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Influence of Buildability Factors on Flooring Labour Productivity

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***Abstract*: Buildability is most important factor which impacts the labour productivity. Since Flooring is most important and repetitive activity in the construction of many types of industrial and residential buildings. Hence buildability factors in flooring considerably affect the labour productivity. In this study buildability factors involved in flooring are studied by selecting 40 building sites. Data collected from sites is analysed by using categorical regression analysis. The effects of factors such as geometry of room, screed thickness, tile area on buildability are discussed. Conclusions are drawn to show the impact of buildability on floor fixing operations. This study provides information to construction project managers or and site engineers to improve their labour productivity for the flooring activity on building sites.**

***Keywords*: Buildability, Categorical regression analysis, Flooring, Labour productivity.**

1. Introduction

In a production process, productivity is generally defined as the ratio of output to inputs. Productivity derives from the efficiency of the manufacturing process, in particular the efficiency with which labour and capital (men and machines) are used to turn inert materials into end products which are socially functional. Labour efficiency (i.e. the man-hour relationship and the quantity of work installed) is a significant measure of construction labour performance. Since labour is a key building resource. Construction labour productivity is described as "physical progress per hour." The cost time and quality of any construction project depend on the productivity. Building industry is a labour-intensive industry, and labour costs account for 30–50 percent of the overall project cost in most countries. A cornerstone of a good calculation is the cost of labour, which relies on assessing the projected efficiency of labour.

The accepted definitions of buildability developed by the Construction Industry Research and Information Association (CIRIA) in the UK, as: "Buildability is the extent to which the design of a building facilitates ease of construction, subject to the overall requirements for the completed building (CIRIA, 1983). Illingworth (1993) defined buildability as design and detailing which recognize the assembly process in achieving the desired result safely and at least cost to the client.

Moore (1996) modified Illingworth's (1984) definition as a "design philosophy, which recognizes and addresses the problems of the assembly process in achieving the construction of the design product, both safely and without resort to standardization or project level simplification."

Buildable designs lead to more labour productivity and lower construction costs (Dong 1996; Carter 1999; Williamson 1999). Design simplification is achieved through the implementation of the following three major buildability principles: (1) rationalization; (2) standardization; and (3) repetition of elements (Dong 1996). Design rationalization is defined as "the minimization of the number of materials, sizes, components or subassemblies," whereas standardization is "a design philosophy requiring the designed product to be produced from those materials, components, and subassemblies remaining after design rationalization has taken place" (Moore 1996b). The design repetition principle involves repeating bay layout, floor grids, dimensions of elements, and storey height.

2. Flooring Operation Overview

The Floor Tiling Productivity Monitoring Form has been designed to standardize the monitoring of productivity for floor tiling. Flooring involves following basic process-

A) Marking of reference and level lines
B) Preparation of sub-grade
C) Laying of mortar bed
D) Laying of tiles

A. Marking of reference and level lines

After completing the preparatory activities, a reference line is marked on room walls. On the basis of this reference line, a level for sub grade, mortar bed and the tile-finished surface are established taking into consideration the slope required & their thickness. Thereafter, respective level lines are transferred/marked on the walls with the use of line thread and indigo (Neel).

B. Preparation of sub-grade

The sub-grade, for flooring laid on the ground floor is known as "Base Concrete" whereas flooring laid over structural slabs, is known as "Cushioning layer". The base concrete shall be

either lime concrete or cement concrete of specified mix. The thickness of base concrete shall be as specified (normally up to 85-90mm).

C. Laying of mortar bed

Over properly laid sub-grade, the mortar layer is evenly and smoothly spread. Both cement mortar as well as lime mortar can be used for this purpose.

1. Preparation of mortar for bedding.
2. Spreading of mortar.

D. Laying of tiles

It consists of following operations:

1. Marking of layout lines
2. Plan/pattern for the tile application
3. Fixing of tiles

3. Objective of the Study

The main objective of this study is to identify the buildability factors which impacts on the flooring labour productivity. Major factors are identified by visiting the sites located in Kolhapur city. The specific objectives of the study are as follows:

- To study the concept of buildability from the available literature.
- To study construction labour productivity on the basis of activity level.
- To find out the impact of buildability factors on the flooring labour productivity by regression analysis using PhStat software.

4. Experimental Work

A. Data collection through interview for productivity calculation

For the flooring labour productivity calculation, 40 sites were visited and interviewed to collect the data of vitrified tile installation. 3 Major buildability factors were observed on the sites 1. Tile Size, 2. Screed Thickness, 3. Geometry of the room.

B. Productivity calculation

Data collection sites were located in Kolhapur city.

Productivity calculation is done by time study. Productivity is calculated in the by general formula output divided by input. Here output is tiled area and input is time required to complete the tiling the entire room.

Productivity = $\boldsymbol{Tiled\ Area}$ (m^2) /$\boldsymbol{required\ time\ in}$ ($\boldsymbol{hr}$)

For categorical regression analysis, tile size, screed Thickness are measured and geometry is observed weather it is rectangular or non -rectangular. Also, tiled area and time require to install the tiles are also recorded.

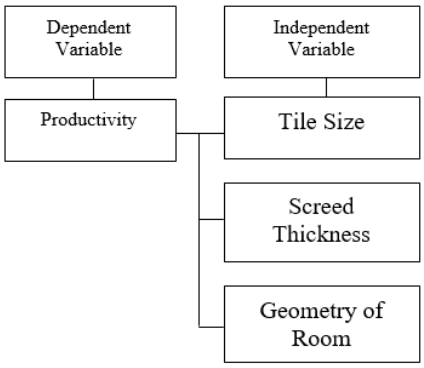

Fig. 1. Block diagram

The tile installation labour productivity data were collected at from 40 different construction sites located in the State of Maharashtra, Kolhapur.

Observations involved monitoring the overall activity within the trade, where the total productive labour inputs associated with completing the overall activity were recorded, therefore, a single labour productivity index, i.e., tiled area (m^2) per total productive labour input (man-hour, commonly abbreviated as mh), was achieved. The labour inputs collected at this level included both contributory time, i.e., time spent in cleaning and setting-out, preparing work areas, levelling, transporting and distributing tiles within the job site, and identifying element locations, and direct or effective time used to complete the activity, that is, preparation of base material, lifting, placing tiles, and securing ages in positions final checking and tamping.

The buildability factors explored included: the: tile size, quantity screed that is thickness of screed, and geometry of room. The variability of column sizes was expressed by the total number of different sizes encountered within the activity.

Regression analysis is a statistical technique that attempts to explore and model the relationship between two or more variables. Usually, the investigator seeks to ascertain the causal effect of one variable upon another. To explore such issues, the investigator assembles data on the underlying variables of interest and employs regression to estimate the quantitative effect of the causal variables upon the variable that they influence.

In this study the multiple categorical regression model formulated in the conceptual framework was used to show the relationship between the three independent variables of labour and the dependent factor. With the input from the secondary data, multiple regression analysis was conducted to reveal how independent factors impacted on labour productivity. That is regression analysis helped to understand how much the dependent variable changed, when one or more independent variables changed in the equation.

The smaller the p-value of the corresponding factor, the greater the extent of disagreement between the data and the null hypothesis, and the more significant the result is. In general, if the p-value of the regression coefficient is less than the significance level, i.e., p-value < 5%, the null hypothesis is

rejected in favor of the "alternate hypothesis (Ha)", that is, the regression coefficient of the corresponding buildability factor, i.e., the average rate of change of the factor in the model is significantly different from zero, and hence its effect on labour productivity is statistically significant (Sincich et al. 2002).

The quality of fit of the regression model, moreover, was assessed by the correlation and determination coefficients. The correlation coefficient (R) measures the strength of the linear correlation between the dependent and independent variables in the regression model, whereas the coefficient of determination (R2) indicates the percent of variance in the dependent variable, which can be explained by the independent variables of the model. The higher the coefficients of correlation and determination the better the quality of fit. The algebraic sign of the regression coefficient, on the other hand, denotes the direction of the corresponding buildability factor's effect on labour productivity, i.e., positive or negative.

5. Data Analysis

Flooring labour productivity parameters collected included the area (m^2) placed and its associated productive labour input (mh), for each installation method observed.

Flooring Labour Productivity:

$$\frac{Tiled\ Area\ (m^2)}{required\ time(mh)}$$

The screened data were entered into the spread sheet with which the regression analysis were conducted by using the PhStat software, a statistic add-in for Microsoft Excel.

Multiple categorical regression equation for the flooring activity.

Productivity= Size of tile + Screed Thickness + Geometry+ Error

Productivity=0.6654-0.0259(TS)+10.299(ST)

For shape factor 0

Productivity=0.6919-0.0259(TS)+10.299(ST)

For shape factor 1

TS-tile size and ST-screed Thickness and shape factor is assumed for the geometry of the room size While using the factor for rectangular 1 and for non-rectangular 0 factors is used.

A. Relationship between factors influencing labour productivity

Correlation and multiple regression analyses were conducted to examine the relationship between productivity and various potential predictors in labour.

Following is the regression model summary:

Table 1

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.93662138	0.8772	0.867031243	0.069550882

The multiple regression model with all three predictors produced R^2 = 0.08772, p<0.001. The research findings indicated that there was a strong positive relationship between the variables. The study also revealed that 89.24% of the labour productivity factors can be explained by the independent variables.

B. ANOVA test

Table 2

Model	Sum of squares(ss)	Degree of freedom(df)	Mean Square	F	Sigma
Regression	1.2446	3	0.4148	85.7	1.83614*E-16
Residual	0.1741	36	0.0048		
Total	1.4187	39			

6. Result and Discussion

The relationship between labour productivity and buildability factors was, therefore, quantified by regression model equation.

Productivity	=	0.6654- 0.0259(0.36) + 10.299(0.04) =1.068 For non- rectangular
Productivity	=	0.6919-0.0259(0.36)+10.299(0.04) =1.094 For rectangular

Average difference in productivity of the rectangular and non-rectangular room shape:

$$\frac{(1.094-1.068)}{1.094} * 100 = 2.4\%$$

In comparison with rectangular room shape installing tiles in non-rectangular is associated with an approximate average loss of 2.4% in labour productivity.

This investigation has determined the effects and relative influence of primary buildability factors affecting the vitrified tile installation labour productivity. Few published quantitative results exist, especially at this activity level, with which to compare the findings of this study, however, such data as exists have been examined and discussed.

O'Connor et al. (1987) and Alshawi and Underwood (1996) discussed the negative effect of the variability of element sizes on the complexity of the construction process. Nonetheless, their work was limited to general guidelines without any quantification of the impact of this factor on the productivity of the operation. The results obtained by this research show that, as the variability level of room sizes increases by one unit, labour productivity decreases, on average, by 2.4%.

The screed thickness has negative influence on labour productivity, whereas the area of tile has positive influence on the flooring labour productivity.

7. Conclusion

Because flooring is the small activity but it is repetitive and important activity involving skilled labours in every building related construction, improving labour productivity of this activity can help reducing the risk of labour costs overrun and increase the efficiency of operation. This study has focused on investigating and quantifying the influence of buildability factors on the flooring labour productivity.

The effects of variability of size of tile, thickness of screed and shape of room or geometry of room are determined and found to be significant on tile installation labour productivity.

As the size of tile increases time required for the installation will become less therefore productivity increases.

On the other hand, the thickness of screed affects the flooring labour productivity it depends on the weight of the tile which will lay on the screed, i.e. more the weight of tile more will be the thickness of screed. If Screed thickness is more, time required to work will be more and hence lesser the productivity.

As the geometry or shape of the room is non-rectangular time required for cutting and fitting the tiles is low as compared to rectangular room size therefore efficiency of installation operation significantly decreases.

The findings will substantiate the importance of applying the rationalization and standardization concept to the design stage of construction project. The effect of variability of the shape of room suggests that the designers should rationalize the shapes of room according to designer and architecture.

Practical recommendations are presented, which upon implementation can prove the buildability level of the activity and hence translate into higher labour productivity and lower labour costs.

The pattern of result may provide guidance to construction managers for effective activity planning and efficient labour utilization.

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