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Quantification of Mosaic Waste Generated in Housing Construction Sites via Site Sampling: Development of a Linear Regression Model

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Abstract: Construction waste generation is one of the challenging tasks that related to the materials used at site. Waste generation needs to be managed in a proper manner at all point. Accurate estimation is part of the major concern for proper future waste management strategy. Mosaic waste is also part of the waste generated in construction sites. This paper determines the mosaic waste generated in construction stages and conducts linear regression analysis for the amount of mosaic waste generated. The mosaic waste management practices is also revealed in this study. The methodology employed involves site observations, interviews with site personnel and the sampling of mosaic waste via the weighing method. The regression model established based on the sample data reported an R^2 value of 0.793; therefore, the model can predict approximately 79.3% of the factor (area) involved in mosaic waste generation. Specifically the prediction model is focusing on the relationship between the area of work and the amount of waste generated. The factors contribute to the mosaic waste sources is also identified. Moreover, the linear regressions can be applied as tools to predict the mosaic waste generated at construction sites and as a tools for the contractor to track the mosaic waste sources in the future.

Key words: mosaic causes · Observation · Analysis

INTRODUCTION

Decision-making has become increasingly based on quantified measurements or predictions expressed in numerical form. However, it is noted that as the complexity of the issues to be decided increases, less hard and reliable data is available. Construction waste is no exception. One critical factor is the need to accurately estimate waste generated from construction projects. So far, information on the amount and type of waste generated on construction sites has been few and fragmentary. If adequate decisions are to be made on how construction wastes should be managed on and off the construction site, how they should be used, recycled or deposited, hard data on the amount, type, time and place of their generation is essential. Recently, researchers have shown an increased interest in the wastes generation rates. However, most of the data related to construction waste is based mostly on assumptions. The collection of true data is important in order to be able to establish treatment solutions for construction waste that will be based on reliable data on the quantities of construction waste [1]. Decisions were often based on cursory observations, best guesses and simplified inferences by the construction site managers [2].

Until recently, little attention was given to methodically gathering the necessary information on mosaic waste generation at construction sites and their possible utilization. The various construction activities are usually itemized and taken into account using the quantification map and the price list of the project. But too often wastes are simply estimated at representing 5% of the construction materials for quantity surveying and pricing purposes. This is by no means the best approach, as without due quantification of the wastes on construction site the true amount and type remains unknown and consequently adequate management of the wastes is hindered [2]. Quantities are usually unknown and even when monitored the resulting waste is neither sorted at the source nor afterwards [3].

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Broken mosaic tiles are one of the waste materials largely available from new construction sites or from mosaic industries or from demolition of old structures. Disposal of such materials is difficult in view of the scarcity of suitable dumping grounds and meeting the increasingly critical environmental requirements, in metropolitan cities [4]. However, broken mosaic tiles obtained from new construction sites, as well as from demolition wastes can be used to produce useful aggregates, which in turn, can be used for making new concrete of acceptable quality.

The sources of finishing waste range widely from surplus cement mortar arising from screeding works over the building floors, broken raw materials such as mosaic tiles, ceramics, stone fragments, plastering materials and paint primer. The packaging materials of household appliances, such as gas cookers, bathtubs, washtubs and window frames, are also part of finishing wastes [5].

In the finishing work stage, brick and block laying, plastering, tiling, floor screeding and installation of sanitary ware and joinery work were the major areas of concern [6]. In this study, we develop a linear regression model for the amount of mosaic waste generated and also reveal the real implementation of mosaic waste management at the jobsites.

Methodology

Site Observation: The selected construction sites for study are located in Pulau Pinang, Malaysia. The type of housing examined is a two-story terrace house. The methods employed in this research are site observations, site sampling and personnel. Site observations involve monitoring activities at the construction site. The researcher visited the area during the performance of mosaic installation activities to review site operations.

The observation process began during the early stage of mosaic installation and ended with the completion of this task. The researcher also interviewed site to obtain information related to these activities. Data on the area, the number of skilled and unskilled workers and their years of experience were documented as well.

Weighing Method: According to Lau [7], the scattered (random and weigh) waste can be divided into two which is the waste such as broken bricks, cement bricks, roof tiles and cement bags. The second consists of waste with large variation in size, such as off cuts of steel sheet, plastic packaging and off cuts of gypsum or plaster board. Idealizing from his study, the weight method was applied to the mosaic waste. The equipment used for the weight method includes the following: a) buckets, b) a weighing scale and c) shovels. The weight was obtained in kilogram (kg). The weighing process was shown in Figures 1 and 2. The weighing procedures follow the procedures suggested by Mahayuddin and Zaharuddin [8]:

- Providing adequate bucket for collection of all types of construction waste. For this study the bucket size is 0.7 x 0.5 x 0.4 m.
- Recording the data in inventory format. The main data recorded is the amount of waste generated, the numbers of skilled and unskilled workers, the

The data were analyzed through linear regression to identify the relationship between the dependent variable *Y* (waste) and the independent variables, X (area). All analyses were conducted with IBMSPSS statistical software.

Fig. 1:

Fig. 2:

RESULTS AND DISCUSSIONS

Methods of Mosaic Waste Handling: Based on the observation, it was found that once the installation work was done, a worker would collect all the waste and would throw it out through the window of the building.

The wastage was usually thrown unsystematically, not at one particular or designated area for the waste. According to the site supervisor, this phenomenon was normal. At the end of each construction project, excavators would be used to clear the site. During this process, all construction waste would be put into lorries to be thrown to the nearest dumping area. In short, this was a common picture of how the waste management system was carried out at studied construction sites.

From the observation, there are no on site-sorting at sources for the purposes of waste management control and it was concluded that are no informal or formal orders from the management. Therefore, the experience grown up from Hong Kong e.g. using a refuse chute for on-site sorting [4], can be very useful reference for this practice in Malaysia. Establish a transit system to the disposal site and thus could be used as a transit area sales center materials used for construction materials. The implementation of this type of system will promote for construction waste sort, reused or recycled and motivate the workers to earn extra reward.

A more efficient system of waste management at a construction site should be implemented from the initial stage. Different types of containers should be provided at the construction site to put various construction waste. Lorries will only dispose one type of waste at one time, thus recycling process can be carried out. A transit system should be established so that recyclable construction materials from the waste can be collected and sell to those in need. In fact, these materials might be useful to those who are poor to build their dream houses.

Generation of Waste: Wall and floor finishes work needs skilled workers because it requires perfection which is a very critical element. Moreover, mosaic installation work is very sensitive and requires high skill/skillful workers. Skill level of tile worker may be influenced by many factors such as their age and working experience. If the mosaic is wrongly cut, it can no longer be used.This will add more cost to the work because mosaic is usually very expensive. Thus, the management of the construction site has to take the issue seriously and monitoring at the site

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 3,4,5,6: Disposal of Mosaic Waste at Construction Sites is very important to avoid waste of money over the activity.To avoid unnecessary waste in the future, the management can implement a few methods such as involving only the skilled workers for the work and estimate the minimum wastage which is allowed to be produced by each worker. If the waste exceeds the given limit, the estimated value of the waste will be deducted from their salary.

The causes of construction waste generated, depending on several factors such as false cutting etc. The main reason is the unskillful workers were used. The number of workers assigned for the mosaic installation of each toilet is only one and the preparation stage is done by the general workers. From the site observation, the workers assigned for the house number one was skill worker and the way how he arrange, cut and hold the mosaic, during the work was also different. Mosaic installation is very sensitive and requires high skill. In this case, the main problems occurred because of the different in sub-contractor where workers came from the other subcontractor but the material is bought by the main contractor itself. Those workers was provided by the subcontractor who responsible in supplying the workforce only. The separation of the subcontractor contributed to the waste generated at the jobsites.

Construction site management should take seriously on this issue and on-site monitoring is important in ensuring that there is minimum waste generated in all types of activities.

To reduce waste in the future, the management can implement variety of ways including ensuring the participation of skilled workers solely for this event and estimate the minimum of waste should be produced by the employee and, if exceeded, the implementation of pay cut method need to introduced.The implementation of relevant policies and regulations also helps to enhance the awareness and willingness of contractors to address waste management [9].

Development of Linear Regression Model: To investigate the correlation between waste and independent variables (area), a regression analysis was conducted based on the correlation coefficient value (R^2). The R^2 value of the developed model is 79.3%, thus implying that 79.3% of the variations in the amount of mosaic waste generated are explained by the regression model that covers this area.

According to Montgomery *et al*. [10], the model is subject to a multicollinearity problem if the VIF value is larger than 10. Therefore, the proposed mosaic waste prediction model is free from multicollinearity because the VIF value (1) is lower than 10.

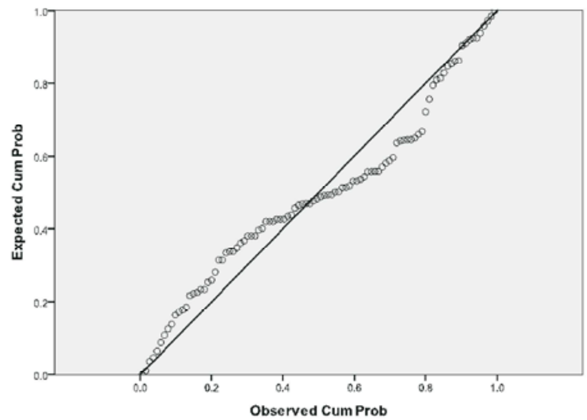

Fig. 7: Residual Plot

Table 1: Linear regression and performance indicator

Model	MW = 0.524 area +2.88
Normalized Absolute Error (NAE)	0.172
Index of Agreement (IA)	0.961
Prediction Accuracy (PA)	0.933
Coefficient of determination (R^2)	0.802

Linear regression analysis establishes several key assumptions, one of which is that the residuals are normally distributed with zero mean and constant variances. Residual analyses are important in determining the adequacy of statistical models. The criteria for normal distribution refer to the degree to which the plot of the actual values coincides with the line of expected values. The plot of the residuals shown in Figure 1 for this problem fits the expected pattern well enough to support the conclusion that these residuals are normally distributed with zero mean.

This residual plot exhibits a random scatter; as such, no obvious pattern can be observed in Figure 7. The assumption that the residual displays a constant variance is satisfied when the scatter plot exhibits an equal spread and approach to the regression line (homoscedacity). Moreover, the assumption that the residuals are uncorrelated with the independent variables is satisfied because the Durbin–Watson value (2.2) is close to 2. In summary, the analysis described above verifies that the developed model can be used to predict the mosaic wastes generated by housing construction projects.

Table 1 shows the performance indicators for mosaic waste, which were obtained from the linear regression models. The predicted values of the accuracy measures IA, PA and R^2 are 0.961, 0.933 and 0.802, respectively, for mosaic waste. Furthermore, the predicted average error value (NAE) is 0.172. The values of PA, IA and R^2 are close to 1; thus, the model is suitable for predicting mosaic waste generation. Furthermore, the NAE value is close to zero.

CONCLUSION

This study recommends the use of linear regressions to investigate the amount of mosaic waste generated from mosaic installation activities in housing construction sites. The analyses were only conducted from the construction stages. The projected amount may be utilized for future improvement in mosaic activities. The most common mosaic waste producers are the unskilled workers who had been assigned to do the skill work. Because educational work (to become the skill one) is a process, waste may come from many areas within this process. The site management is the person who responsible in controlling the amount of waste produces at sites.

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