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Analysis of Constructions Productivity based on Progress Payment Certified (PPC)

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Abstract - *Productivity has for many years been an issue for the construction industry in India. The industry is deeply concerned that construction productivity is not only below that of the manufacturing sector, but is also below the national average. The industry has identified several factors that have impeded construction productivity, namely, a shortage of suitably trained, skilled supervisors and workers; a weakening local construction workforce; and a large, mostly unskilled and transient pool of foreign workers. The main objective of the research programme was to assist contractors improve their site productivity performance. A three-pronged approach was adopted, comprising a review of current construction productivity issues affecting the India construction industry; a survey of top civil engineering and building contractors to understand their perceptions on productivity; and a study of measurement techniques of site productivity for on-going building projects.*

Key Words: NPC, HAB, RAB, HOB, CIDB

1. INTRODUCTION

The first phase of the research programme comprised a comprehensive study of construction productivity issues in the **Gandhi medical college, Bhopal** context, followed by an extensive questionnaire survey. The objective of the survey was to identify the perceptions of senior management of large civil engineering and building contractors with regard to: factors that would improve construction productivity; and problems encountered at construction sites. This phase of the research resulted in several recommendations to be made to industry in order to improve construction productivity. These recommendations included the recruitment and training of a new generation of skilled local workers; continuous upgrading of management and technical skills of supervisory staff; the study of long-term viability of construction automation processes; promotion of buildable designs. The second phase of the research comprised a study of productivity measurement techniques for various on-going building projects in India. Two areas were investigated, namely: measurement of overall site productivity of projects on a monthly basis; and measurement of labour productivity of formwork, reinforcement and concreting operations. A prescribed productivity equation was used for measuring overall productivity, and data included monthly site manpower and monthly progress payments certified by the project consultants. Three categories of building projects were investigated, namely buildings, public residential buildings and private residential buildings.

Figure 1: Satellite of Gandhi Medical College

Unlike several other industries, the level of technology in the construction industry has remained relatively unchanged over several decades. The lower pace of technological development in construction places the industry at a disadvantage when compared with other industries where enhanced productivity is achieved through the use of modern technology. As the construction industry is a diverse sector of the national economy which involves a wide range of scarce resources, its productivity is therefore not only concerned with many individual activities, but the industry as a whole. 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.

2. METHODOLOGY

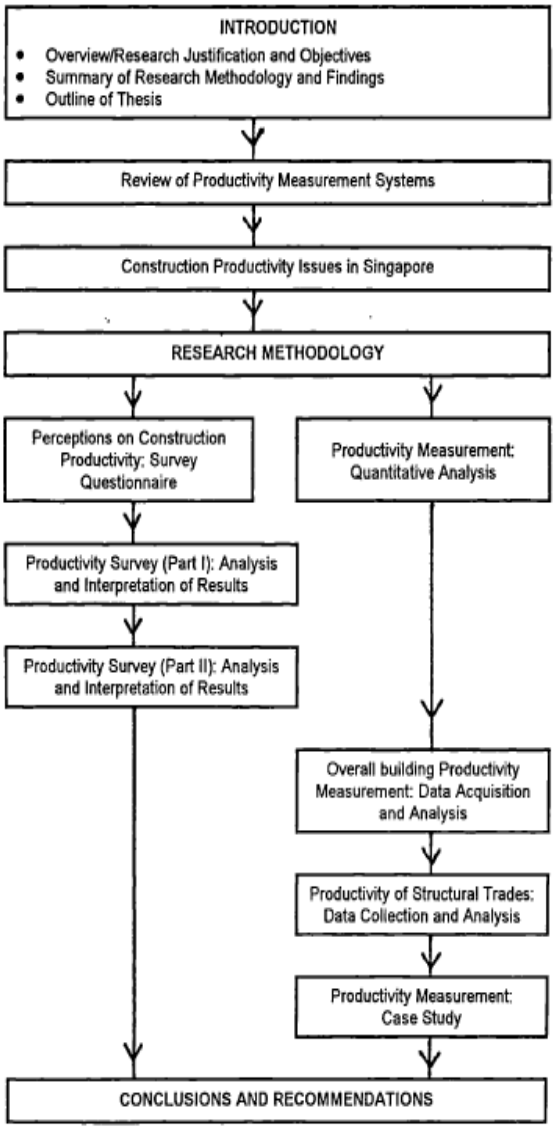
In brief, the research methodology can be summed up as follows:

- literature review of books, journals and conference papers on various aspects of construction productivity, both globally and in India;

• gathering of manpower data and other information for the purpose of measuring overall construction productivity of building projects in India;

• gathering of manpower data and material quantities from selected construction sites for the purpose of evaluating the productivity of formwork, reinforcement and concreting operations in building projects;

• verifying and checking all data received for correctness and



Analysing the information obtained;

• presenting all data and analysis through tables and graphs;

• dialogue with contractors on validity and usefulness of data obtained;

• conclusions and recommendations for future research work related to construction productivity.

Data Analysis

There are a few ways of obtaining data for productivity computation of buildings under construction. One method is to station a supervisor on site daily to work out the daily quantities of: formwork installed (in square metres); reinforcement bars installed (in tonnes); and concrete poured (in cubic metres).

Figure 2: View of Gandhi Medical College Constructions Site.

The supervisor has also to record the daily workforce under the three categories of formwork, reinforcement and concreting. The number of hours spent daily by the workers for each of the trades above are also monitored. From the above records, it is then possible to compute the following on a daily basis:

• Labour productivity (formwork)

Area of formwork installed (m2)

No. of man-hours

Unit of measurement: m2/man-hour

Quantity of rebars installed (tonnes)

• Labour productivity (reinforcement)

Unit of measurement: tonnes/man-hour

• Labour productivity (concreting)

Unit of measurement: m 3 man-hour

Quantity of concrete poured(m3)

No. of man-hours

One of the difficulties of the above method is that, in addition to monitoring the number of workers for each of the above trades and their daily working hours, the supervisor also has the audios task of calculating the daily quantities of formwork installed, reinforcement bars installed and concrete poured. In order to obtain meaningful data, the supervisor has to keep such records for several months in order to monitor the trends in labour productivity. It has been found that such a method is not practical on construction sites as contractors are unable to spend time and manpower to monitor the daily quantities of formwork, reinforcement bars and concrete used. Further, it is doubtful as to whether the quantities collected would be at all accurate, especially for reinforcement bar installation, where the supervisor has to count the actual number, length and diameter of bars used daily. In order to overcome this difficulty, it is proposed to exclude the task of calculating the daily quantities used. Instead, the number of workers and the number of working hours are identified daily for the three structural trades for the construction of a consecutive number of floors. The only quantities needed are the form work area, the reinforcement tonnage and the concrete volume used for each of the floors under investigation. These quantities are provided by the Quantity Surveyor and this takes the responsibility off the site supervisor. This will eliminate the task of obtaining the quantities on a daily basis. At the end of construction of a particular floor, the total man-hours for each of the three trades are calculated and the labour productivities are then obtained, using the same equations as mentioned earlier.

$$\text{Productivity}(m^2/\text{man-day}) = \frac{\left(\frac{\text{Monthly Progress Payement Certified}}{\text{Total Contract sum}}\right) \text{X Gross Floor Area}}{\text{Monthly Man Power}}$$

This technique is much simpler to adopt in practice and is used in this research programme. In order to study variations in labour productivity from floor to floor, it was further suggested to study identical floors for a few high-rise buildings under construction in India. The decision to use identical floors is a valid one as it eliminates the problem of differences in floor layouts and floor areas if non-identical floors are selected. Different floor layouts would mean different beam lengths and sizes and other structural configurations and it would make a floor-to-floor comparison of labour productivity difficult.

In the productivity computation, it is also the task of the supervisor to take note of the type of formwork used, the floor system adopted by the design engineer and any other features of the structural frame of the building that would affect labour productivity. In the reinforcement computation, it is important to note the floor system used and whether or not reinforcement cages, prestressing tendons and 200 welded wire mesh reinforcement are used.

As for the concreting works, it is useful to note the source of the supply, i.e. whether it is site mixed or ready mixed concrete, the type and number of concrete pumps used and the availability of tower cranes for lifting of concrete as these items can affect productivity. It is also important to note if any precast concrete units are used, as then the number of man days for the precast works would have to be allocated to the factory. Unless otherwise stated, the labour productivity in this research programme is for activities on site only and excludes works executed in the factory.

RESULT AND DISCUSSION

Table 1: Technical factors affecting formwork productivity

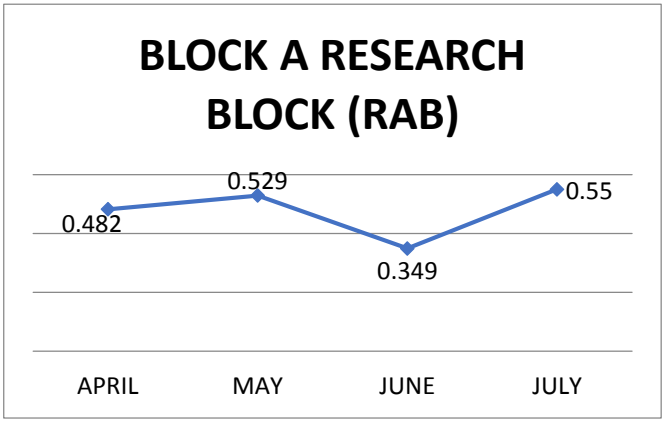
Factor	Remarks
1. Floor layout: conventional beam-and-slab system or flat slab system.	Formwork for flat slabs are easier to install than beam-and-slab system.
2. Type of cranage used	Use of suitable cranes enables larger formwork panels to be lifted.
3. Types of formwork system used.	Proprietary formwork enhances productivity as it is faster to install and dismantle.
4. Type of support scaffolding used.	Proprietary metal type support scaffolds are easier to install and dismantle. They are also more durable than timber props.

Table 2: Technical factors affecting reinforcement productivity

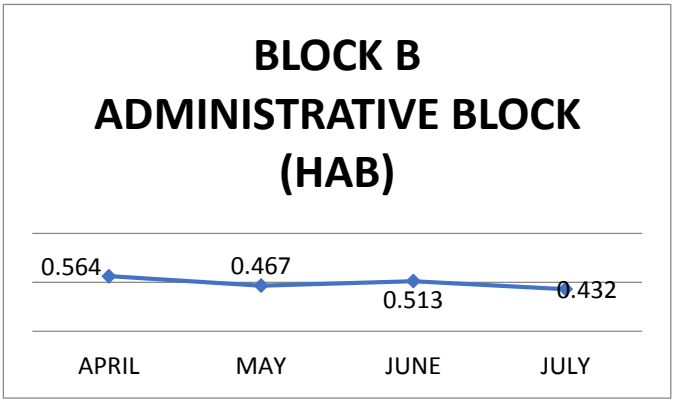
	Factor	Remarks
1.	Type of reinforcement used: prestressed tendons, tied reinforcement bars, welded mesh reinforcement	Prestressed tendons and welded mesh reinforcement are easier to install than tied reinforcement bars.
2.	Quantity, shapes and sizes of reinforcement bars	Congested reinforcement as well as use of different bar sizes and shapes slow down installation.
3.	Arrangement of reinforcement	Complicated layout of reinforcement bars lowers site productivity.
4.	Use of prefabricated reinforcement (i.e. caged bars, tied in factory).	Faster to erect on site as much work already done in factory.

Table 3: Technical factors affecting concreting productivity

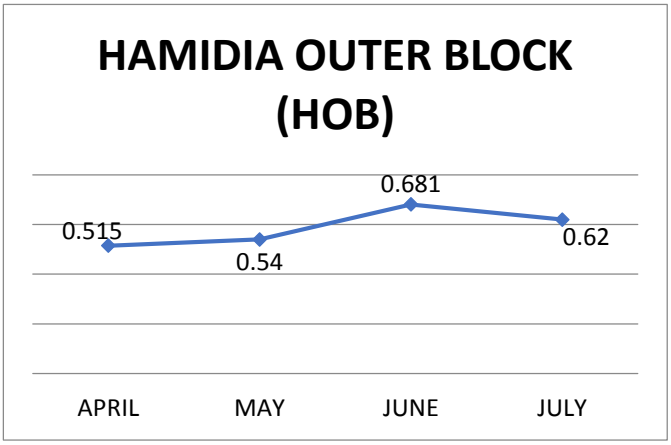
	Factor	Remarks
1.	Supply of concrete	Continuity of concrete supply enhances productivity. Delays in supply of concrete should be minimised.
2.	Workability of concrete	A high workability enhances pumping of concrete, makes concrete placing and vibrating easier.
3.	Shape and size of structural member	Deep, narrow structural members make concreting difficult.
4.	Reinforcement quantity	Congested reinforcement causes difficulty in compacting concrete.
5.	Machinery for vertical transportation	Use of concrete pumps and tower cranes enhances productivity.



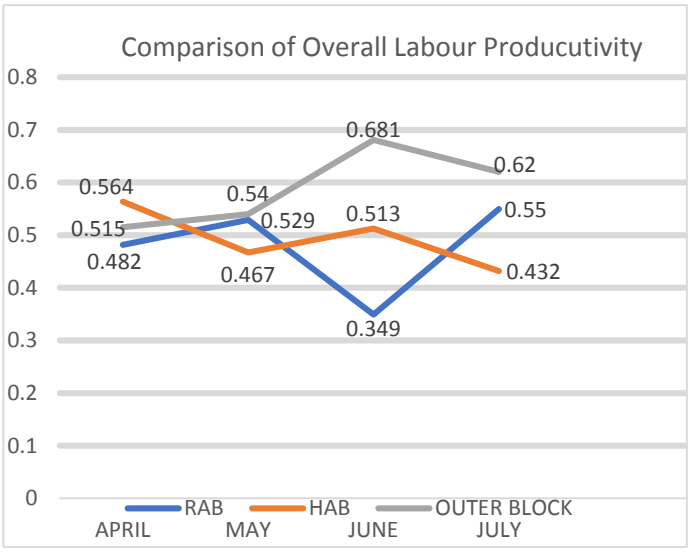
Graph 1: Constructions productivity based on pavement certified of Block – A Research Block (RAB)



Graph 2: Constructions productivity based on pavement certified of Block – B Administrative Block (HAB)



Graph 3: Constructions productivity based on pavement certified of Hamidia outer block (HOB)



The issues raised by the survey on construction productivity is only qualitative in nature and a complete understanding of productivity must therefore include some quantitative analysis. The availability of data from various on-going projects in India enabled an in-depth investigation of

productivity measurements to fulfil the quantitative aspects of productivity.

National Productivity Council

Hence, the major part of this research programme involved the development of techniques for measuring construction productivity of on-going building projects in India. It was found that overall construction productivity can be reliably measured by using the prescribed productivity equation of this Research paper. Although the accuracy of the results given by the above equation is subjected to:

• the monthly progress payments being truly representative of the actual work
done; and
• the correct manpower figures being reported by the contractors,

the productivity equation is nevertheless a useful one to adopt for measuring site productivity. This research concludes that monthly productivity of individual
projects can vary considerably and values are:

(i) generally low during the start of projects due to the learning curve effect; and
(ii) generally high during the months when there is an increase in architectural works, especially so for buildings with expensive architectural finishes.

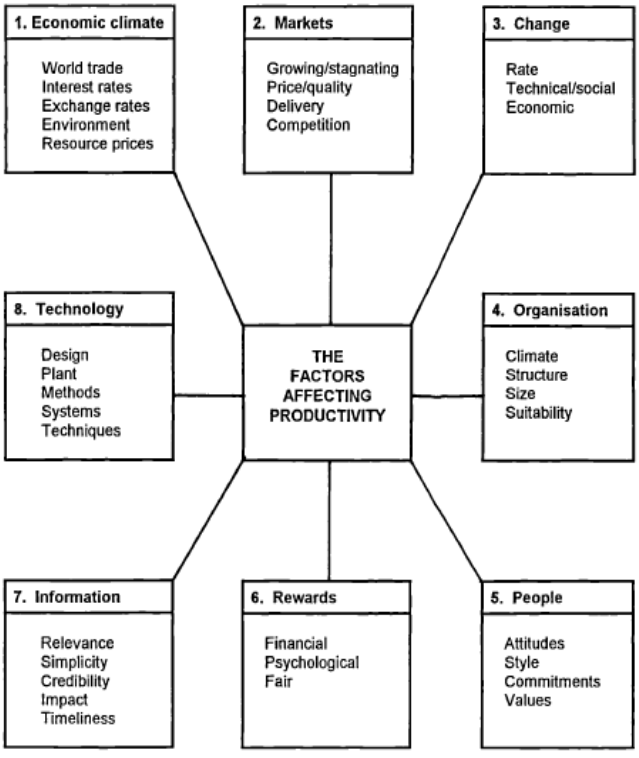
Item is endorsed by the fact that when there is an increase in the architectural workforce, the productivity figure rises due to the increase in progress payments arising from the higher payments received from increased architectural works. This is the case with and private residential projects as they have more elaborate architectural finishes compared to public residential projects.

3. CONCLUSIONS

The research concludes that collectively, the productivity values of public residential projects are higher than those of private residential projects. The reason for the above phenomenon is that public residential projects are more buildable, since their designs are basic and simple, compared to the intricate designs of the other two categories of buildings. However, the users of the productivity equation must be cautioned against calculating productivity values of projects for only a few month's duration of the construction works. The productivity values have to be monitored over as long a period of construction as possible and certainly not less than say fifty percent of the total construction period. If a building takes two years to complete, it is recommended to monitor the productivity values for at least twelve months to study the behavioural pattern of the productivity figures, manpower usage and progress payments. It is unwise to take readings for a mere three months and then make conclusions as to the productivity pattern.

The results of the productivity survey indicated that of the ten groups of items surveyed, the following were identified as being the most important in improving construction productivity:

• guidance from consultants;
•collaboration between contractors and sub-contractors/suppliers
• collaboration between contractor's head office/site office; and
• attributes of managers and supervisors.



However, with emphasis by the Construction Industry Development Board on buildability, quality and productivity, it is very likely that the use of prefabrication has recently been given more importance by contractors. From the results of the construction productivity survey and the findings of the NPC (National Productivity Council) report, it

is possible to identify several manpower issues that have impeded construction productivity, namely:

• a shortage of suitably trained, skilled supervisors and workers in the construction industry;
• a weakening local construction workforce, with job seekers keeping away from the construction sector; and
• a large, mostly unskilled and transient pool of foreign workers.

Construction trades are increasingly unattractive to Indians for various reasons such as the severe and more hazardous working environment, the presence of too many foreign workers and the general lack of recognition. Contractors have to meet stiff competition for manpower from at his more aggressive and attractive sectors. The difficulty in recruitment may be due to outdated strategies used by employers. For example, very few contractors recruit engineering trainees before they graduate from the universities and polytechnics, as is practised by large corporations in other sectors of industry. The answer to the manpower problems encountered by the construction industry in India lies in better trained and skilled manpower, more attractive employment incentives, improved management techniques and increased use of plant and equipment.

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