of pour size, x_3, shows statistically significant results for all pours as represented by:

$$y = 3.5+0.11x$$

This model corroborates the model R=3.8+0.11S obtained by Anson and Wang (1998) for all pours in Hong Kong buildings where, R = placing speed, (m^3/h) and S = pour size (m^3).

From both models, the productivity for all pours placed increased by 1.1 m^3/h for every 10m^3 increase in pour size despite the fact that the mean productivity of all pours observed in this study (7.5 m^3/h) is about 43% of that obtained in the Hong Kong study(17.4 m^3/h).

The mean pour size in this study (37 m^3) is however about 31% of that obtained in the Hong Kong study (120 m^3), indicating that there is a much lower mean overall productivity observed on Nigerian sites due to the small concrete pour sizes. This, as observed in Table 1, could lead to several pours for a big structure thus requiring additonal safety provisions and more uses of the available site resources such as plant, operatives and other materials. The consequence is lower operational efficiency and higher cost implications.

This study has demonstrated that the identified indices of concreting productivity, especially pour size, are clear signals to the Nigerian construction industry and contractors to be attentive to in their concreting operations so as to boost productivity.

RECOMMENDATION

It is recommended that pour sizes should not be so small that too many concrete pours are required in a big structure or site labor is made idle for a sizeable proportion of the daily operational period, thus reducing efficiency and increasing operational costs. Pour sizes should however be carefully planned and correlated with labor usage to boost concreting productivity because, as submitted by Anson and Wang (1998), it is conceivable that a very long pour might suffer because of labor fatigue even though larger pours achieve higher productivities.

Finally, the obtained index of productivity increase per pour size may be standardized for use in improving on-site productivity in the Nigerian construction industry and for advice by professional bodies to site managers and practitioners.

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