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Factors influencing efficiency of line pumped concrete for multi-storey building

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ABSTRACT

Concrete has played an important role in the efforts of architects and engineers who wanted satisfactory and economical materials for concrete and high-rise buildings. Concrete for small-height buildings (up to three -5-storeys), whether common or RMC, is transported and used to transport concrete using buckets, wheel barrows and culverts or sometimes cranes. As the building rises and improves, it takes time to place the concrete in the crane and bucket manner because it is not an endless process and can interfere with the productivity of the concrete works. In such a case, pumping is a concrete method of pumping concrete. The concrete pump offers many favorable advantages such as increased productivity. Increased productivity is important because this means faster completion allows the owner to quickly return on his investment. Therefore, a study is formed for the factors that affect the efficiency and productivity of pumped concrete resources in place of the concreting of buildings. The general information about the concrete pumped in this study, the factors that affect the productivity of the concrete in a high-rise building, the need for pumping concrete equipment and machinery. Other factors affecting the placement of concrete will be considered in the study.

Keywords: *Productivity, Pumped Concrete, Pumping Equipment*

1. INTRODUCTION

Concrete cement is just close to water as far as the amount of texture utilized on our planet. Over numerous years, concrete has turned into the texture of decision for developing private and business structures, infrastructural offices like highways, dams and bridge, channels, ports and other significant offices .The fame of cement owes to its economy, capacity to the cast into any shape, capacity to be manufactured basically anyplace and to wrap things up , its innate strength countless recorded land marks in concrete say a lot about its solidness and adaptability .

For small high-rise buildings (up to three -5 floors) concrete is loaded or unloaded or transported by RMC loaded wheel barrows or bolts, or sometimes lifts are rented for concrete transportation purposes. But when the building goes higher and better, placing concrete with the hoist and wheel barrows method is become time consuming because it isn't endless process and it hampered the productivity of concrete works. One among the techniques that have helped the development industry tremendously is pumped concreting. Pumped concreting is an alternate method to placing the concrete using concrete pump. Most traditional construction mixes are often pumped with little or modification. However several technical and managerial factors affect the productivity of pumped concrete must be considered when while concreting.

Machines and equipments utilized in concrete pumping like concrete pumps are mainly wont to transfer wet concrete into the building formwork.

Concrete pump offers many benefits such as increased productivity. The pump provides high volume power in areas where human access is difficult. Demand for concrete pumps also varies in performance measurements due to the type of pump. Various structures, from high school buildings to small shops, require concrete, and are a good way to push concrete to the point where it needs to be pumped. Increasing productivity is essential because its rapid completion allows the owner to return quickly on their investment.

1.1 Objectives of study

1) Measuring and comparing the productivity rates based on the no. of strokes applied by the pump, time required for pumping and overall time required including all activities and delays.
2) Identify the factors responsible for causing delays in concreting operation and try to minimize possible factors and delays and try to increase actual productivity.
3) Based on production rates obtained at various heights of multistoried buildings try to plot generalized regression curve.
4) Develop regression equations for the curve for predicting the production rates of pumped concrete at various heights of buildings.

1.2 Need of study
Study deals with performance of concrete placing by using pumping technique. The most purpose of the research is to continuously monitor equipments/workers performing pumping activities within a construction site to get an estimation of productivity of pumped concrete at different heights of buildings. Consequently, the anticipated production rates enable site planners and construction managers to plan and assess the duration of pump related activities.

Production rate of concrete in construction projects is suffering from several factors and therefore the accuracy of productivity estimate might be challenged when effect of multiple factors is taken into account simultaneously. The pouring concrete operation is taken into account as a critical activity at construction projects which affect the duration of the project. The increases within the project duration caused thanks to any delays in pouring concrete activity have negative effects on the project cost, as that point delays usually equal cost over runs. Productivity rates rank amongst the foremost essential data needed within the study of construction productivity because planning engineers require these rates to estimate and schedule concrete pours, resource levels also as for accounting control.

1.3 Limitations of study
- The observations are taken and calculations made only for stationary line pump.
- Readings are taken just for multi-storey buildings, no other structures are considered.
- No consideration given to concrete mix proportions.
- Observations are noted only for footings, slabs and columns.
- No consideration is given to cost of work.

2. METHODOLOGY
Study of literature:-

Study of available literature on pumped concrete productivity.

Collecting data from site:-
1) Access to construction site and collect detail information and data from the site.
2) Record the number of strokes applied by concrete pump for discharging concrete and calculates productivity.
3) Record the time required only for pumping activity without considering any delay.
4) Record the overall timing for pumping considering all delays.

Analysis of site data:-
1) Calculate the productivity rates based on application of strokes, duration for pumping without delays and including delays.
2) Make comparison between productivities based on all circumstances given in above step.
3) Identify the factors those causing delay and reduce the rate of productivity and identify extreme important factors.
4) Try to plot equation of regression line with all productivities values of various heights of building.

3. LITERATURE REVIEW
1) Michael Anson and Shou Qing Wang (April 1998), "Performance of Concrete Placing In Hong Kong Buildings."Journal of Construction Engineering management,Vol. 124, No.2 March/April, ASCE, ISSN 0733-9364/98/0002-0116- 0124, Paper No. 14663.

A study was conducted on the use of labor and equipment resources for on-site concreting of Hong Kong buildings in the early 1990s. The study included 154 POS and 38 combined costs 38 days at construction sites concrete batching plants at some point at each. Much detailed productivity information has been derived and therefore the different concrete placing methods are compared. Other factors affecting the placing rates, pour size , sort of pour , and provide of concrete are produced not just for measuring progress within the standards applying in Hong Kong as time goes by but also for creating comparisons with other large cities. The objectives of study are measure the productivities being achieved by site labor and equipment in concreting of buildings and by RMC plants and by truck mixers , to compare the resource utilization of the different concrete placing methods in use and to produce performance yardsticks for future use. And to make comparisons between performance in Hong Kong and performance elsewhere.

2) Neil R. Guptill (1996) , "Placing Concrete by Pumping Methods", Reported by ACI Committee 304 (1996) ACI 304.2R-96

Pumps for transporting and placing concrete are described in this report. Sturdy and versatile pipelines are discussed and couplings and other accessories are described. Recommendations for the ratio of pumpable concrete indicate the optimal height of the gravel; Describes water, cement and entry requirements; And emphasizing the need to evaluate test compounds for pumpability. The importance of saturating light aggregates is emphasized. Suggestions were made for the layout of the lines; To maintain the same delivery rate as the same quality of concrete at the top of the line; And to clean pipelines. The concrete in the report is transported by pipe or pipe in the form of a pump defining the concrete. Concrete pumping through metal pipelines through piston pumps was introduced to us in 1933 in Milwaukee. This concrete pump used a mechanical connection to make the pump work and is usually extended through pipelines with a diameter of 6 or more. Since then many new developments have taken place in the concrete pumping area. These include new and improved pumps, truck-mounted and stationary placing booms, and pipeline and hose that withstand higher pumping pressures. As a results of these innovations, concrete placement by pumps has become one among the foremost widely used practices of the development industry. Pumping is also used for many concrete structures, but it is especially useful where space for construction equipment is limited. Pumping with concrete frees the concrete pumping legs and cranes to provide materials that are resistant to construction. In addition, other handicrafts are not affected by concrete activity. A smooth supply of pump-capable concrete is important for satisfactory pumping. Pump-capable concrete, like conventional concrete, requires good internal control, namely, uniform, properly graded gravel, the material is uniformly batch and well mixed.

3) Emad Abd-El Hamied El-Maghraby,(Dec. 2014), "Predicting the Production Rate of Pouring Ready Mixed Concrete Using Regression Analysis", Journal of Civil Engineering and Science, Dec. 2014, Vol. 3 Iss. 4, PP. 219-234.
Ready mixed concrete (RMC) placing is a crucial operation on construction projects in many countries. This is often particularly true as in Egypt high- rise buildings construction increased within the building industry, many of those buildings are still constructed using the normal method of in-site concrete placing. Concrete must be batched remotely and delivered to sites by truck mixers Therefore, the assembly rate of Pouring Ready Mixed Concrete (PRMC) might be considered as great importance to enhance the productivity of the entire housing industry in Egypt. The aim of this paper is to create a replacement regression model using correlation analysis method for predicting the assembly rate of PRMC using tower cranes. The model building was supported an in depth observation of 418 pours cycles from ten different construction building sites for the pouring concrete in columns, slabs, and beams, each from the start to finish operation. Additionally, it studied the factors affecting the assembly rate of PRMC using tower cranes. The restrictions of this research are: this research collected data only from Egyptian construction projects, therefore the results might not be applicable to environments outside Egypt, this research used tower cranes and skip pouring concrete method only, and this research is restricted to the activities associated with pouring concrete.

4)Bhupinder Singh, S.P. Singh and Bikramjit Singh "Some issues related to pumping of concrete", The Indian Concrete Journal (September 2004),.
This paper focuses on the impact on solid pumping and the various parameters associated with it. The effect of those parameters in determining the efficiency of concrete pumps is discussed and an example on the calculation for the selection of a concrete pump for the conditions obtained at a particular construction site is presented. Recent years have seen a considerable increase within the use of pumped concrete, especially in infrastructure projects within the country. Ready-mixed concrete (RMC) suppliers have played a serious role in popularizing the concept of concrete pumping in India. Invariably, most of the applications are concentrated in and round the metros and it's only lately that the concept and application of pumped concrete is percolating to the mofusil areas where more often then not, pumped concrete is viewed as an unaffordable luxury. These skewed perceptions stem not such a lot from indifference as they are doing from sheer ignorance. Quite enough has been said and written about the characteristics and requirements of pumpable concrete. Many specialist literature on pumpable concrete is out there within the property right though an equivalent can't be said about the specifications, capacity and selection of pumps to be used for pumping of concrete. An effort has been made here to debate a number of the problems associated with characteristics of concrete pumps so on enable the reader to form an informed choice of pumps for pumping concrete. The parameters of interest are pump capacity, power requirements and characteristics of the delivery pipelines.

5) Paul Dunlop, Simon Smith (2000) "A Non-Deterministic Investigation of the Concrete Placing System".
This study provides the cyclic construction process of concrete batching, delivery, pumping and return. Many areas of the development industry rely heavily upon cyclical processes, a number of which don't always deliver a satisfactory level of performance. One such area is that the system involved in concrete placing operations. Decisive analysis of those processes does not leave a random distribution of system actions that lead to unrealistic system characteristics. The method of concrete batching, transportation and finally placement is subject to interruptions, manipulations and fluctuations and can be considered as a random system. Providing good quality service to contractors is fundamental to managing these uncertainties as best as possible. Accordingly, this paper follows the flow and transfer of the concrete laying process and "lean" methods are often applied to investigate the efficiency of the method. For this study, examples are presented using data gathered over a two-year period from a serious engineering project within the North-West of England. The info consists of the relevant times from over seventy concrete pours. The bulk of concrete operations observed involved concrete being pumped into formwork, which was seen to be a posh queuing system.

6) Olaoluwa Olatunde, Ojo Stephen Okunlola and Adesanya David Abiodun (June 15, 2012), "Effect of Pour Size on Concrete Placing Productivity in Nigeria", Research Journal of Applied Sciences, Engineering and Technology 4(12): 1649-1658, 2012 ISSN: 2040-7467© Maxwell Scientific Organization, 2011 Pouring volume has been researched as one of the site factors affecting concreting to determine its effects on concreting productivity. A total of 167 different concrete peels were found at 25 construction sites in Lagos, Nigeria, of which 35 joints were placed by cranes and skips; 26 dumpers placed; 58 Added by Wheelbarrow; 37 pans kept by pan; And 11 are combined with pump, wheelbarrow and head pan. Data collected from daily concrete components were analyzed in accordance with the operational productivity rate. The relationship between increasing productivity and quantities was investigated using regression analysis to develop productivity-related models for quantity. Results show that productivity typically increases by 1.1 m3 / h for every 10 m3 increase, regardless of the method of placement.
7) Seung Hee Kwon, Kyong Pil Jang, Jae Hong Kim, and Surendra P. Shah, "State of he Art on Prediction of Concrete Pumping.", International Journal of Concrete tructures and Materials ,Volume 10, Number 3 Supplement, pp.S75– S85, September 2016
In this paper, the status of art is demonstrated on the assessment of concrete pumping, including analytical and experimental works. The prevailing methods for living the geological properties of the slip layer (or lubricating layer) were first introduced. Second,

supporting the rheological properties of the slip layer and parent concrete, the model is described to estimate the concrete pumping (flow rate, pumping pressure and pumpable distance). Third, the impact factors of concrete pumping along with the test results of different concrete mixes are discussed. Finally, the future need for research on concrete pumping is recommended.

The performance of the slip layer concrete pumping during concrete pumping is controlled by the apertures of the slip layer formed between the piping surface and therefore the concrete is used in different mixtures of concrete according to the coarse and fine gravel and cement type grading. The thickness of the sleeper is proportional to the cement pipe, cement ratio from water and hence the dosage of the super systemizer. The slip layer thickness is also reduced with better sanding. The length and diameter of the pipeline are also considered as variations in the thickness of the slip layer.

8)Geert De Schutter, Dimitri Feys, "Pumping of Fresh Concrete: Insights and Challenges", RILEM Technical Letters (2016) 1: 76 – 80, Published online: 25 November 2016

Pumping of fresh concrete is of utmost importance for concrete practice. Required pumping pressures are typically estimated supported design charts. However, with the increased use of chemical admixtures and therefore the development of more flowable concrete mixtures, the accuracy of traditional design charts is questioned. In recent years, significant progress has been obtained in understanding the flow of the fabric within the pumping pipe, including the behavior of the lubrication layer near the pipe surface. As compared with traditional design charts, this leads to more reliable pressure predictions when considering very fluid concrete types like self- consolidating concrete. Some remaining challenges are often defined however.

9) Viraj D. Taldeokar, Hariharan Subramanyan, "Effective Selection Of Pump For Water And Concrete Pumping System",International Journal of Mechanical And Production Engineering, ISSN: 2320-2092, Volume- 2, Issue- 6, June-2016.

Improper selection of pump for the actual application may cause over cost, wastages of energy and time, delay in overall project also. Selection of the pump depends on power for various head isn't preferable. Hence, then there's a requirement to enhance the system which can decide the right and suitable sort of pump for various pressure head. The paper specialise in selection of suitable capacity and sort of pump required for the pumping water and concrete in construction project. This study required into the preparation of power chart and pressure chart for water pumping system and concrete pumping system respectively, by which the acceptable and economical sort of pump are often selected. The target of this research is to pick the acceptable sort of pump for the location application during construction phase. The most focus is on power required, pressure head of applications and pressure required for pumping for having proper and economical selection of pump.

10)Prof.Dr.A.W.Dhawale1, Kazi Rizwan Nizamuddin , "Effect Of Height On Pumped Concrete Placing At Highrise Structures",International Research Journal of Engineering and Technology , Volume: 03 Issue: 02 Feb-2016

This paper addresses the importance of checking out the efficiency and productivity of the pumped concrete and utilization of pumping equipment resources within the in place concreting of buildings. The study involves close observation of quite 60 pours using pumped concreting on residential building construction sites to get the matter statement for the study. The knowledge regarding productivity of concrete is additionally derived and factors affecting an equivalent are analysed. The aim of this study is to analyse the factors affecting the placing rates of concrete. And efforts are taken to attenuate the lacunas in it by providing necessary enhancements for an equivalent.

4. DATA COLLECTION

The observation shown here is only for one site.

Observation

- Pumping Height : 8 meters.
- Type of Pump : Putzmeister 1407 D
- Theoretical output: 71 m^3/ hr.
- Maximum strokes/ minute : 27 (Theoretical)
- Pumping cylinder : Length = 1400 mm , Diameter = 200 mm

Table 1: Strokes and Durations

Start Time	Duration (minutes)	No. of Strokes	Total Duration (mins.)	Total Strokes (no.)	Remark
11:35 am	0:51	22	5:36	138	-
11:37 am	1:33	38			-
11:40 am	0:36	14			-
11:44 am	0:38	16			-
11:46 am	1:03	25			-
11:52 am	0:55	23			End of 5.5 m3
-					
12:02 pm	0:10	4			Clamp breakdown
12:20 pm	0:58	24			-
12:24 pm	1:01	24			-

12:27 pm	1:44	42	5:56	145	-
12:30 pm	1:03	26			-
12:32 pm	1:00	25			End of 5.5 m3
No Concrete Available					
2:15 pm	1:23	34	5:53	144	-
2:19 pm	1:09	28			-
2:24 pm	0:31	12			-
2:31 pm	0:59	24			-
2:33 pm	2:26 pm	1:05			
2:34 pm	0:40	16			End of 5.5 m3
-					
2:40 pm	0:45	18	5:39	131	-
2:42 pm	0:06	2			-
2:43 pm	1:18	31			-
2:46 pm	0:57	21			-
2:50 pm	0:29	11			-
2:51 pm	0:57	23			-
2:53 pm	0:03	1			-
2:55 pm	1:04	24			End of 5.5 m3

Table 2: Weight age of Factors Affecting Productivity.

Factors	**1**	**2**	**3**	**4**	**5**
Condition of type of Pump	-	-	√	-	-
Condition of Pipelines clamps and bends	-	-	-	√	-
Availability of Transit mixers at site	-	-	-	-	√
Working Space at site	-	√	-		-
Workability of Concrete	√	-	-	-	-
Workmanship at Site	-	√	-	-	-
Supervision at site	-	√	-	-	-
Type of pour	√	-	-	-	-
Weather Condition	√	-	-	-	-
Height/Depth & distance of Pour from pump	√	-	-	-	-
Continuity of work	-	-	-	-	√
Communication at site	-	√	-	-	-

Table 3: Other Data Collected

Arrival Time of TM (minutes.)	10-15	16-30	31-45	46-60	More than 60
	-	-	-	√	-
Time req. to take position (minutes.)	1-3	3-5	5-7	7-10	More than 10
	√	-	-	-	-
Distance of RMC plant from site (kms)	Within 5	5-10	11-15	16-20	More than 20
	-	-	-	-	√
Working conditions for placing concrete	Very Easy	Easy	Average	Difficult	More difficult
	-	√	-	-	-

No. of Choke-up occurs	No choke Up	1-2	3-4	5-6	More than 6
	√	-	-	-	-

5. DATA ANALYSIS

The analysis shown here is only of one site reading.

Calculations for no. of strokes per minute

No. of strokes per minute =Total no of strokes applied / Total duration required in minutes

For 1st, No. of strokes per minute=138/5:36=24.64

For 2nd, No. of strokes per minute=145/5:56=24.43

For 3rd, No. of strokes per minute=144/5:53=24.47

For 4th, No. of strokes per minute =131/5:39=23.18

Average no. of strokes per minute = (24.64+24.43+24.47+23.18)/4=24.18

Duration Calculations

- Time required for pumping without considering any delays (minutes)
  = 5:36 +5:56+5:53+5:39 = 23:04
- Overall time required for pumping considering all factors and delays is consider as total time between 11:35 am and 2:55 pm = 200 minutes.

6. PRODUCTIVITY CALCULATION

Actual Productivity is calculated as:

a) Considering the no. of strokes applied concrete pump :

Volume of concrete pumped per stroke = Volume of pumping Cylinder

$= \pi \times r^2 \times h$

Volume of concrete pumped per stroke = $\pi \times 0.1^2 \times 1.4 = 0.0439\ m^3$

Average Maximum strokes per minute applied by the pump are 24.64

∴ Volume of concrete pumped per minute = $0.0439 \times 24.18 = 1.061\ m^3$

∴ Volume of concrete pumped per hour = $1.061 \times 60 = 63.66\ m^3$

b) Considering the time required for pumping without considering delays

Table 4: Quantity and Time requirement

S no.	**Quantity (m^3)**	**Required time (minutes)**
1	5.5	5:36
2	5.5	5:56
3	5.5	5:53
4	5.5	5:39

∴ Average time required for pumping $5.5m^3$ = (5:36+5:56+5:53+5:39)/4 = 5:46 minute

∴ Volume of concrete pumped per hour= (60/5:46) ×5.5= 57.22 m^3/hr.

c) Considering the time required for pumping considering delays:

For 22 m^3 it takes 200 minutes i.e. 3 hours 20 minutes

∴ Volume of concrete pumped per hour =22/3:20=6.6m^3/hr.

7. CONCLUSION

- From this study it has been concluded that there is considerable difference in the theoretical and actual production rates of pumped concrete. The productivity per hour, when it is calculated by giving regard to the number of strokes applied by the pump is always more than the productivity by consideration given to the actual time required for pumping without considering delays caused by factors.
- It has been observed that delays occur due to various factors resulting in to increase in overall timing of concrete pumping. Some efforts are made in this study to minimize the possible factors and somewhat try to increase the productivity of overall time.

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