Comparative Study & RII Analysis of Factors Affecting Productivity of Pumped Concrete

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Abstract- *Study deals with performance of concrete placing by using pumping technique. The main purpose of the research is to continuously monitor equipments/workers performing pumping activities within a construction site to obtain an estimation of productivity of pumped concrete at different heights of buildings. Consequently, the predicted production rates enable site planners and construction managers to plan and assess the duration of pump related activities. Study involved the comparison between the theoretical and actual productivity of pumped concrete. Again this study provides the information about factors those influences productivity of concreting in high rise building and identifying the most affecting factors by taking observations at various heights of multistoried buildings on 13 deferent construction sites. A relation between height of building and speed of concrete placing is derived using the regression equation, during the project the methodology adopted was to visit site and collect data and further analyze it to draw conclusion. In this observations of three different capacities of pumps that are included.*

Keywords *- efficiency; factors affecting; productivity; ; pumped concrete regression equation*

I. INTRODUCTION

Concrete has played an increasingly important role in the efforts of architects and engineers to find a satisfactory and economical material for high-rise multistory buildings. Cement concrete is only next to water in terms of the amount of material used on our planet. The popularity of concrete owes to its economy, ability to the cast into any shape, ability to be fabricated practically anywhere and last but not least, its inherent durability innumerable historical land marks in concrete speak volumes about its durability and versatility.

The production rate of concrete in construction projects is affected by several factors and the accuracy of productivity estimate could be challenged when effect of multiple factors is considered simultaneously. The pouring concrete operation is considered as a critical activity at construction projects which affect the duration of the project. The increases in the project duration caused due to any delays in pouring concrete activity have negative effects on the project cost, as that time delays usually equal cost over runs. 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.

For small height buildings the concrete whether it is site mix or RMC is transported and placed by using hoist ,wheel barrows and pulleys or sometimes cranes are also hire for the purpose of transportation of concrete. But when the building goes higher and higher, placing concrete with the hoist and wheel barrows method is become time consuming as it is not a continuous process and it hampered the productivity of concrete works. One of the techniques that have helped the construction industry tremendously is pumped concreting. Pumped concreting is an alternative method to placing the concrete using concrete pump. Most standard construction mixes can be pumped with little or modification.

Machines and equipments used in concrete pumping such as concrete pumps are mainly used to transfer wet concrete into the building formwork. A concrete pump offers many favorable advantages, such as increased productivity. The pump delivers high volume in short period and at the places where access for human is difficult. The demand for concrete pumps varies with the performance measures as well as the type of pump. Various structures from tallest skyscrapers to the smallest convenience store require concrete and concrete pumping is great way to get it where it needs to go. Increase productivity is important because it means faster completion allowing the owner to receive a return on their investment sooner.

II. OBJECTIVES

This primary objective of the report is to gather information about the factors that influences the productivity of pumped concrete and comparing theoretical and actual productivity which include:

A. Measuring the number of strokes applied by the pump to discharged the concrete.
B. Calculating the productivity based on the number of strokes applied by pump.
C. Measuring the time only for pumping the concrete without considering factors and delays and calculating productivity per hour based on this time.

D. Measuring the overall time required for pumping the concrete considering all factors and delays that affect productivity

E. Identify the factors responsible for causing delay in concreting operation and make effort to minimize possible factors and delays and try to increase actual productivity.

The secondary goal of this research is to develop a regression equation using scatter diagram for predicting the production rate of pumped concrete at various heights of multistory buildings, consequently, the predicted production rates enable site planners and construction managers to plan and assess the concrete pumping activities.

The production rate of concrete in construction projects is affected by several factors and the accuracy of estimate could be challenged when effect of multiple factors is considered simultaneously. In addition, the pouring concrete operation is considered as a critical activity at construction projects which affect the duration of the project. The increases in the project duration have negative effects on the project cost, as that time delays usually equal cost over runs. For this reason, developing the regression model to predict production rate of concrete can assist planners and estimators to reduce the effort required to plan the construction operation and to improve the accuracy of production rate estimate to complete a project within budget and schedule.

III. METHODOLOGY

The approach involved in this work has been divided into four different phases. The details of the work in phase are narrated below.

Phase-I:-

1) Study of available literature on pumped concrete productivity.

Phase-II:-

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 only for pumping activity without considering any delay .
4) Record the overall timing for pumping considering all delays .

Phase-III:-

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.

Phase-IV:-

1) Try to plot equation of regression line with all productivities values at various heights of building.
2) Make conclusion on the base of collected data and the identifications & report preparation.

IV. THEORETICAL CONTENTS

A. Pumping of Concrete

Placement of concrete in inaccessible areas has necessitated the use of pumps in today’s construction. Especially with the growth of ready mixed concrete across India, the need for pumping has increased manifold. While the ease of pumping depends on the type of pump available, the distance over which concrete is to be pumped, and the properties of the concrete, a number of finer aspects can affect the operation.[8]
Pumping is very efficient and reliable means of placing concrete, which makes it a very economical method. Sometimes a pump is only way of placing concrete in ascertain location. Such as a high rise building or large slabs where the chutes of the concrete truck can’t reach where the concrete is needed. Other time the ease and speed of pumping concrete makes it the most economical method of concrete placement.

B. Concrete Pump

A concrete pump is a machine used for transferring liquid concrete by pumping. In modern times, large quantities of concrete can be transported by means of pumping through pipelines over appreciable distances, often to locations that may not be easily accessible by other means of delivery.
The system for pumping concrete essentially consists of a hopper into which the concrete is discharged from the mixer, which in turn, feeds the concrete pump itself and finally the delivery pipelines through which the concrete is delivered.

C. Types of Pumps Used for Pumping of Concrete

i. Line Pump: Line pumps are versatile, portable units typically used to pump not only structural concrete, but also grout, wet screeds, mortar, shotcrete, foamed concrete, and sludge. Line pumps typically employ ball-valve-type pumps. While the smaller models are often called grout pumps, many can be used for structural concrete and shotcreting where low-volume output is suitable.[9]

ii. Boom Pump: Boom trucks are self-contained units consisting of a truck and frame, and the pump itself. Boom trucks are used for concrete pours for everything from slabs and medium high-rise buildings, to large volume commercial and industrial projects. Booms for these trucks can come in configurations of three and four sections, with a low unfolding height of about 16 feet. This low unfolding height is ideal for placing concrete in confined areas. Longer, five-part booms can reach up or out more than 200 feet. Because of their reach, boom trucks often remain in the same place for an entire pour. This allows ready mix trucks to discharge their loads directly into the pumps hopper at one central location and helps to create a more efficient jobsite traffic flow.[10]

D. Factors Affecting the Productivity

Concrete placing productivity is influenced by many factors. The placing method is major determinant of the speed of pacing, but the shape of the pour and its location are technical factors that also influence the productivity. The skill and enthusiasm of the enthusiasm of the placing gang are obviously relevant as is the timely supply of concrete to the site. The latter involves good coordination with a RMC supplier, the preparation needed for the pour to be completed on time, accurate estimation of the quantities of concrete and truck mixer movements and parking arrangements that bring about an uninterrupted supply at the truck mixer discharge point. Site congestion and other access conditions can make uninterrupted supply difficult or impossible, even when the concrete supplier is able to maintain a regular delivery. The concrete supplier scheduling problem is complicated by the fact that during the pour almost half of the sites change their order quantities, sometimes considerably.

In the majority of concrete pours it is possible to determine a number of factors that are detrimental to the quality of the concrete placing process. Establishing these factors, which are the cause of the stochastic nature of the system, may well allow a reduction in the variability of concrete operations and so reduce wastage and improve productivity. The factors have been evenly split into two groups, technical and managerial factors, which show that equal emphasis should be placed on good managerial practice. [11]

V. OBSERVATIONS

Data collected from the various sites at different heights of building include the theoretical productivity of pump ,maximum numbers of strokes applied by pump(theoretical), maximum numbers of strokes applied by pump for particular height of building , time required only for pumping activity , and considering all delays, factors that causing delays and total quantity of concrete produce etc.

TABLE I

AVERAGE MAXIMUM NO. OF STROKES APPLIED BY THE PUMP AT VARIOUS HEIGHTS FOR DELIVERY OF CONCRETE

Site No.	Building Height in (Meters)	Theoretical Productivity of pump ($m^3/hr.$)	Maximum no.of strokes applied by pump per minute (Theoretical)	Avg. Maximum no.of strokes applied by pump per minute (Actual)
1	-2.5	51	24	23.47
2	0(G.L)	71	27	26.23
3	3	51	19	18.85
4	8	71	27	24.64
5	10	51	19	17.99
6	10	71	27	25.49
7	12	51	27	25.28
8	12	73	24	20.63
9	14	73	24	17.60
10	20	51	19	17.60
11	24	51	19	17
12	27	51	19	14.42
13	30	73	24	22.76

TABLE II

TIME REQUIRED FOR PUMPING CONCRETE

Site No.	Building Height in (Meters)	Theoretical Productivity of pump ($m^3/hr.$)	Total quantity of concrete produce in m^3	Time required for pumping without considering any delays (minutes)	Overall time required for pumping considering all factors and delays (minutes)
1	-2.5	51	24	30:19	80
2	0(G.L)	71	27.5	28:12	78
3	3	51	20	24:49	109
4	8	71	22	23:08	200
5	10	51	24	30:31	167
6	10	71	33	34:08	186
7	12	51	20	28:07	108
8	12	73	18	22:35	140
9	14	73	24	30:55	144
10	20	51	24	34:49	188
11	24	51	20	33:41	104
12	27	51	16.5	48:33	195
13	30	73	11	16:52	216

VI. RESULT AND DISSCUSIONS

All the data recorded from different sites has been analyzed and productivity rates are calculated considering the strokes applied by pump, time required for pumping and overall time including delays and factors those are responsible for the delays are identified .Efforts are made to minimize possible factors and delays and try to increase the rate of actual productivity per hour of the pumped concrete. Productivity rates for three different capacities of pumps i.e.; 51m^3/hr., 71 m^3/hr. , 73 m^3/hr.

TABLE III

PRODUCTIVITY RATES CONSIDERING NUMBER OF STROKES APPLIED AND TIME REQUIRED FOR PUMPING WITHOUT DELAY

Sr. No.	Height of Building (meters)	Theoretical Productivity $(m^3/hr.)$	Productivity Considering strokes applied by Pump $(m^3/hr.)$	Productivity considering the time required only for Pumping $(m^3/hr.)$
1	-2.5	51	50.13	47.57
2	0(GL)	71	68.92	58.57
3	3	51	49.74	48.387
4	8	71	64.90	57.06
5	10	51	47.49	47.16
6	10	71	67.14	57.89
7	12	51	47.636	42.65
8	12	73	62.13	47.89
9	14	73	53.01	46.55
10	20	51	46.45	41.30
11	24	51	44.77	35.13
12	27	51	37.98	20.24
13	30	73	68.56	39.13

TABLE IV

PRODUCTIVITY RATES CONSIDERING OVERALLTIME FOR CONCRETE PUMPING CONSIDERING FACTORS AND DELAYS AND AFTER MINIMIZING POISSIBLE FACTORS AND DELAYS

Sr. No.	Height of Building (meters)	Theoretical Productivity $(m^3/hr.)$	Productivity considering the overall time required considering factors and delays $(m^3/hr.)$	Productivity after minimizing possible delays and factors $(m^3/hr.)$
1	-2.5	51	18	18
2	0(GL)	71	21.15	27.5
3	3	51	11	11
4	8	71	6.6	16
5	10	51	8.62	11.52
6	10	71	10.64	13.94
7	12	51	11.11	11.11
8	12	73	7.71	8.44
9	14	73	10.14	10.95
10	20	51	8.57	10.43
11	24	51	11.54	12.30
12	27	51	5.07	5.56
13	30	73	3.08	3.08

After calculating all the productivities values for different sites at various heights of building these rates are represented in graphical format using bar charts for clear understanding. While plotting, bar charts production rates of 71 and 73 m^3/hr. are represented in one chart and rates of 51 m^3/hr. are plotted in separate chart.

Fig. 1 & Fig. 2 showing bar charts representing Comparison between Theoretical productivity, Productivity of strokes applied and Productivity for time required for pumping without considering any factors causing delays for 51 m^3/hr.

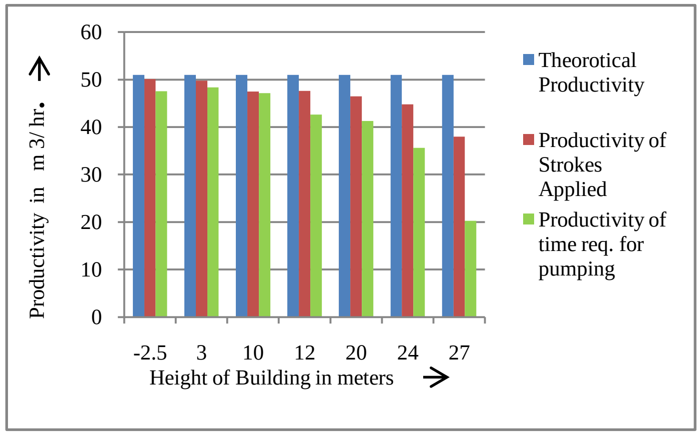
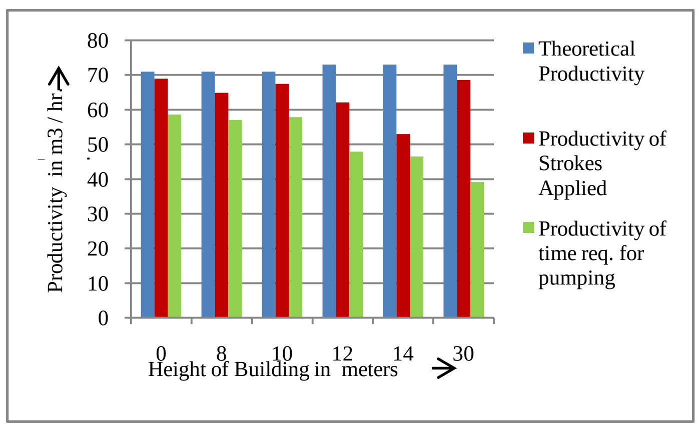


Fig.1 Comparison of Productivity rates for 51 m^3/hr. capacity pumps

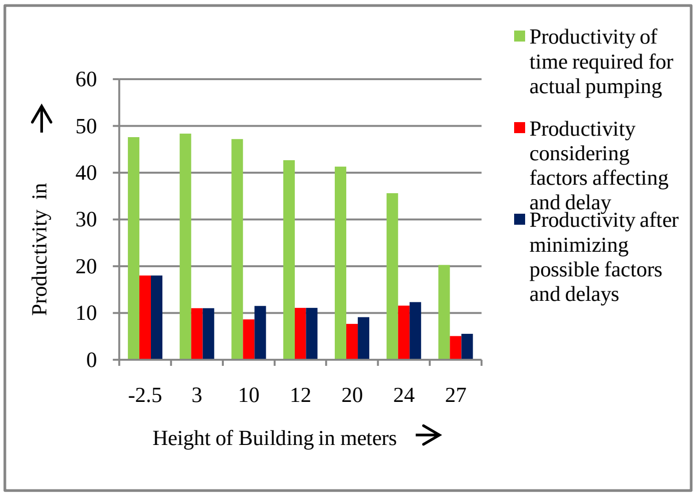
Fig. 2 Comparison of Productivity rates for 71 & 73 m^3/hr.



capacity pumps

Fig. 3 & Fig. 4 showing bar charts representing comparisons of productivity rates for time required without considering factors causing delays, considering overall time including delays and productivity after the minimizing possible factors causing delays for 51m^3/hr. and 71 &73m^3/hr. capacity pumps at various heights of building are shown below.

Fig. 3 Comparison of Productivity rates for 51 m^3/hr. capacity pumps



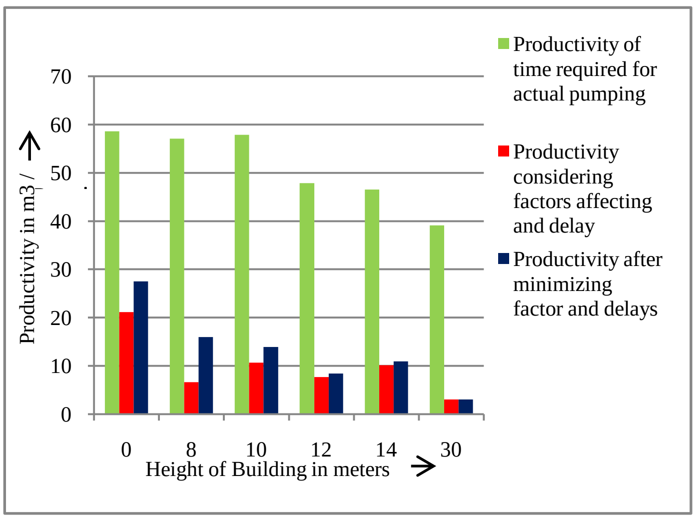


Fig.4 Comparison of Productivity rates for 71 & 73 m^3/hr.

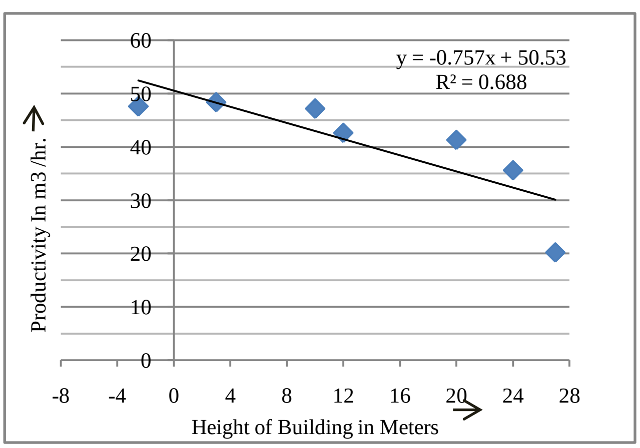


Fig. 5 Productivity rates verses height of building for 51 m^3/hr. Capacity pump

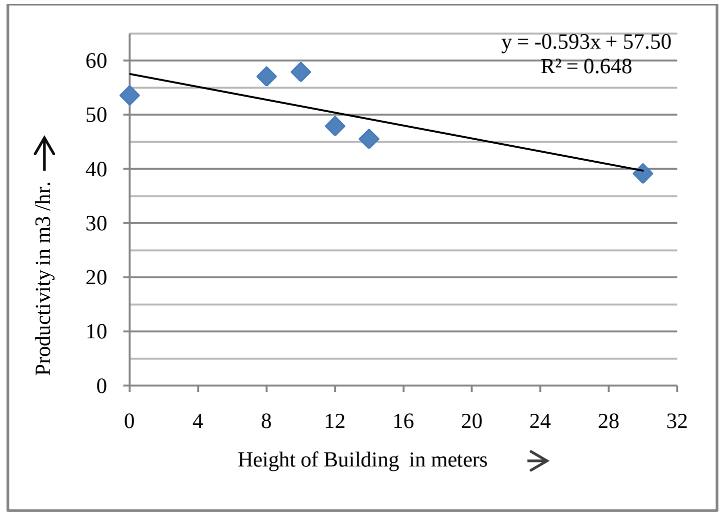


Fig. 6 Productivity rates verses height of building for 71 &73 m^3/hr. Capacity pump.

The data collected in the survey for various factors that affect the productivity rates of pumped concrete analyzed by Relative Importance Index (RII) method to determine relative importance of factors influencing productivity of pumped concrete and find out which factors are responsible for reducing productivity rates. Ranks are given to all the affecting factors depending upon their importance in affecting the rate of productivity.

TABLE V

FACTORS AFFECTING PRODUCTIVITY AND THEIR RANKS BASED ON IMPORTANCE IN REDUCING THE PRODUCTION RATES

Sr. No.	Factors	Rank
1	Condition and Type of type of Pump	9
2	Condition of Pipelines , clamps and bends	6
3	Availability of Transit mixers at site	2
4	Working Space at site	8
5	Workability of Concrete	11
6	Workmanship at Site	5
7	Supervision at site	4
8	Type of pour	10
9	Weather Condition	12
10	Height/Depth & distance of Pour from Pump	3
11	Continuity on of work	1
12	Communication at site	7

VII. CONCLUSION

From this study it has been noticed 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. There is large difference in the productivity considering the timing required only for the pumping activity and the productivity for the overall timing contemplating all others activities such as positioning transit mixer, changing connection of pipe lines, spreading and compacting concrete by using vibrators etc.
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. From this study it is found that amongst all those factors which are responsible for reducing the productivity, the continuity of work is extremely important factor which is mostly based on some other factors such as regular uninterrupted availability of transit mixers at site, workmanship and supervision at site working space available at site as site congestion create obstruction in movement of transit mixers. Also from over all study it has been found that the rate of productivity is less in case of pumping concrete in columns and beams as continuity of work is less on other hand in case of slabs it is more due to well continuation of all the work and activities and production rates automatically decreases as the height of building get increases and in this study this is found for all the readings that are taken for the 51 m^3/hr. Capacity pumps. While in case of 71 &73 m^3/hr. Capacity pumps it has been found that rates of production are not decrease with increase in height of building. This is because these pumps are of higher power and create huge pressure on the pipelines while pumping of concrete and there are chances to damage the pipelines and slipping of clamps ,thus the pump operators runs these pumps with slower speed and with some care depending on the situation.

In this study the from all the readings obtain and rate of productivity calculated for various heights the efforts are made to establish regression equations and those are:

$$y = -0.7574x + 50.537$$

&

$$y = -0.5939x + 57.506$$

for 51 m^3/hr. and 71 to 73 m^3/hr capacity pumps respectively. These equations can be used for predicting the production rates assist site planners and construction managers to plan and assess the concrete pumping activities.

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