A study on productivity of concreting work in building construction in Bengaluru city, India

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Abstract – *Productivity in Indian construction industry is a least studied topic. This study involves the measurement of productivity for concreting, formwork and rebar work. The data for this study is obtained from residential and commercial projects under constuction in the city of Bangalore, in India. Data spanning for a period of over 3 months is utilized in this study. The productivity for each day was calculated and the results were analyzed to identify any trends in productivity. On an average the productivity for formwork varies from 0.4 sqm/man hr to 0.84sqm/manhr for conventional formwork. But when Mivan type of formwork is used the productivity increases drastically and is in the range of 2.7 to 4.2 sqm/manhr. For concreting, the productivity varies from 0.91 cum/manhr to 1.88 cum/manhr and for rebar the productivity varies from 0.02 MT/manhr to 0.14 MT/manhr.*

***Key Words*: Productivity, Concreting, Formwork, Rebar.**

1. INTRODUCTION

Productivity refers to the physical relationship between the quantity produced (output) and the quantity of resources used in the course of production (input). Productivity measurement includes partial or factorial productivity and overall productivity. Measurement of productivity is a very difficult task because it depends on so many factors. It can be measured separately for each factor of production such as men, machines, materials etc. Productivity measurement is helpful in goal setting, cost reduction, resource allocation, motivation for improvement, forecasting output and national income etc.

An increase in productivity means an increase in output that is proportionately greater than an increase in inputs. If a concern is engaged in the production of a single product, output can be measured in physical terms, ex : number of units produced, volume, weight etc.

As such it would be worthwhile to study various quantitative methods, including construction productivity measurements for reason of:

- Decreased total cost and duration of production.
- Improved quality.
- Providing management with an effective tool to direct and control the productivity performance of a construction site.
- Offering feedback to employees on their productivity performance.
- Creating the basis for sharing the gains of higher productivity.

The issue of raising the level of construction productivity has been discussed time and again. There are many fundamental and wide-ranging topics that need detailed discussion before the industry can improve its status. Such issues have included: The impact of raising productivity, factors that affect productivity, need for productivity measurement and methods of measuring productivity.

In general there are many factors that affect productivity, and these include: Quality of the workforce, type of management, complexity of project, quality of finished work, degree of mechanization, type of contract used, weather, buildability, and type of construction techniques.

Productivity measurement at construction site level enables companies to monitor their own performance against their site performance. Productivity at construction site level can be grouped under various activities like productivity in concrete, steel work and shuttering, masonry etc.

2. LITERATURE REVIEW

2.1 Concrete Productivity

A study by Polat, G and Arditi, P in 2005 involves, case study of various sites regarding the productivity of concrete. This study involves collection of data information speed on concrete placing, time of concreting, volume, rate of concreting and relation between them with respect to height and type of structural member is analysed. (Dhawale A.W, Nizamuddin K.R). This research aims at investigating the effects of site productivity factors in the most prevalent mechanized concrete placement method in Nigeria with a view to optimizing its usage. To achieve this objective, data involving 26 concrete pours extracted from a total observation of 167 concrete pours on Lagos building construction sites were analyzed using the multiple regression method. (varma s ,apte .M.R). 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.

2.2 Formwork Productivity

Productivity improvement techniques are based on qualitative and quantitative data collected at a project site. This information can then be analyzed to identify trends, evaluate causes of productivity fluctuation and measure improvement program effectiveness. This method has been used successfully on projects worldwide with consistent results. Using this technique, productivity is defined as labor input divided by work output over a finite time interval. For example, if a crew required 12 work hours to install 100 square feet of completed concrete forms, the productivity rate would be 12 work-hours per 100 square feet of contact area (SFCA). (Bilal and Thomas 1990).

2.3 Steel Productivity

A pattern was recognized in effects of productivity with steel construction and it can be explained by the rationale that, for the same quantity of reinforcement, as the rebar diameter increases, fewer number of reinforcing bars are fixed, hence resulting in higher labor productivity. Furthermore, since the fixing process comprises, mainly, placing and tying rebar in positions, tying reinforcement bars is a time consuming process, but it is approximately the same for tying thin or thick bars. As a result, within the same labor input, thick bars can be tied; thus fixing larger reinforcement quantity and therefore higher labor productivity can be achieved. However this pattern depicted in this particular study was termed to be valid for the rebar diameters observed, which ranged from a minimum of 8 mm to a maximum of 25 mm. Apart from the rebar fixing, the rebar diameter, reinforcement quality, slab geometry and reinforcement layer location are also significant on the labor productivity. (Jarkas, A. M. 2010)

Reinforcing concrete structures is generally a rather expensive and time-consuming process, for designers as well as for constructors. The reinforcement design participates with about 50 % in the total design costs, and with around 30 % in the total work costs (Markovic et al. 2003). Fiber reinforcement, on the other hand, has the advantage of being significantly less labour-intensive than rebar reinforcement, and thus meets both the demand for improved efficiency and future shortage of skilled workers. Future concrete might, therefore, be envisioned without traditional reinforcement.

2.4 LABOUR PRODUCTIVITY

As construction is a labor-intensive industry, this paper focuses on labor productivity in the construction industry. This study considers the current state-of-the-art issues relevant to this subject. It covers the construction labor productivity definitions, aspects, measurements, factors affecting it, different techniques used for measuring it and modeling techniques. The main outcome from the literature is that there is no standard definition of productivity. (Shehata M.E, El-Gohary K.M. 2012). This study provides a guide for necessary steps required to improve construction labor productivity and consequently, the project performance. It can help improve the overall performance of construction projects through the implementation of the concept of benchmarks. Also, it gives an up to date concept of loss of productivity measurement for construction productivity claims. To achieve the income expected from any construction project in general, it is important to have a good controlling hand on the productivity factors that contribute in the integrated production composition, like labor, equipment, cash flow, etc. (Sonmez and Rowings 1998; Hanna et al. 2008)

Hourly outputs are widely used to measure labor productivity in construction research using a labor hour as the input unit and the physical quantity of the completed work as output. For example, concrete placement uses a labor hour as input and the cubic yards of concrete placed as output. For concrete placement, labor productivity can be expressed as hours per cubic meter or cubic meters per hour. The ratio can be in the format of input/ output. (Sonmez and Rowings 1998; Hanna et al. 2008), A study stated that policies to rise productivity are not always similar in each country. Their study identified different factors affecting labor productivity and grouped them according to their characteristics such as, design, execution plan, material, equipment, labor, health and safety, supervision, working time, project factor, quality, leadership and coordination, organization, owner/consultant, and external factors. (Polat, G and Arditi, P 2005)

Productivity factors causing low productivity are industry-related factors, labor-related factors, and management-related factors. Industry-related factors, essentially, are the characteristics of the construction industry, such as the uniqueness of construction projects, varied locations, adverse and unpredictable weather, and seasonal variations. Labor-related factors include the union's influence, little to no potential for learning, and lack of motivation. Management-related factors usually refer to a lack of management for tools or techniques. (Adrian, J 1987).

3. DATA COLLECTION AND ANALYSIS

This study has total eight case studies which are located at different locations in Bengaluru, a city in India. Out of which four are residential apartments and four are commercial buildings. Also one case study is of mivan formwork building system and the remaining seven use conventional formwork in its construction. The height of residential buildings ranges from 4 to 13 floors, various grades of concrete ranging from M-15 to M-40 are used based on design requirements. The types of concrete pumps used are boom pumps and line pump or trailer-mounted concrete pumps. The different formworks which are used for the buildings are Mivan formwork and the conventional type of formwork. Conventional execution methods and techniques were adopted for the structural elements of the buildings. Steel of various grades and diameters were used according to the design specifications.

A data collection template for formwork is shown below which was used in all the sites to collect the relevant data. The data for 90 days is collected and analysed.

Total formwork quantity(sqm)	*38509.88*
Total number of carpenters	*976*
Total number of helpers	*447*
Total carpenters+ helpers	*1423*
Total duration in hours	*480*
Total man-hours	*14230*
Productivity(sqm/man-hours)	*2.70*

The productivity is calculated by Z =X/Y (sqm/man-hours), where Z=Productivity of formwork, X=Quantity of formwork in sqm, Y=Total man-hours. Plot a graph of productivity v/s quantity of formwork, and average productivity, factors affecting and influencing productivity were identified.

To find rebar productivity a similar data table was prepared and the productivity was calculated as Z =X/Y MT/man-hours where Z=Productivity of steelwork, X=Quantity of steel in MT, Y=Total man-hours. Plot a graph of productivity v/s quantity of rebar, and average productivity, factors affecting and influencing productivity were identified.

Similarly the productivity of concrete is calculated as Z =X/Y cum/man-hours, where Z=productivity of concrete, X=quantity of concrete in cum, Y=total man-hours. Plot a productivity graph of productivity v/s quantity of concrete. The factors affecting and influencing concrete productivity identified.

4. RESULTS AND DISCUSSIONS

The productivity of formwork obtained from the case studies varies from 0.4 sqm/man hr to 0.84sqm/manhr for conventional formwork. But when Mivan type of formwork is used the productivity increases drastically and is in the range of 2.7 to 4.2 sqm/manhr.

For concreting, the productivity varies from 0.91 cum/manhr to 1.88 cum/manhr and for rebar the productivity varies from 0.02 MT/manhr to 0.14 MT/manhr.

The results are plotted in a graph for further analysis. Two graphs are plotted for each activity for each site. One depicts the relationship between the average productivity of each site and the quantity of work done whereas the other shows the relationship between crew productivity and the quantity of work done.

Crew productivity depicts the variation of productivity with various crew combinations for each site

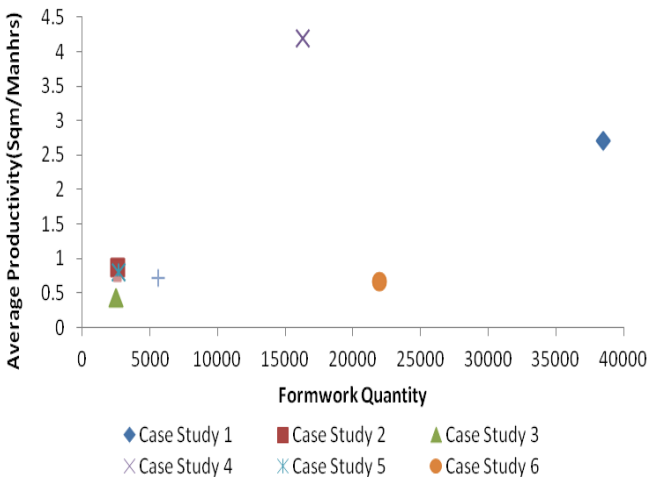

Fig 4.1: Relationship between Formwork Quantity v/s Average Productivity

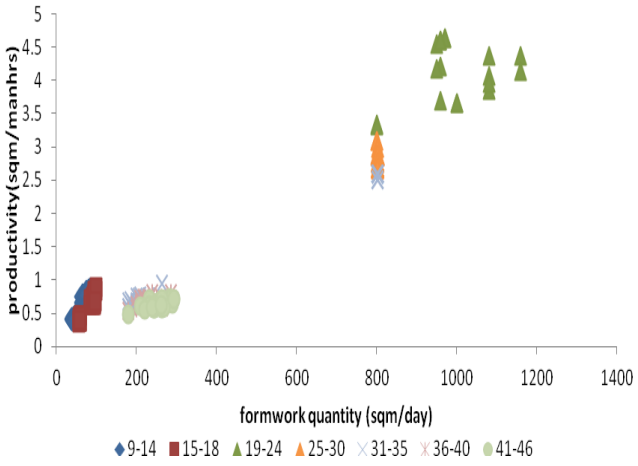

Fig 4.2: Crew Productivity for Formwork Case Studies

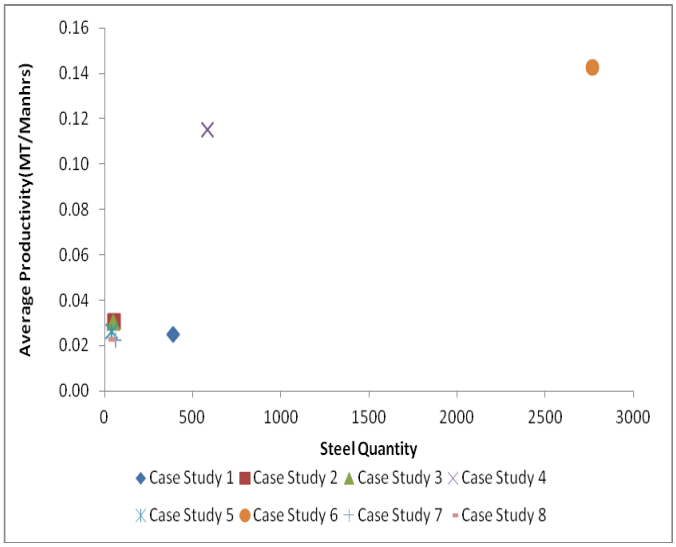

Fig 4.3: Relationship between rebar work Quantity v/s Average Productivity

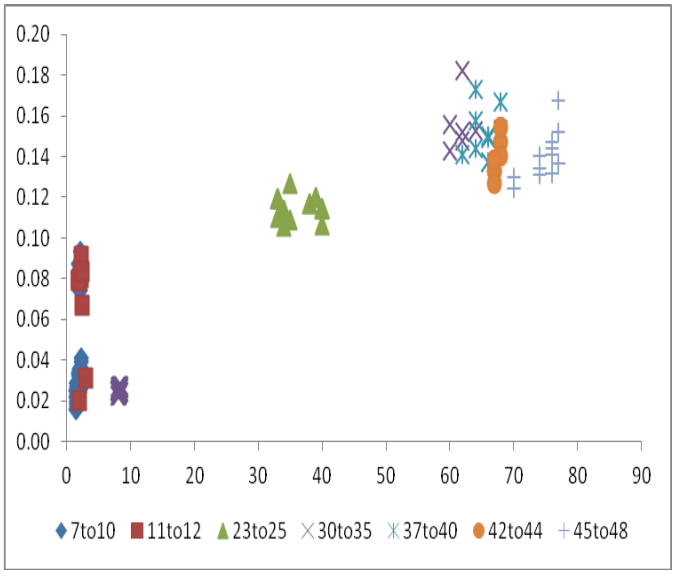

Fig 4.4: Crew Productivity for rebar work Case Studies

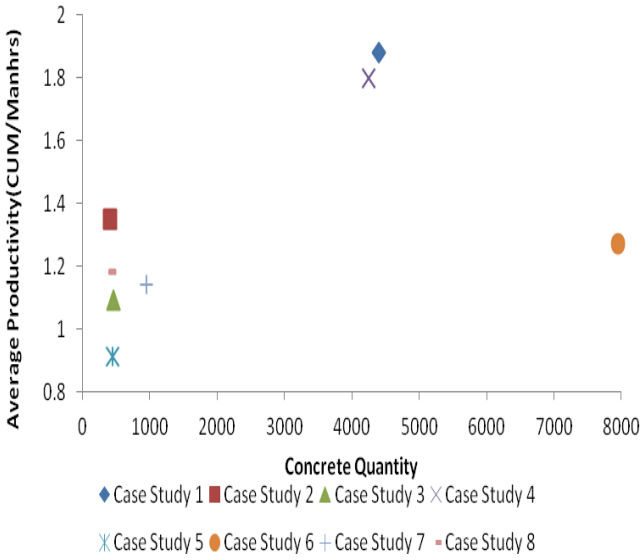

Fig 4.5: Relationship between concrete work Quantity v/s Average Productivity

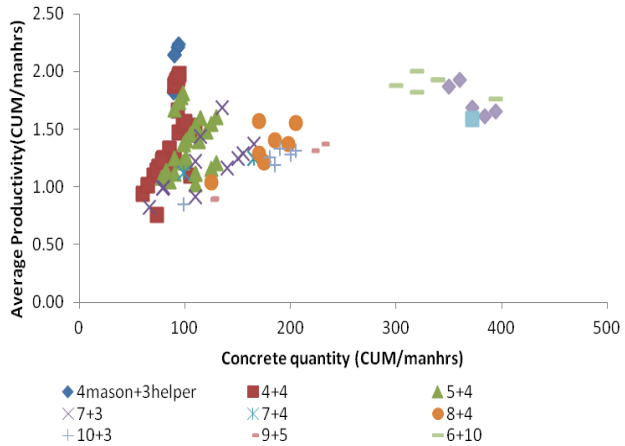

Fig 4.6: Crew Productivity for concrete work Case Studies

4.1 Comparison with literature review

The results from this case study are compared with literature review to better understand the productivity rates in India with respect to global standards.

Table 4.1 Comparison of productivity of formwork with literature review

Author name	Smith & Hanne(2011)	Minea & Limc	From this study
Quantity(sqm)	-	-	21737
Total manhrs	-	-	33345
Average productivity(sqm/manhr)	0.70	0.99	0.65

Table 4.2 Comparison of productivity of Rebar with literature review

Author name	Forsythe (2007)	Abdulaziz (2010)	From this study
Quantity(MT)	198	37.13	228.62
Total manhrs	1949	268	9116
Average productivity	0.1	0.14	0.08

Table 4.3 Comparison of productivity of concreting with literature review.

Author name	Olatude &Ojo Stephen (2011)	Suhad & Abbas (2008)	From this study
Quantity(MT)	515	-	19221
Total manhrs	1775	-	13265
Average productivity	0.29	1.25	1.44

5. CONCLUSIONS

From this study the productivity for concreting, rebar and formwork is obtained and after analyzing the various factors from the available data, the following conclusions can be drawn.

Productivity of Formwork:

- The use of Mivan shuttering increases the productivity many fold, as it is very easy process of formwork and having various advantages and also have dimension flexibility, it has a great advantage in the construction building with shear wall frame structure.

- Traditional shuttering with large plywood sheets also have the great productivity where the floor height is restricted to below 12 floors because the high level of the floor needs other various equipment and machineries for handling and placing of formwork.

- The conventional formwork is the most widely used type of formwork in the Indian construction industry. Conventional techniques have various advantages and disadvantages and also the productivity of this type of formwork is less when compared to the modular method of formwork as there is no dimension flexibility and there exists complexity in the construction of beam-slab system.

- The productivity of formwork also depends on the dimension of the floor layout, dimension of the beam and column connections and variation in floor height and some complex parts like staircase and lift lobby.

Productivity of Rebar :

- Reinforcement of concrete is not an easy task, so its needs a detailed analysis of load and proper execution on site. The productivity of reinforcement depends on various factors like machineries, skilled labour, equipment used and design and detail of the structure.

- The productivity increases even if there is complex design when there is a skilled labor with the necessary machineries and equipment.

- The productivity may also vary on the supply of the bars stack holders and also delay in design and detailing.

- Productivity depends on design of the beam and slab with a greater depth or with the complex number of bars detailing.

- Productivity decreases when the supply bars from the stack holders are damages in the sense it has various bends

Productivity of the concrete

- The productivity in concreting work depends on the various factors such as type of design and complexity of the building and it also depends on the distance from RMC plant from the site.

- Productivity of the concrete increases when the concrete is brought from the RMC and then conventional concrete process are used and it also varies on the type of pumps and the method used in concrete placing where the boom pump has higher productivity compared to the other line pump and man placing.

- Supply of concrete, including delivery times and intervals also affectv productivity.

- The shape and size of the structural member, since the ease or difficulty of pouring fresh concrete will depend not only on the state of the fresh concrete and the presence of steel reinforcement, but also on the shape and dimensions of the concrete member.

- The presence of steel reinforcement, as the numbers, size and spacing of the bars can affect the pouring and proper compaction of fresh concrete.

- The accessibility of machinery for example concrete pumps and tower cranes, as these can decide the speed at which concreting can progress.

- The climate conditions on the time of concreting, as work activities can be affected by wind, rain and sunshine.

- Productivity of concreting does not end only after placing it, but also proper compaction and leveling are necessary where as various methods and type of vibrators used for compaction for better of concreting.

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