

Modelling design information to evaluate pre-fabricated and pre-cast design solutions for reducing construction waste in high rise residential buildings

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Abstract

This paper describes how modeling information flows in the design process may be used to evaluate design solutions when seeking to reduce construction waste in high rise residential buildings. A survey of practicing designers identified a number of possible ways to reduce construction waste. The most advantageous solutions were based on pre-casting and pre-fabrication. Reviewing three of these solutions using information modeling techniques shows the changes in the design process required to accommodate the different design solutions. This method presents an effective basis for reviewing the impact of design decisions on the design process. To reduce construction waste demands an understanding of the impact of decisions on the level of waste produced, a full understanding of the implications throughout the ‘waste-chain’, consideration of the life-cycle impact, life-cycle costs and the impact of design decisions upon the overall construction process. Additional tools and techniques are required to fully meet the needs of designers.

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1. Introduction

The construction industry is a major material waste producing activity. The UK for example produces over 435 million tonnes of waste annually [1]. Of this, approximately 17%, equalling, 70 million tonnes, is generated by the construction and demolition industries. In Hong Kong, construction waste presents a similar environmental issue. The Hong Kong construction industry generates a huge quantity of

construction and demolition waste amounting to 37,690 tonnes per day (year 2000 figures). Of this waste some 80% is currently transported to public filling areas for reclamation, and the remaining 20% is disposed of in landfill and public filling areas [2]. The availability of landfill sites is reducing rapidly and landfill charging has recently been introduced to encourage industry to reduce the generation of waste material produced within the construction process.

The Construction for Excellence Report of the Construction Industry Review Committee [3], recommended that construction waste should be minimized at source, i.e. the reduction of construction waste should be considered throughout the design process. Our research explores the needs of designers if this is to be achieved. The focus of the research is the construction of high-rise residential buildings. These types of buildings were considered because of their major importance to the housing of people in cities such as Hong Kong. These building types are characterized by their standardized building design based on a

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concrete structure. The floor layout is repetitive and the building details and services provision to a New Harmony Building are standardized. Building plans, sections and elevations are similarly standardized wherever appropriate to minimize design requirements [4].

Previous research has shown the main causes of physical waste in such buildings are ‘improper preparation and handling, misuse of materials and incorrect processing of materials’. [5] This paper describes research which extends previous work by analysing the design process when evaluating different design options aimed at reducing waste. These options, (pre-cast and pre-fabricated design), selected for study were identified as the priority areas for waste reduction by interviews with practicing designers and confirmed by a wider survey of both architects and contractors.

To assess the impact of different design decisions an information modelling approach was adopted in order that these decisions, either individually or in combination, could be considered from the perspective of the necessary changes within the design process to ensure both the optimisation of the design process and the timely production and issue of design information could be achieved. (The issue of incorrect or late information is a common cause of remedial work at the construction stage.) It is concluded that modeling designers’ information requirements may assist design teams examine opportunities to reduce construction waste but that additional new tools and techniques are needed to make this more effective.

2. Methodology

The current design and construction process for high-rise residential buildings was reviewed by literature review and case study. Previous research was studied to identify the causes and solutions to the problem of construction waste. The potential for reducing construction waste in high rise residential buildings was considered by discussing potential opportunities for waste reduction with experienced construction professionals. The effectiveness of different solutions was considered together with the difficulty of implementing such solutions and their cost effectiveness. The findings of the interviews were endorsed by a survey of architects and contractors. This enabled the priority areas for review if construction waste is to be reduced to be identified.

The Analytical Design Planning Technique, (ADePT), [6] was used to model and analyse the information requirements of designers. The ADePT technique models the information requirements of the design team by developing an IDEF model of the information needs for each design task and then analyzing this model using the Design Structure Matrix Technique, (DSM), to optimize the order of the design tasks [7]. The use of the DSM technique for such evaluation is recognized by practitioners in other industries and other researchers [8,9].

ADePT utilizes a generic building design model as a basis of the information modeling method. In our research this generic model was amended to incorporate the information requirements for a typical high rise residential building. The type of building, known as the New Harmony, was selected because of

its common use by the Hong Kong Housing Association. The model that was produced, (the base model), was validated by review by experienced design professionals and by direct comparison with design and construction of an actual building.

From this base model the information requirements and the order of design tasks when considering different design solutions for reducing construction waste could be assessed [10,11]. The DSM approach was used to optimize the design process and assess the impact of changes in both design and construction processes. The use of the technique was then evaluated and other potential issues relating to the reduction of construction waste in high-rise residential building construction and other types of buildings were considered.

3. Construction waste in high rise residential buildings

Skoyles [12], classifies construction material waste as natural waste, (unavoidable waste allowed for in the tender), indirect waste, (material used for purposes other than that for which it was ordered), and direct waste, (material which is encountered for and may be measured). The research undertaken by the writers and described in this paper concerns the reduction of physical construction waste that arises from both permanent and temporary materials that form the main materials of construction. (These do not include demolition materials and toxic materials) The problem of direct and indirect construction waste has attracted increasing attention from many researchers. Several studies have looked at waste minimization through preventing and/or reducing the generation of waste at source, and encouraging the re-use, recycling and recovery of waste material. (see for example Ferguson et al. [13]; Guthrie et al. [14]).

Poon et al. [2,5,15] have reviewed the levels and causes of construction waste, together with the opportunities to reduce and minimize construction waste in residential buildings. Table 1 adapted from [2] shows typical percentage waste figures for various trades on high-rise public residential housing projects in Hong Kong. (Similar figures for high-rise private residential housing projects indicate higher levels of waste.) ‘Opportunities to reduce and minimize construction waste arise from construction method selection, material selections and the design process’. [5] The most effective way to minimize construction waste is by changes in the design approach. “Design decisions and approaches can significantly affect waste minimization during construction as well as the re-use and recycling of construction materials.” [15]

To identify the design decisions most appropriate for the reduction of waste in high rise residential buildings the views of practitioners were sought. Initial interviews with a small group of design professionals indicated that, unless it was a specific client requirement, little or no consideration is given to the issue of construction waste in the design process. All the participants agreed that the control of construction waste should be implemented in both the design and construction stages. Barriers to this included lack of client interest and lack of initiative amongst the construction team. The potential solutions for reducing construction waste identified from the interviews included: balanced cut and fill in excavation; modular design

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