Potential for construction waste minimisation through design

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Abstract

Recent figures published by the UK Government reveal that construction and demolition waste in the UK is around 90 million tonnes per annum, including an estimated 13 million tonnes of unused material. Furthermore, the introduction of new *legislation*, the emergence of new technologies and practices in both waste disposal and recovery, and the rising tide of public awareness are all conspiring to change the face of waste management. The opportunities and responsibilities to minimise construction waste rest with clients, contractors, suppliers and designers (architects/engineers). The aim of this paper is to investigate the feasibility of construction waste reduction through design. The paper evaluates current government policies and waste practices in the UK construction industry; and identifies problems for the implementation of effective waste minimisation during the architectural design stage of building projects. The objective of the paper is to develop a framework for a doctoral study entitled 'Construction Waste Minimisation by Design' which is investigating the role of architects in reducing construction waste. The paper covers: waste management and minimisation policies; strategies and industry practice construction for waste management and reduction; waste production; and current methods of monitoring; and designing out onsite wastage. The paper concludes that current waste-reduction processes mainly concentrate on the physical minimisation of construction waste and identification of site waste streams, i.e. the when onsite waste has already been produced. It recommends the adoption of a proactive approach to waste minimisation, as legislative and fiscal measures are likely to increase. The content should be of interest to building designers who have a decisive role in helping to reduce waste at all stages.
Keywords: UK, waste management, waste minimisation, legislation, design waste, building design.

1 Introduction

Emerging sustainable building practices offer an opportunity to create environmentally-sound and resource-efficient buildings by using an environmental approach to design. Achieving sustainable *building design* is closely linked to the way the construction industry deals with its waste. A study by the World Resource Institute of material flows in a number of industrialised countries, showed that a half to three quarters of the annual material consumed was returned to the environment as waste within one year (Hutter [1]). Minimisation of construction waste can occur at various levels along the supply chain, the opportunities and responsibilities to minimise construction waste lie with clients, designers, contractors and suppliers. Reducing physical waste could be achieved by redirecting the focus to the design stage of projects so that there will be no onsite waste to manage. The aim of the paper is to examine the potential for construction waste reduction through design. It reviews: *UK* Government waste policies and *legislation*; current terminology; classifications of types and origins of waste; and approaches to address waste reduction by design.

2 Definitions of construction waste

There is no generally accepted definition of construction waste. One common definition of construction waste, as issued by the European Council Directive 91/156/EEC , is "any substance or object which the holder discards or intends or is required to discard" (Directive 91/156/EEC [2], Article 1, Letter a). This definition applies to all waste irrespective of whether or not it is destined for disposal or recovery operations. However, Skoyles and Skoyles [3] defined *construction waste* as a material "which needed to be transported elsewhere from the construction site or used on the site itself other than the intended specific purpose of the project due to damage, excess or non-use or which cannot be used due to non-compliance with the specifications, or which is a by-product of the construction process". Similarly, the adopted definition of *construction waste minimisation* for this research is "the reduction of waste at source, by understanding and changing processes to reduce and prevent waste" (Environmental Agency [4]).

3 Waste management policies

In 1996, the *UK* Government produced a strategy 'Making Waste Work', having for objective the reduction of controlled waste going to landfill by 60 per cent (DETR [5]). Controlled waste is the most hazardous category of waste such as materials and components that exhibit toxicity. It includes waste arising from works of demolition, construction and preparatory work. In its consultation paper on 'Less Waste More Value', the Government considered how goals for *waste minimisation* might be set out and how these long-term ambitions might be translated into medium term targets (DETR [6]). This was followed by the

Government publication of a consultation paper, 'A Way with Waste', which proposed changing public and industrial attitudes to waste, and product design for re-use and re-cycling (including the requirement that manufacturers take back used goods) and better markets for recycled materials (DETR [7]). In response to the demands of the Landfill Directive [8], and other European directives on waste, the *UK* Government launched the Waste Strategy 2000 report (DETR [9]). The Strategy reflects the Government's belief that the amount of commercial and industrial waste sent to landfill sites can be cut by increasing landfill taxes and introducing new regulatory controls that challenge not only the way waste is disposed of but also its production. Waste Strategy 2000 sets out a target to reduce by 2005 the amount of industrial and commercial waste sent to landfill to 85 per cent of land filled in 1998 (DETR [9]). In examining performance against the waste targets set out in the Strategy, a report by the Environmental Audit Committee's highlighted the fact that "no target has been set for waste minimisation. The resources available…have been largely directed at recycling projects rather than waste minimisation efforts" (The Environmental Audit Committee [10], Paragraph 28).

As the Government is committed to *waste minimisation*, the construction industry should anticipate the impact of new and increasingly stringent regulations and by doing so it should adopt a proactive approach towards *waste minimisation*. In addition to environmental and financial benefits, the voluntary initiative should allow it to plan ahead and put in place a coherent and integrated waste reduction strategy.

4 Waste legislation

Most legal frameworks on *waste management* in the *UK* derive from European Union directives. Directive 75/442/EEC, also known as the Waste Framework Directive, provides the overall structure for an effective *waste management* regime within the EU. Over the past decade, the *UK* Government introduced new acts and policies to tighten the control on waste generation and disposal. The key acts that have brought about changes in the *UK* construction waste disposal practices during the last few years are summarised below.

- Waste Minimisation Act 1998 enabled local authorities to make arrangements to minimise the generation of waste in their area by working with local businesses, without placing any obligation on them to carry out such initiatives.
- The Climate Change Levy aim is to encourage the non-domestic sectors (i.e. industry, commerce and the public sector) to improve energy efficiency and reduce emissions of greenhouse gases.
- Aggregates Levy has been set at £1.60 per tonne of aggregates produced. This Levy should force the construction industry to look closely at its sources of raw materials and seriously consider reducing its consumption of virgin raw materials by using recycled materials and waste products.

- The Landfill Tax increased the standard rate of landfill tax from £14 to £15 per tonne. The standard rate of landfill tax will subsequently be increased by £3 per tonne per annum starting in 2005, up to a medium- to long-term rate of £35 per tonne.

The *waste management legislation*, particularly the Landfill Tax should act as disincentive to waste production. However, as yet this does not appear to have seriously reduced the amount of waste production, the Government is likely to introduce other fiscal measures and *legislation* in the future, which will push the construction industry towards a closed loop production system.

5 Types of construction waste

It is estimated that it is as much as 30 per cent of the total weight of building materials delivered to a building site (Fishbein [11]). The disposal of construction waste accounts for more than 50 per cent of overall landfill volumes in the *UK* (Ferguson et al. [12]). In terms of weight, brick masonry and concrete present by far the largest potential for recycling in the building sector (Emmanuel [13]). This has been supported by the findings of comprehensive research conducted across USA, *UK*, China, Brazil, Korea and Hong Kong, which compared the types and volumes of construction waste in these countries (Chen et al. [14]). The types and composition of onsite wastes are highly variable, depending on the construction techniques used. For example, "there will be very little waste concrete and timber forms for disposal if pre-cast concrete elements are adopted" (Poon et al. [15]). However, Guthrie and Mallett [16] split construction and demolition waste into three categories, materials which are: potentially valuable in construction and easily reused/recycled, including concrete, stone masonry, bricks, tiles/pipes, asphalt and soil; not capable of being directly recycled but may be recycled elsewhere, including timber, glass, paper, plastic, oils and metal; and not easily recycled or present particular disposal issues, including chemicals (i.e. paint, solvents), asbestos, plaster, water and aqueous solutions. Coventry et al. [17] went further by identifying seven different types of waste: bricks, blocks and mortar (33%); timber (27%); packaging (18%), dry lining (10%); metals (3%); special waste (1%); and other waste 10%. McGrath [18] used a case study approach to audit types of building materials wasted on three different types of construction projects: social housing; leisure development; and a restaurant. The results demonstrated that the most significant waste stream in all three case studies was inert material comprising soil removed during the construction and the clean up of the site. Packaging, that includes all plastic wrappings, plastic bubble wrap and cardboard, was another major contributor to waste generation.

6 Origins of construction waste

There are a variety of different approaches to the classifications of the main origins of construction waste. For example, Bossink and Brouwers [19] classified sources of construction waste according to the nature and technology

of using materials into building products such as concrete, bricks and wood. Whereas Craven et al. [20] grouped construction waste sources into design; materials procurement; materials handling; operations; residual or leftover scraps. A similar approach was taken by Ekanayake and Ofori [21] who categorised construction waste according to design, operational, material handling and procurement sources. The authors revealed that a substantial amount of construction waste is closely related to design errors. They ranked design changes, while construction works are in progress and the lack of information on the drawings, as the most significant contributors to waste generation. They also identified other design related waste causes i.e., complexity of detailing, selection of low quality materials and lack of familiarity of alternative products. They ranked the highest 'operational' waste contributors as damages to subsequent works, errors by tradesmen and improper planning, while inappropriate storage facilities at site and loose forms of material supply to the site were the major waste generation actors due to 'material handling'. 'Procurement' wastage was mainly related to over-ordering of building materials. Waste can also occur during the design stage due to errors in contract clauses or incomplete contract documents (Craven et al. [20]; Bossink and Brouwers [19]). Furthermore, Nguyen et al. [22] classified the sources of construction waste into two phases: pre-construction and construction. During the pre-construction phase, waste occurs during: planning and designing (e.g. lack of coordination with standardisation of materials and extra materials ordering, estimating); and purchasing (e.g. over allowance and materials' variable dimensions; and finally manufacturers and suppliers (e.g. goods are damaged during delivery and loading). They cited a number of sources leading to generation of waste during the construction phase: operational waste due to the nature of the construction process (e.g. time pressure, poor craftsmanship, lack of supervision and poor work ethics); access to site for delivery vehicles, methods of loading and off-loading are all causes of waste related to transportation and delivery; and storage where waste is generated by poor site management failing to provide adequate protection for materials.

According to Baldwin et al. [23] waste is generated during the design process for a number of reasons: 'building complexity', through the emergence of a variety of design specialities and responsibilities within the same project leading to design changes; 'co-ordination' and 'communications' problems due to the multi-disciplinary nature of design projects where the information that passes to contractors is highly variable and open to misinterpretation contributing inevitably to waste generation. Therefore, there is a need to: understand the underlying causes of *design waste*; change processes and practices; and adopt a holistic approach to *building design*.

7 Designing out construction waste

Coventry and Guthrie [24] defined *design waste* as "the waste arising from construction sites both by acts and by omissions on the part of the designer, including opportunities to reduce waste lost by not using reclaimed materials".

Adopting an integrated design philosophy should reduce the amount of raw material used and therefore the amount of wasted resources discarded.

7.1 Addressing waste minimisation through design

The extant of literature reveals various approaches, guidelines and strategies to reduce design-generated waste. These broadly cover four major axes of the design process to include: contract language; design issues and construction techniques; building materials specification; and education.

7.1.1 Contract language

CRiBE [25] highlighted that contract and contractual agreement stages play important roles in reducing waste through incorporating *waste minimisation* activities by means of the use of specifically-oriented contract tender clauses. Dainty and Brooke [26] and GMV [27] suggested using contractual clauses to penalise poor waste performance. Greenwood [28] went further to call for a fully integrated *waste minimisation* system at the contractual stage that "should identify and communicate the responsibilities for *waste minimisation* between all project stakeholders".

7.1.2 Design issues and construction techniques

There is a general consensus in the literature that design variations and changes can lead to considerable amounts of design-generated waste. Coventry et al. [17] pointed out that variations frequently change the type or quantity of the building materials required. Dainty and Brooke [26] identified standardisation of design as a construction method to improve buildability and reduce the quantity of off-cuts. Gibb [29] argued that standardisation and prefabrication of both building layouts and components result in less waste. Design for deconstruction, is seen by several authors to be an efficient way to reduce waste (Greenwood [28]; and Skoyles and Skoyles [3]).

7.1.3 Building material specification

Waste can be reduced in a number of ways by specifying the use of efficient framing techniques, standard size supplies, prefabricated materials and the incorporation of green building materials into the design. Designs that require more material than necessary, through over-specification of the material quantities, facilitate generation of waste (Greenwood [28] and Nguyen et al. [22]). Coventry and Guthrie [24] recognised the role of design to reduce surplus excavation materials, which form one of the most important waste streams of a construction project.

7.1.4 Education

The *building designe*r needs to have a voluntary approach towards *waste minimisation* promotion and education, in particular bringing the associated financial benefits to the attention of the client. The flow of information and dissemination of best practice to reduce *design waste* will require investment and publicity in technology and education to reshape societal attitudes to waste

disposal. This will involve partnerships between national government, local authorities, industry, the media and community organisations.

8 Discussion

Waste minimisation can be viewed as a threat requiring ever-increasing expenditure on end-of-pipe technologies to meet ever-increasing *legislation*, or as an opportunity to cut costs and improve performance. The choice should be obvious, but there is a need for a culture change. This requires re-engineering current practice to contribute to a cleaner environment through efficient and cost effective sustainable *waste minimisation* strategies. However, for *waste minimisation* to be effective and self-sustaining, it is important that all stakeholders along the construction supply chain adopt a more proactive approach in dealing with waste, i.e. designing out waste. In recognition of the responsibility of the architectural profession, through its leading role in project management and a key player in the construction industry, architects should move beyond the concept of 'Eco-efficiency' through bolt-on environmental strategies and strive to adopt 'Eco-effective' practices by implementing a holistic approach to design.

9 Conclusion

The current thinking of *waste minimisation* practices is heavily focussed on the physical minimisation of construction waste and identification of site waste streams. Tools, models and techniques have been developed to help handle and better manage onsite waste generation. While these tools facilitate auditing, assessment and benchmarking, a waste source evaluation approach does not offer long-term benefits, as it fails to address the causative issues of waste production.. The impact of *legislation*, particularly the 'Landfill Tax' and 'Aggregate Levy', and its effects on the behaviour and practices of the construction industry has resulted in a number of research studies. The last few years witnessed the publication of *waste minimisation* and recycling guides, which give broad guidance for *building design*ers to adopt sustainable *waste minimisation* approach in their projects. However, the recommendations in these guides do not realistically relate waste to all parameters of the designers' environment, including the complex design and construction process across the supply chain. In addition to this, they do not specifically identify waste-stream components in relation to their occurrence during the design stages. Consequently, the current research in the field addresses various issues related to waste when it has already been produced. The approach of this research is to assess *waste minimisation* potential through source reduction, via a focused effort to eliminate building material waste before it is generated. Therefore, this research, entitled, 'Construction Waste Minimisation by Design', endeavours to track site waste backwards and relate it to the associated design stage where it occurs.

Important questions arise from reviewing the literature: is waste inevitable, or can factors and processes responsible for its creation be changed or modified to

reduce its occurrence? is there a particular stage in the building process at which waste occurs or does it occur in all stages? which stages of the design life cycle lead to waste? how do we address *design waste*? and finally how can *building design*ers adopt *waste minimisation* as an integral part of the design process?

10 Methodology and way forward

The next stage of the research will be a focussed literature review on *design waste* by investigating and assessing existing frameworks and methodologies; best practice; and benchmarking. Building on the initial findings, and as a primary survey, two sets of questionnaires will be designed and administered to the two key players of the construction industry: one will be destined to architects, aiming to ascertain their views on *design waste* practices within their profession and the associated barriers; and the second will be sent to contactors to investigate their current responsibilities and methods of site *waste management* and auditing. This will be followed by field work on live sites to conduct interviews with contractors and site personnel to identify underlying causes of site waste and explore the relationship between waste generation and the design process. A framework will be developed, implemented and validated to map the creation of physical waste across the various design stages. The original contribution of the research will be through the development of a set of recommendations to assist building designers in integrating and sustaining *waste minimisation* strategies in their projects.

References

[1] Hutter, C., *The Weight of Nations -Material Outflows from Industrial Economies*, World Resources Institute: Washington, 2000.
[2] Directive 91/156/EEC, http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&lg=en&type_doc=Directive&an_doc=1991&nu_doc=156
[3] Skoyles, E.R. & Skoyles, J.R., *Waste Prevention on Site*. Mitchell: London, 1987.
[4] Environment Agency, *Waste Minimisation Good Practice Guide* – Revised, Lincoln, 2001.
[5] DETR, *Making Waste Work: A Strategy for Waste Minimisation in England and Wales*, The Stationery Office: London, 1995.
[6] DETR, *Less Waste More Value*, The Stationery Office: London, 1998.
[7] DETR , *A Way with Waste*, The Stationery Office: London, 1999.
[8] *The Landfill Directive* -99/31/EC, http://europa.eu.int/eurlex/pri/en/oj/dat/1999/l_182/l_18219990716en00010019.pdf
[9] DETR , *Waste Strategy 2000*, The Stationery Office: London, 2000.
[10] The Environmental Audit Committee's Fifth Report of Session 2002-03, Waste: An Audit, HC99, 2003.

[11] Fishbein, B.K., *Building for the Future: Strategies to Reduce Construction and Demolition Waste in Municipal Projects*, INFORM: New York, 1998.
[12] Ferguson, J., Kermode, N., Nash, C.L., Sketch, W.A.J. & Huxford, R.P., *Managing and Minimizing Construction Waste*: a Practical Guide, Institution of Civil Engineers: London, 1995.
[13] Emmanuel, R., Estimating the environmental suitability of wall materials: preliminary results from Sri Lanka. *Building and Environment*, 39 (10), pp. 1253-1261, 2004.
[14] Chen, Z., Li, H. & Wong, C.T.C., An application of bar-code system for reducing construction wastes. *Automation in Construction*, 11(5), pp. 521-533, 2002.
[15] Poon, C.S., Yu, A.T.W. & Ng, L. H., On-site sorting of construction and demolition waste in Hong Kong. Resources, *Conservation and Recycling*, 32(2), pp. 157-172, 2001.
[16] Guthrie, P. and Mallett, H., *Waste Minimisation and Recycling in Construction*, CIRIA Special Publication 122., CIRIA: London, 1995.
[17] Coventry, S., Shorter, B., & Kingsley, M., *Demonstrating Waste Minimisation Benefits in Construction*, CIRIA C536, CIRIA: London, 2001.
[18] McGrath, C., Waste minimisation in practice. *Resource, Conservation and Recycling*, 32(3-4), pp. 227-238, 2001.
[19] Bossink, B.A.G. & Brouwers, H.J.H., Construction waste: quantification and source evaluation. *Journal of Construction Engineering and Management*, 122(1), pp. 55–60, 1996.
[20] Craven, D.J, Okraglik, H.M. & Eilenberg, I.M., Construction waste and a new design methodology. *Proc. of the First Conference of CIB TG 16 on Sustainable Construction*, ed. C.J. Kibert, Tampa: Florida, pp. 89–98, 1994.
[21] Ekanayake, L.L. & Ofori, G., Construction material waste source evaluation. *Proc. of the 2nd Southern African Conference on Sustainable Development in the Built Environment: Strategies for a Sustainable Built Environment*, Pretoria, 2000.
[22] Nguyen, B., Gupta, H. & Faniran, S., Waste Minimisation Strategies in the Construction Industry- A Geelong Case. *Proc. of Young Waste Professionals Conference*, NSW Waste Board: Sydney, 1999.
[23] Baldwin, A., Keys, A. & Austin, S., Designing to encourage waste minimisation in the construction ndustry, *Proc. of CIBSE National Conference*, Dublin , 2000.
[24] Coventry, S. and Guthrie, P., *Waste Minimisation and Recycling in Construction -Design Manual*, CIRIA SP134, CIRIA: London, 1998.
[25] CriBE, *Waste Minimisation Through Counselling Building Project Teams & Collecting of Building Project Teams and Collecting Waste Arising*. Welsh School of Architecture: Cardiff University, 1999.

[26] Dainty, A.R.J. & Brooke, R.J., Towards improved construction waste minimisation: improved supply chain integration. *Structural Survey*, 22(1), pp. 20-29 , 2004.
[27] GMV-*Greenwich Millennium Village, Reduction, Re-use and Recycling of Construction Waste*: A Project Management Guide. BRE: Watford, 2003.
[28] Greenwood, R., *Construction Waste Minimisation* –Good Practice Guide, CriBE: Cardiff, 2003.
[29] Gibb, A., *Standardisation and Customisation in Construction*: A review of Recent and Current Industry and Research Initiatives on Standardisation and Customisation in Construction. CRIPS: London, 2001.