WASTE MANAGEMENT PRACTICES IN THE SMALL-SCALE CONSTRUCTION INDUSTRY

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SUMMARY: The environmental impacts of the construction industry can be reduced through sustainable waste management (SWM). A substantial proportion of the responsibility for improving waste management practices in the construction industry falls on small-scale construction (SSC) firms operating on projects valued under £300,000. Through on-site waste audits and a postal questionnaire survey of SSC firms, we investigated key factors that affect waste generation on SSC sites. The study found a deep-rooted wasteful culture within the SSC industry. Soil and stones, wood and plastic were the major components of the waste stream. It is perceived that a considerable proportion of waste generated is unavoidable because of current working practices. SWM activities were undertaken infrequently by the majority of respondents, with the main reason being a commonly-held perception that SWM is not cost-effective. Considerable scope exists for improving waste management practices on SSC sites, with the most promising measures identified as being the introduction of stock control measures and the use of skips for segregation of specific materials.

1. INTRODUCTION

The construction industry generates vast amounts of waste. In the UK, ~90 million tonnes of waste is generated by the industry annually, making up 33% of the total waste stream (Defra, 2009). While a proportion of this waste is recycled, the majority ends up in landfill. In addition, the construction industry is a leading consumer of resources, with around 380 million tonnes of materials consumed by the industry each year in the UK alone (Hobbs, 2008). This level of resource consumption and material wastage needs to be addressed as populations grow, environmental legislation and competition becomes tougher and as supplies of natural resources deplete further.

In recognition of these problems, the UK government set a target of reducing construction waste disposed in landfill by 50% (Defra, 2007). To help achieve this, the Site Waste Management Plans Regulations 2008 were passed, making it a legal requirement for all construction projects worth over £300,000 to produce a Site Waste Management Plan (SWMP). SWMPs are intended to assist

contractors in improving their on-site waste management so as to reduce the level of waste they produce. Any construction project estimated to cost under £300,000 is exempt from this legislation. These small-scale construction (SSC) projects are generally run by small, project-based firms employing 1-59 employees; 99% of the UK construction industry is composed of such organisations and in 2007 they carried out 43% of the entire work done by the sector (ONS, 2008). Thus, a substantial proportion of the responsibility for improving waste management practices in the construction industry falls on SSC firms.

1.1 Sustainable waste management

The SWMP Regulations 2008 are part of a broader UK government initiative which promotes the concept of sustainable waste management (SWM) within the construction industry. SWM encourages waste minimisation – the reduction, re-use or recycling of waste – and promotes the more efficient use of materials and broader incorporation of recycled materials into building construction. As much as 80% of UK construction and demolition waste is re-usable or recyclable (Ferguson et al., 1995), although only 52% of such materials are currently recycled (Defra, 2009).

SWM offers several benefits for the SSC industry: firstly, it reduces the environmental impact(s) of the construction process through reducing dependence on raw resources and reducing pollution associated with the production of materials, transportation and landfill (Tam and Tam, 2006); secondly, it has been shown to incur substantial financial savings for construction firms (Begum et al., 2006; McDonald and Smithers, 1998); and thirdly, SWM creates new opportunities for employment in secondary materials markets (Kofoworola and Gheewala, 2009). Despite recognition of such benefits, there has been little research into which SWM initiatives may be most effective and easily implemented within the SSC industry.

1.2 Construction waste composition

In order to identify effective SWM methods to reduce wastage on construction sites, it is necessary to identify the chief components of the SSC waste stream (Gavilan and Beronold, 1994). A substantial body of literature has attempted to quantify the composition of the waste stream on large construction sites (Bossink and Brouwers, 1996; McDonald and Smithers, 1998; Poon et al., 2004). However, there remains an unmet need for research into the composition of the SSC waste stream so that effective SWM solutions can be identified.

1.3 The role of human attitudes in waste generation

A number of studies have investigated the role of human behaviour in waste generation. The earliest studies were conducted in Australia by Lingard et al. (2000) and Teo and Loosemore (2001) and more recently, studies have been carried in the UK (Dainty and Brooke, 2004; Saunders and Wynn, 2004). The outcome of this research effort is recognition that, whilst construction industry participants recognise the impact(s) of their actions, there is reluctance within the industry to implement waste minimisation initiatives. Furthermore, despite recognition that human attitudes have major influence on waste generation (Teo and Loosemore, 2001), there has been little research into the role of human attitudes in waste generation on SSC projects, despite these comprising 99% of all work undertaken in the construction sector.

1.4 Research aims

This study, which supports the activities of the ZeroWIN project (see www.zerowin.eu), aimed to: (1) investigate the factors which affect the generation of waste on SSC sites; and (2) identify effective and practical SWM solutions for implementation within SSC projects.

2. METHODS AND MATERIALS

2.1 On-site waste audits

Snapshot waste audits were conducted on SSC sites in Cambridgeshire in 2009. Two sites were managed by a large, regional construction firm employing >50 full-time staff and operating on small to medium sized construction projects, whilst the third site was managed by a small, local construction firm with only 3 full-time employees. The audit methodology was based on the "visual characterisation method" (Kelly and Hanahoe, 2007) as it is quick and requires minimal direct contact with the waste materials. All waste materials deposited in on-site waste skips were audited.

2.2 Postal questionnaire survey

A postal questionnaire survey of SSC firms based in the counties of Dorset, Hampshire and Essex and registered with the Federation of Master Builders (FMB) – the largest independent trade association of small and medium-sized building firms in the UK – was conducted in early 2010. A total of 200 firms were randomly selected from an FMB membership list in order to ensure that it would be distributed among professional private building firms operating in the SSC sector.

The questionnaire contained 21 closed questions divided into 6 sections. To determine the relative ranking of factors, the mean values of respondents' answers were transformed to importance indices based on Equation 1 (Tam *et al*., 2000):

$$\mathrm{RII} = \frac{\Sigma w}{AN} \qquad (1)$$

Where w is the weighting given to each factor by the respondent. Ranges went from 0-3, 0-4, or 1-5 depending on the question, in which '0 or 1' (lowest weight) is the least important and '3, 4 or 5' (highest weight) the most important; A is the highest weight, in this study A = 3, 4 or 5 depending on the question; N = total number of samples; RII = relative importance index, ranging from 0 to 1.

3. RESULTS AND DISCUSSION

3.1 Waste composition on SCC sites

The composition of the average SSC waste stream (by volume) from the 3 on-site audits is displayed in Figure 1. "Plasterboard" comprised the largest fraction of the SSC waste stream (24%), with bricks and blocks (17%) and wood (13%) also contributing substantially. It was felt that these audits did not represent a particularly reliable means of quantifying on-site waste arisings because of the inaccuracy of the "visual characterisation method" and a practical inability to audit anything other than the uppermost layer of a waste skip. Therefore, as an alternative approach, a question relating

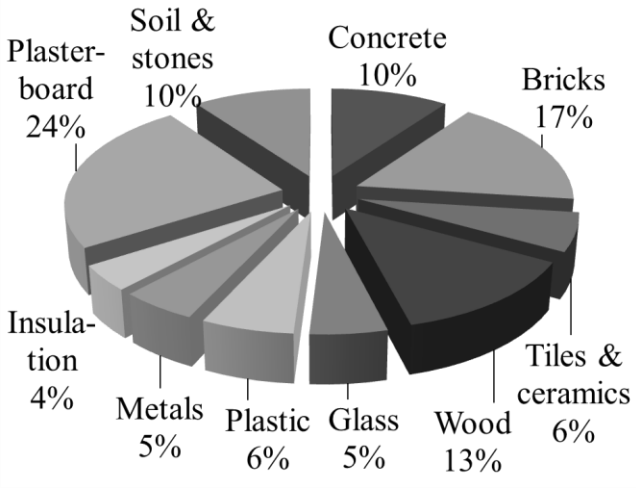

Figure 1. Composition of the average waste stream (by vol.) (via on-site audits; 2009).

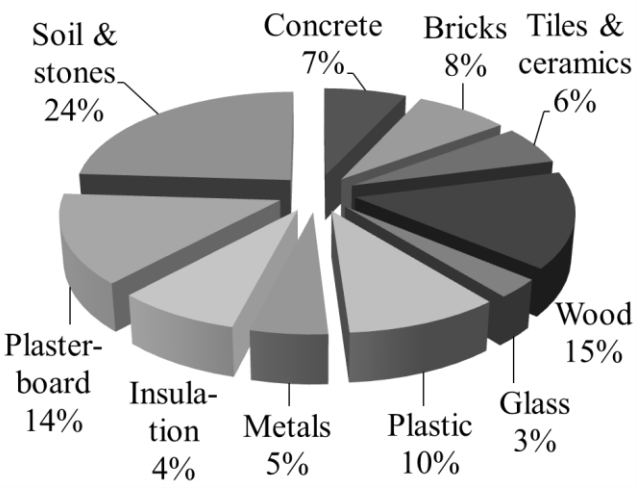

Figure 2. Composition of the average SSC waste stream (by vol.) (via survey; 2010).

to SSC waste stream composition was incorporated into the questionnaire survey.

A total of 38 questionnaires were returned; a response rate of 19%. Figure 2 displays the composition of the average SSC waste stream (by volume) from the survey. "Soil and stones" comprised the largest proportion of the reported waste stream (24%); most is apparently generated through excavation during the site preparation/demolition and foundational phases. There is considerable potential to re-use soil/stone waste on SSC sites, for example, Begum et al. (2006) showed that a substantial proportion of excavated soil/stone waste can be re-used after piling.

Wood was reported as contributing 15% of all waste. Most wood waste is generated during the structural phase (McDonald and Smithers, 1998), where standard sized timber is cut to fit the project design. There is little opportunity to minimise wood wastage on SSC sites due to the non-standardised building designs used and the unavoidable nature of waste from cutting. However, there is considerable potential for recycling timber waste, although to maximise this potential, on-site segregation of waste wood materials would be necessary. The other significant components of the waste stream reported were plasterboard, plastic, bricks and blocks and insulation material.

The results of the questionnaire survey compare moderately well with those of the on-site audits. Seven of the ten waste materials measured through the survey are within 4% variance of the respective audit data (see Figures 1 and 2). There are, however, notable differences for several materials; soil and stones, plasterboard and bricks. The greatest variance (14%) was recorded for "soil and stones" which, while comprising the largest fraction according to the survey, ranked significantly lower in the audit results (10%, ranking = 4). According to the survey, "plasterboard" totalled 14% of the waste stream, however it represented the largest fraction according to the audits (24%); a variance of 10%. These differences may be indicative of the incomplete nature of the audit data – only a few snapshot audits were conducted during the early- to mid-stages of SSC projects. Further research is needed to develop an accurate, practical audit methodology.

3.2 Causes of waste on small-scale construction sites

The major causes of waste reported on SSC sites are shown in Table 1. By using the relative importance index (RII), it was found that waste from packaging (RII = 0.770) was considered to be

Table 1. Major causes of waste reported on SSC sites (n=38) in 2010.

	$\sum w$	*Relative importance index*	*Ranking*
Waste from packaging	117	0.770	1
Leftover materials/off-cuts	106	0.697	2
Poor storage of materials	97	0.638	3
Design/detailing errors	81	0.533	4
Design changes	78	0.513	5
Handling of materials	75	0.493	6
Theft	67	0.441	7

the most important cause of waste on SSC sites. For most materials packaging is necessary, and its waste is therefore seen as unavoidable. A more concerted effort is required by material producers to ensure that mechanisms are in place to allow project managers to recycle their packaging waste.

The second most important cause of waste was found to be leftover materials/off-cuts (RII = 0.697). The quantity of leftover materials/off-cuts generated is particularly high on SSC sites because of the non-standardised building designs generally used in SSC. Recycling of these leftover materials represents the most promising SWM option.

3.3 Current waste management practices

The frequency of SWM practices undertaken by SSC companies is shown in Figure 3. A significant positive correlation between undertaking SWM practices and perceived effectiveness of waste management practices has been identified (Spearman r, $_{rho}$ = 0.475, P = 0.003), implying that respondents recognised SWM as being an effective waste management solution. However, aside from taking steps to avoid soil contamination - 57% of respondents reportedly always undertake this practice - the majority of SSC companies do not frequently undertake SWM practices.

Material re-use on- and off-site was reported on all projects by just 16% and 14% of respondents' companies, respectively (Figure 3). Sending waste to a recycling facility was a more frequently undertaken SWM practice, with 32% of respondents' companies reporting this activity on all projects. However, given that on-site waste segregation was apparently "always" carried out by just 19% of companies, waste must generally be sent to recycling facilities as an un-sorted, heterogeneous mix. This makes it difficult to recover any recyclable materials, and significantly limits the recycling potential of the waste stream (Tam and Tam, 2006). Considerable scope exists for improving waste management practices on SSC sites.

3.4 Potential sustainable waste management solutions

The introduction of stock control measures was identified as having the greatest potential for minimising waste on SSC sites (RII = 0.656). Such measures are intended to avoid over-ordering of materials, and ensure that all materials are available when required. Although the potential impact (in terms of reducing wastage) was considered less than other measures (RII = 0.629, ranking = 5),

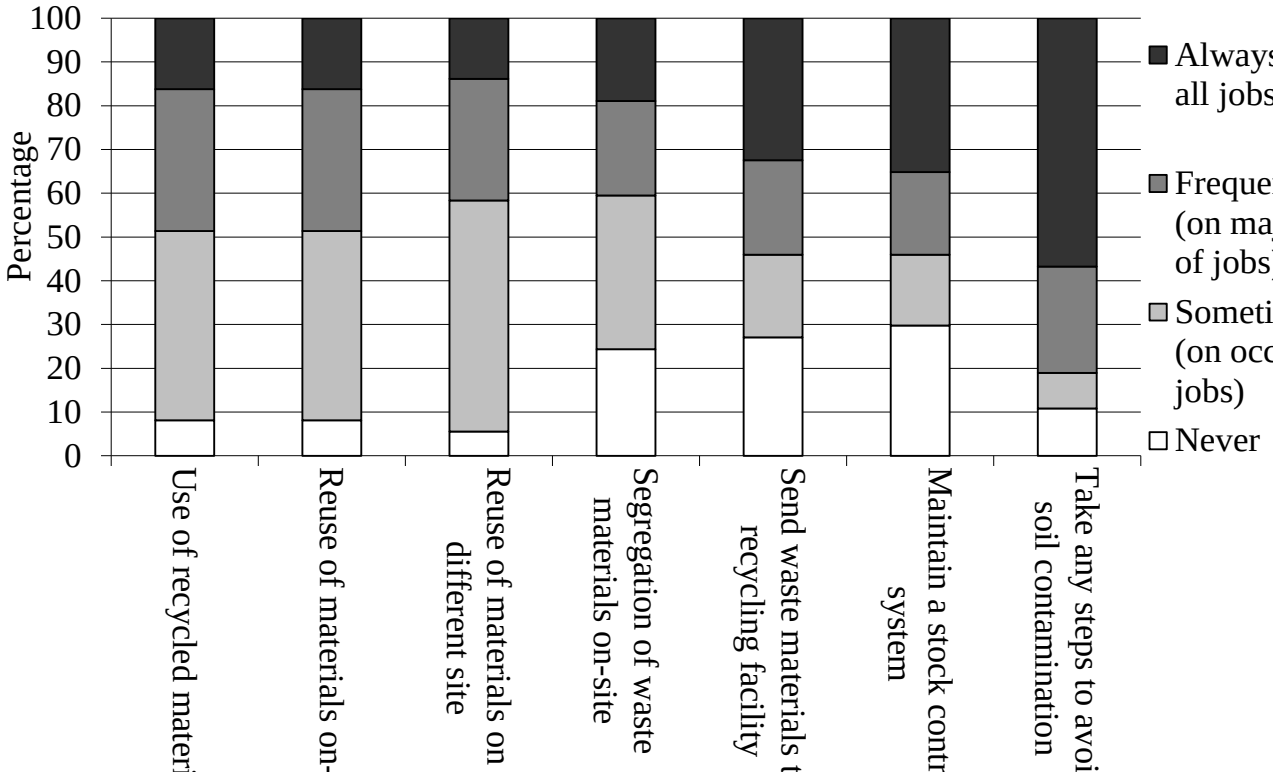

Figure 3. Frequency of SWM practices reported by SSC companies in 2010.

stock control measures seem to be relatively easy to implement (RII = 0.684, ranking = 1), making them a realistic and feasible SWM solution for the SSC industry.

The second and third most promising SWM practices were identified as being the use of skips for segregation of specific materials (RII = 0.650) and on-site sorting of wastes (RII = 0.651), respectively. This implies that SSC industry participants could be willing to segregate waste materials on-site and dispose of different waste components in separate containers so as to ensure more sustainable practice. However, respondents also indicated that this approach would be difficult to implement (RII = 0.579, ranking = 7), most likely because SSC sites lack the space required for several waste skips. One solution could be to provide bulk bags rather than skips, thus ensuring SWM practice without infringing on on-site space (Fox and Hilton, 2008).

3.5 Barriers to sustainable waste management

The study's results suggest that a great many difficulties exist in implementing SWM in the SSC industry. The greatest barrier to SWM is the perceived low financial incentive for such practices (RII = 0.779). This, coupled with the fourth ranked barrier – perceived increase in overhead costs (RII = 0.705) – indicates that there is a self-professed belief within the SSC industry that the implementation of SWM will cause financial losses. In fact, it has been shown on large construction sites that SWM can be a cost-saving practice (McDonald and Smithers, 1998). This false perception within the SSC industry must be addressed if SWM is to be more routinely practiced.

The study has highlighted the presence of a deep-rooted wasteful culture within the SSC industry (RII = 0.742) and that this level of wastage as is generally regarded as unavoidable. As it has been

shown that the attitudes of the workforce have a significant influence on behaviour, and consequently, on waste generation on-site (Begum et al., 2009; Teo and Loosemore, 2001), these findings indicate that wastage on SSC sites may decline if a cultural change programme could be implemented e.g. site workers' negative attitudes could be addressed via an education campaign.

4. CONCLUSIONS

Through a small number of on-site waste audits using a visual characterisation method and a postal survey of professionally-affiliated SSC firms, this study sought to investigate the factors which affect the generation of waste on SSC sites. It was found that soil and stones, wood and plastic are the major components of the SSC waste stream. The majority of on-site waste is caused by packaging and leftover materials/off-cuts. It is perceived that a considerable proportion of waste generated from these causes is unavoidable because of current working practices; whilst reducing this wastage might prove difficult, there is clearly a substantial opportunity to re-use or recycle much of the waste generated on SSC sites.

The study also attempted to identify effective and practical SWM solutions for implementation within the SSC industry. The most promising SWM measures were identified as being the introduction of stock control measures, the use of skips for segregation of specific materials and on-site sorting of wastes. Despite broad recognition that SWM could be beneficial within the SSC industry, respondents highlighted several barriers to the implementation of such practices. The most prominent of these barriers was a perceived financial burden, despite evidence from the literature suggesting that the implementation of SWM can be financially beneficial to construction firms (McDonald and Smithers, 1998). Respondents also identified the presence of a deep-rooted wasteful culture within SSC as being a major barrier to SWM; these could be addressed by educating the SSC workforce in the benefits of SWM and the provision of inspiring case studies as exemplars.

There is considerable potential within the industry to improve waste management practices. However, the widespread perception within the industry that SWM is expensive is preventing this potential from being realised. These barriers can be overcome through programmes and case studies that demonstrate how SWM can be cost-effective and targeted education campaigns.

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