Overview of Demolition Waste in the UK
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Executive Summary

This study forms part of the Construction Resources & Waste Platform (CRWP) programme undertaken during 2008. CRWP is managed by AEA and BRE, and is funded by Defra. CRWP provides industry focused support in the area of construction resource efficiency and works in partnership with Government in terms of developing evidence for policy.

Current regulatory drivers and requirements on the demolition industry have been reviewed and the quantity and type of materials processed and managed by the Industry has been established.

The demolition industry had grown significantly in the last decade demonstrated by the increasing value of work undertaken and workforce employed, which showed a 7% increase between 2006 and 2007.

> In 2007 the demolition industry processed 32.7 Mt of demolition arisings.

> Approximately 88% of the inert materials handled by the demolition contractors are either recycled and used on site or recycled on site and sent for off site sale.

The members of the National Federation of Demolition Contractors (NFDC) report on aggregate demolition arisings and hazardous waste arising. Currently the Industry, via the NFDC is not reporting on the non-aggregate materials such as timber, insulation, plasterboard, and plastics.

Based on BRE’s pre-demolition audits it is estimated that demolition arisings are made up of;

> Concrete (59%), inert (21%) metals (10%) timber (7%) and plasterboard (1.4%);

> Insulation and plastics materials are both below 1% of the overall quantity of demolition arisings.

There are many regulatory and technological drivers affecting the demolition Industry in the UK today. The aims of these instruments are to ensure that the workforce adheres to safe practices as a result of the stringent Health and Safety regulations. There is an increasing level of environmental regulation being implemented to drive the industry towards sustainable waste management practices to ensure the recovery of materials.

With the increase in the use of popularity of Modern Method of Construction (MMC) and Off Site Manufacturing (OSM) techniques and more innovative construction products that incorporate composite materials it is likely that demolition contractors will encounter materials in the future that cannot be as readily recycled as current demolition arisings.

BRE and others offer the service of pre-demolition audits whereby the building and the components within it are audited to determine what the key demolition products are and make recommendations for their reuse (on and off-site), recycling or final disposal. The main aim of these audits is to maximise materials available for reuse and recycling and to minimise materials going to landfill. Four pre-demolition audit case studies have been written to provide the industry with assistance in achieving resource efficiency through auditing and setting appropriate targets, which is becoming more imperative when re-development and refurbishment projects get the green light.
Recommendations

The following recommendations have been identified:

Measurement - the demolition industry needs to be more transparent about the type and quantity of waste they produce on an annual basis; a system to collect data based on pre-demolition audits and SWMPs should be devised.

The future recyclables of materials - With the increase in MMC predicted for the future it is also likely that the use of composite materials will be more prevalent in the new build and refurbishment sectors. Research on new recycling or recovery technologies that could efficiently deal with the rising quantities of specialist building products such as insulation panels, timber products and composite building elements would be beneficial for the future.

Raising the awareness of clients – through tools such as pre-demolition audits and Site Waste Management Plans (SWMPs), awareness of the importance of demolition in terms of resource efficiency should be addressed. This includes providing appropriate timescales for the demolition of a building/structure to ensure full recoverability of the demolition arisings including high value reuse.

Environmental assessment – the savings in environmental impact should be measured in terms of diverting demolition waste from landfill and replacing raw materials; this should be embedded into pre-demolition audits and SWMPs.
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Introduction

This study forms part of the Construction Resources & Waste Platform (CRWP) programme undertaken during 2008/09. CRWP is managed by AEA and BRE, and is funded by Defra. CRWP provides industry focused support in the area of construction resource efficiency and works in partnership with Government in terms of developing evidence for policy.1

The construction and demolition industries are interlinked and interdependent as the quantities of demolition waste greatly depends on the volume and quality of structures and buildings constructed in the UK. The demolition of buildings and structures is the reverse of construction activities. During demolition activities the materials and construction products that have been encased in buildings for 60 years on average are released. The quality of demolition waste greatly depends on the materials put into the structure / buildings in the first place. These materials are segregated and processed by the demolition sector and turned into recovered materials / products to be used again by the construction industry.

This study reviewed current drivers and requirements on the demolition Industry in relation to the type and quantity of materials they are processing and working with. With the help of the National Federation of Demolition Contractors (NFDC) the latest quantity of aggregate materials and hazardous waste being handled by the NFDC members has been provided.

The study also reviewed the latest findings on non-aggregate waste streams arising from demolition activities and how they are managed. Furthermore regulatory drivers in terms of environmental, technological and health and safety have been assessed. Finally four pre-demolition audit case studies have been included that provide best practice examples of how to plan for the effective management of demolition waste arisings prior to demolishing a building.

1. For more information please go to: www.constructionwwaste.info
The demolition industry

The British Standard code of practice for demolition, BS6187: 2000, defines the order of work as: “Structures should generally be demolished in the reverse order to that of their construction. The order of demolition for buildings should be progressive, storey by storey, having regard to the type of construction.” Anyone who is professionally involved in this type of work practice can be defined as working in the demolition sector. This sector is closely connected to the construction sector as the contractors handle the arisings during the demolition phase of a building project. The materials processed by the demolition contractors in most cases will be used in the building phase as recycled aggregates if there is redevelopment on the same site.

Definition
Demolition has been defined as the removal of old or unwanted buildings. Demolition usually begins inside the building and moves to the outside in the following stages:
> removal of hazardous materials such as asbestos;
> soft strip: the removal of the soft furnishings (fixed or non-fixed) and non structural elements of the building, such as doors, stud walls, skirting boards, architraves and lighting;
> removal of the main frame; then
> removal of foundations.

The National Federation of Demolition Contractors (NFDC)
The number of demolition companies trading today is estimated to be 1,164, an increase of 40% from 1996 (Figure 1), and amongst these, 167 companies have membership with the NFDC. NFDC members are thought to constitute 80% of the top professional companies involved in demolition by the value of contracts they carry out. Information regarding the size and market share of the demolition industry is provided in the Construction Statistics Annual. In 2008 the demolition industry employed 9,600 operatives. When comparing companies in the construction sector to those specialising in demolition, construction companies tend to be larger than demolition companies.

Figure 1: Number of demolition companies

![Graph showing the number of demolition companies from 1996 to 2007](image)

4. Personal communication with Howard Button, National Secretary of the NFDC, 2007
The value of work undertaken annually by demolition companies over the last 12 years is presented in Figure 2. The total value of work undertaken in 2007 is £314 million showing significant growth in the last decade. In 2007, the total number of workforce employed by the demolition sector was 13,500 a growth of 7% from the previous year. These figures demonstrate that the demolition industry is experiencing significant growth both in the work output and operatives employed. However, the downturn in the economy is likely to have had an impact on the demolition industry, with less construction projects starting and therefore fewer requirements for the demolition of buildings occupying land.

Figure 2: Value of work done

The demolition industry plays an important role to recover as much material as possible from demolished buildings and structures. The demolition industry has undergone a major transformation within the last 20 years. Traditionally it has been an unregulated and labour intensive activity reliant upon low levels of skill and technology for the demolition of simply constructed low-rise buildings. The industry is now significantly changed, and many of the processes are now largely mechanised due to:

> increased complexity in building design that would slow up manual dismantling;
> increasing pressure from clients with regard to time and cost;
> restrictions imposed by health and safety controls; and
> advances in plant design.

These changes have resulted in a significant reduction in the time allowed for the demolition process. In addition, contractors derive income from the contract fee, which encourages the practice of demolishing as quickly and as safely as possible. The limited time availability on modern demolition contracts can result in a lower likelihood of reclamation and recycling. However, there have been cases where demolition firms have offered two tender fees, the difference being related to the amount of reclamation and recycling taking place. Baring this in mind, the demolition industry generally diverts approximately 95% of the overall tonnage of demolition materials from landfill.7

Annual demolition waste arisings

In previous surveys aimed at establishing waste arisings from the construction and demolition sectors, it has been common practice to group together quantities of waste for both sectors and present it as Construction & Demolition (C&D) waste. In 2005, the Government commissioned a survey into the arising and use of Construction and Demolition wastes in England.8 This survey was based on data, from landfill operators, mobile crusher operators, screener operators and exempt sites, on the quantities of C&D and excavation waste processed and managed. Total construction and demolition waste for England was estimated at 89.6 million tonnes in 2005. 46 million tonnes were recycled and a further 15 million tonnes were spread on exempt sites (usually land reclamation, agricultural improvement

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or infrastructure projects). The remaining 28 million tonnes were sent to landfill (including backfilling at quarries, and landfill engineering) as waste. The waste arisings only account for aggregate wastes and excludes other non-aggregate waste streams such as timber, plasterboard, insulation and plastics.

There is very little data on the overall quantities of demolition waste and the collection of data is becoming increasingly important at a policy level. A target has been set for the construction and demolition sectors to reduce the quantities of waste sent to landfill by half by 2012 based on a 2008 baseline. The target was introduced by the “Half Waste to Landfill” initiative introduced by the Waste Strategy 2007 the commitment to which was made in the joint industry/Government Sustainable Construction Strategy for England launched in 2008. The NFDC have agreed to set a target for waste diverted from landfill. As previously mentioned, the NFDC is already reporting on demolition wastes handled by their members.

The NFDC was contacted for the annual figure on demolition wastes arising in the UK in 2007 (Table 1). This figure is based on yearly reporting on the tonnage of waste produced by NFDC members from the different regions of England, Wales and Scotland. Data is currently broken down into two categories, inert wastes and hazardous wastes. There are currently no reports on other wastes. Based on the NFDC data the overall quantity of demolition arisings by the demolition industry is given in Table 1.

> The total tonnage of demolition waste produced by the NFDC members in the UK, Scotland and Wales is: 26.5 Mtpa.

> This level of waste is produced by the 167 NFDC members that represent 80% of the contract value of the work that is carried out nationally.

> The remaining demolition contractors undertake 20% of the overall demolition works by value.

> On the basis of the above, it is assumed that non-NFDC demolition contractors produce approximately 5.3 Mtpa.

These figures suggest that over a third of all construction, demolition waste arisings, based on the 2005 survey mentioned above, could originate from demolition activities alone.

Table 1: Total tonnage of demolition waste produced in 2007

<table>
<thead>
<tr>
<th></th>
<th>Mtpa</th>
<th>Number of demolition contractors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 2007</td>
<td>UK</td>
</tr>
<tr>
<td>NFDC Members – represent 80% of contract value of work undertaken in the UK, Scotland and Wales</td>
<td>26.5</td>
<td>167</td>
</tr>
<tr>
<td>Non- NFDC members – represent 20% of contract value undertaken in the UK, Scotland and Wales</td>
<td>5.3</td>
<td>997</td>
</tr>
<tr>
<td>Total Mtpa:</td>
<td>31.8</td>
<td>1,164</td>
</tr>
</tbody>
</table>

Figure 3: Tonnage of demolition waste arisings produced by NFDC member companies in England, Wales and Scotland in 2007

10. Personal communication with Howard Button NFDC
London and the southern counties produce the highest quantities of demolition arisings as shown by Figure 3. Perhaps this is not surprising as redevelopment works in this region are high. The lowest quantity of demolition waste is present in the North East of England suggesting that the lowest level of redevelopment activities are also occurring in this region. The overall quantity of demolition arisings is based on non-hazardous aggregate / inert type materials. This figure does not include hazardous waste handled by the demolition sector, which is approximately 3% or 1 Mtpa of the overall tonnage of demolition arisings. The hazardous waste materials are mostly sent to landfill after being treated, if appropriate. Approximately 6% or 1.9 Mtpa of the overall tonnage demolition arisings produced is disposed to landfill. The hazardous waste and the non-hazardous demolition materials sent to landfill altogether account for 12% of the overall tonnage of demolition materials. This means that approximately 88% of the inert waste handled by the demolition contractors is either recycled and used on site or recycled on site and sent for off site sale. The quantities of non-aggregate demolition arisings are not available and the NFDC only receives information on inert and hazardous waste handled by its members. If the quantities of non-aggregate waste streams could be collected by the NFDC members than the overall quantities of materials would also be higher.

Figure 4: Type of demolition arisings and their management options
The percentage figures above relate to the NFDC members’ demolition arisings and their management options as shown in Figure 4. The largest percentage of the total demolition arisings was crushed and used on site, which suggests that the material did not have to be transported. Therefore this practice has less of an impact on the local environment. 24% of the overall quantities of aggregates were transported from site for processing at a licensed waste transfer station. This waste management option is only practiced if there is not adequate space, machinery or license to crush the inert and concrete materials on site. These management options only apply to the inert and concrete demolition arisings.

In order to find out the tonnage of non-aggregate waste generated, the composition of demolition arisings was investigated utilising BRE’s data from pre-demolition audits.

**Pre-demolition audits (BRE)**

BRE offer the service of pre-demolition audits during which the building and the components within it are audited to determine what the key demolition products are and make recommendations for their reuse (on and off-site), recycling or final disposal. The main aim of these audits is to maximise materials available for reuse and recycling and to minimise materials going to landfill. Altogether, 35 pre-demolition audits have been undertaken on various building types such as; offices, schools, hospitals, social and private housing, leisure buildings, retail units, and industrial buildings. Table 2 presents information collated from five pre-demolition audits. The pre-demolition audits were carried out on schools, social and private housing and a leisure building. These pre-demolition audits were chosen on the basis of recording non-aggregate tonnage arisings as a result of demolition.

**Table 2. Demolition site waste composition by tonnage**

<table>
<thead>
<tr>
<th>Waste Category</th>
<th>Housing/flats (2of)</th>
<th>Leisure (1of)</th>
<th>School (2of)</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramics</td>
<td>12.08%</td>
<td>12.17%</td>
<td>1.88%</td>
<td>6.55%</td>
</tr>
<tr>
<td>Concrete</td>
<td>47.12%</td>
<td>50.57%</td>
<td>68.95%</td>
<td>59.28%</td>
</tr>
<tr>
<td>Inert</td>
<td>30.32%</td>
<td>32.22%</td>
<td>12.82%</td>
<td>20.98%</td>
</tr>
<tr>
<td>Insulation</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.08%</td>
<td>0.05%</td>
</tr>
<tr>
<td>Metals</td>
<td>7.76%</td>
<td>2.99%</td>
<td>12.62%</td>
<td>9.98%</td>
</tr>
<tr>
<td>Plastics</td>
<td>0.01%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Timber</td>
<td>2.09%</td>
<td>2.04%</td>
<td>1.45%</td>
<td>1.74%</td>
</tr>
<tr>
<td>Plasterboard</td>
<td>0.63%</td>
<td>0.00%</td>
<td>2.19%</td>
<td>1.42%</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>100.00%</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

The data above is also represented in Figure 5 on the next page.
The highest tonnage of demolition materials is concrete (59%), inert (21%) and metals (10%). This was followed by timber (7%) plasterboard (1.4%) and insulation and plastics materials were below 1% of the overall quantity of demolition arisings. Based on BRE’s pre-demolition audit findings the overall recycling rate of the demolition arisings on project basis was between 85% and 95%. This figure compares well with the overall recycling rate of demolition arisings submitted by the NFDC members, which reported 88% in 2007.

Figure 5: Composition of demolition arising

Using the findings from the pre-demolition report, for the composition of demolition arisings, the approximate tonnage of demolition material can be extrapolated and used to estimate the composition of demolition arisings in England, Scotland and Wales.

Pre-demolition audit link with BREEAM

The updated BREEAM certification system for 2008, used to assess the environmental performance of different building types, specifies that by undertaking a pre-demolition / pre-refurbishment audit using an appropriate methodology the project can gain one credit under the Construction Site Waste Section.

To achieve this credit:

*sites with existing buildings that will be refurbished or demolished, where demolition forms a part of the principal contractor’s works contract, must comply with the following:
a. Completed a pre-demolition/pre-refurbishment audit of the existing building to determine if, in the case of demolition, refurbishment is feasible and, if not, to maximise the recovery of material from demolition or refurbishment for subsequent high-grade/value applications. The audit must be referenced in the SWMP and cover:

i. Identification of the key refurbishment/demolition materials.

ii. Potential applications and any related issues for the reuse and recycling of the key refurbishment and demolition materials.  

Non-hazardous demolition waste has been diverted from landfill to the amount of 90% by weight or 80% by volume, over the demolition phase of a building project.  

To qualify for this credit all waste types have to be identified for diversion from landfill at pre-construction stage. The same rule applies for receiving the credit if a project is being assessed under the Code for Sustainable Homes certification scheme. 

The pre-demolition audit is defined in the Demolition Protocol’s methodology as; to enable construction and civil engineering projects to utilise all the demolition arisings, by setting reuse and recovery targets that should be met across a range of public and private sector projects.

Once the pre-demolition audit has been undertaken, and the different demolition material types quantified, tracking the quantities and the waste management routes of these materials can be achieved by using BRE’s SMARTWaste plan monitoring tool. This tool has been designed to fulfil the requirements of the Site Waste Management Plan (SWMP) Regulations for new built construction, fit out or refurbishment and demolition projects that have a contract value of over £300,000. Currently, demolition arising data from 15 completed demolition projects are stored. This also lists the overall and the different construction products’ recycling rates achieved at individual project and overall project level. The overall projects’ level data could be used to set up appropriate and meaningful benchmarks for demolition arisings. The demolition project data inputted on the SMARTWaste tool are limited and currently meaningful benchmarks cannot be provided until more data is collected.

Institute of Civil Engineers (ICE) Demolition Protocol, 2008

The ICE developed the Demolition Protocol in 2003 to have a robust methodology to assess the quantities of materials present in buildings and structures and their waste management options considering the waste hierarchy principle, when reaching the end of their lives. The Protocol has been updated, based on feedback received by stakeholders, and the updated version was published in 2008. It also provides an integrated approach to the development of Site Waste Management Plans. The pre-demolition audit is defined in the Demolition Protocol’s methodology as; to enable construction and civil engineering projects to utilise all the demolition arisings, by setting reuse and recovery targets that should be met across a range of public and private sector projects.
Current regulatory Issues and policy facing the demolition Industry

There are many regulatory and technological drivers affecting the demolition industry in Britain. The aims of these instruments are to enable sustainable waste management practices to be adapted by the industry. The Health and Safety (H&S), regulatory, environmental and technological instruments and best practice guidance are summarised below.

Demolition Code of Practice BS 6187: 2000

This British Standard concerns the process of demolition from initiation, through planning, to the execution stages. The BS 6187:1982 was updated in 2000, and this version is essentially a re-write that takes into account the advances in technology and equipment that are available to the demolition industry. The application of techniques and the effect of legislation that has been introduced, has been taken into account for the updated standard. In particular health and safety, and environmental legislation include the Construction Design and Management (CDM) Regulations 2007, the Construction (Health, Safety and Welfare) Regulations 1996 and the Environmental Protection Act 1990 have been taken into account. The document is written for all – including clients - involved in demolition (which include partial demolition) projects and gives emphasis to responsibilities from concept stage to completion, starting with clients. The Standard addresses the safety of both those engaged in the demolition process and also those members of the public who may be affected by the demolition activities.

The most recent edition of BS 6187 has been expanded to cover project development and management, site assessments, risk assessments, decommissioning procedures, environmental requirements, and facade retention. Deconstruction techniques are considered, including activities for re-use and recycling. Principles relating to exclusion zones, their design and application have also been added. This code addresses the health and safety of those engaged in the demolition process and also of those members of the public who may be affected by the demolition activities.

HSE Health and Safety in Demolition Work (working title)

The Health and Safety Executive (HSE) produced health and safety guidance for safety in construction. This guidance document - currently a working document on Health and Safety in Demolition Work - is to:

“help all those involved in the demolition process, from client and designer to contractors and individual workers, to identify the main causes of accidents and ill health and to explain how to eliminate the hazards and control the risks.”

This guidance was developed alongside other relevant pieces of regulation and guidance so as to improve the business of demolition and deconstruction. Complementary documents include BS6187-2000, Construction (Design and Management) Regulations 2007 (CDM) and a range of other laws and guidance including:

- The Health and Safety at work etc. Act 1974
- The Management of Health and Safety at Work Regulations 1999
- The Construction (Design and Management) Regulations 2007
- The Construction (Health Safety and Welfare) Regulations 1996
- The Provision and Use of Work Equipment Regulations 1998
- The Lifting Operations and Lifting Equipment Regulations 1998

15. Health & Safety at Work Booklet - 6E Safety in Construction Work: Demolition
Health and safety is paramount in any construction activity, especially so in the demolition sector. The majority of demolition work is engaged with removing the workforce away from the ‘face’ of the demolition and creating zones of work. This enables the health and safety of the workforce to be safeguarded more effectively. The provision of new technologies, which aid the workforce by providing equipment where demolition can be carried out remotely, will encourage increased health and safety. In particular this will enable deconstruction techniques to be applied effectively which in turn enables the selective removal of products and components for reuse. Regulatory authorities include Government bodies such as the Environment Agency whose main interest is to protect the environment. Traditional demolition techniques can create noise, dust and air pollution which can cause nuisance in the local environment.

Environmental / Fiscal

There are numerous environmental drivers in place with the aim to reduce the quantities of demolition arisings sent to landfill.

Landfill Tax

The landfill tax was introduced on 1st October 1996 and for the demolition sector it is an incentive to divert demolition arisings from landfill. Exemptions for the tax have been provided for dredged waste, mineral waste from mines and quarries, and waste arising from the clearance of contaminated sites. Exemptions also apply to inert materials that are used for landfill restoration or filling former quarries. The tax seeks, as far as is practicable, to ensure that the price of landfill fully reflects the impact that it has upon the environment. It provides an incentive to reduce the waste sent to landfill sites and to increase the proportion of waste that is managed at higher levels of the waste hierarchy.
There are two rates of tax, a standard rate of £40 per tonne for non-hazardous waste which is increasing £8/tonne per year and £2.50 per tonne for inert. The categories of waste to which the lower rate of tax apply – generally inert waste – are set out in the Landfill tax (Qualifying Materials) Order 1996 (SI No 1528). The Landfill Tax (Contaminated Land) Order 1996 (SI No 1529) sets out the provisions for exempting waste from the clearance of historically contaminated land.

**Aggregate Levy**
The Aggregates Levy was introduced in 2000 by the Treasury to encourage the use of recycled and secondary aggregates from lower to higher grade applications and to discourage the extraction of primary aggregates. Currently the cost of the levy is £2.00 per tonne for primary materials. Recycled and secondary aggregates are not subject to the tax, which has encouraged the market to deal in more recycled goods and materials.

**Waste Strategy 2007**
This strategy describes the Government’s vision for managing waste and resources better. It sets out the changes needed to deliver more sustainable development 16. The strategy stresses that the quantity of waste produced must be tackled by breaking the link between economic growth and increased waste. The main theme of the strategy is; “where waste is created we must increasingly put it to good use – through recycling, composting or using it as a fuel.” The strategy also recognises the need to develop new and stronger markets for recycled materials. This Programme will deliver more recycling and reuse, help develop markets and end-uses for secondary materials, and promote an integrated approach to resource use. The strategy identified the construction industry as a priority sector largely due to the amount of waste produced and the resources used.

**Strategy for Sustainable Construction**
The Strategy for Sustainable Construction 17 is a joint industry and Government initiative intended to promote leadership and behavioural change, as well as delivering benefits to both the construction industry and the wider economy. There is chapter devoted to waste with an over-riding target of a 50% reduction of construction, demolition and excavation waste sent to landfill by 2012 compared to the 2008 base line figure. As part of this Strategy, the NFDC has committed to setting a target to divert demolition waste from landfill by 2009.

**Site Waste Management Plans**
Site Waste Management Plans (SWMPs) are a legal requirement for construction, demolition and refurbishment projects in England costing over £300,000 since April 2008. One of the aims of the SWMP Regulations, as stated in non-statutory guidance issued by the Department for the Environment Food and Rural Affairs, is “improving materials resource efficiency, by promoting the economic use of construction materials and methods so that waste is minimised and any waste that is produced can be re-used, recycled or recovered in other ways before disposal options are explored.”

A SWMP provides a framework, for detailing the amount and type of waste that will be produced on construction, demolition and refurbishment sites and how it will be reduced, reused, recycled and disposed of. Material waste is summarised and recorded in a live document that is updated regularly throughout the course of the project and records how the waste streams will be managed. The implementation of a SWMP encourages good practice with regard to waste minimisation and waste management and its use on site should generate both environmental and financial savings throughout the project. Recording the quantities of the demolition materials arising and their management options via the SWMP during the demolition phase of the project, can assist construction project teams with documenting

demolition arisings that could be later incorporated in the new development. This could contribute to waste minimisation activities on a new development by reducing the quantity of materials needed during the construction phase.

**Code for Sustainable Homes**

The Code for Sustainable Homes (CSH) applies to England, Wales and Northern Ireland, but not Scotland. It requires that SWMPs state a target for recovering wastes.

The CSH has a number of non-mandatory elements for SWMPs, with the minimisation of construction waste resulting in two credits being awarded as part of the overall scoring scheme. The requirements involve confirmation that an obligation will be made to (i) reduce construction waste and (ii) divert waste from landfill. Two checklists in the CSH technical guide must be completed (checklists 2b and 2c) to demonstrate compliance. BRE’s pre-demolition audits can provide sufficient evidence that demolition waste is being reduced on site and that waste is being diverted from landfill, by recycling and reusing demolition material on the same site for example.

**Demolition methods and equipment used**

The historical picture of demolition techniques is the ball and chain being swung or dropped from a crawler crane. This powerful image served to identify an industry synonymous with words such a dirty, dangerous and dusty. Some, when questioned, may prefer to associate the demolition worker with hammer in hand perched atop a wall knocking away the brick courses around and below him to reduce the structure. In both instances, with a small concession to drop balling concrete slabs, these types of operations have given way to the tracked excavator based 360° demolition rig equipped with an array of demolition attachments. The early use of such machines had a mixed reception and can be traced back to the relative late period of the early 1980’s in which excavation equipment was utilised to carry out some of the reduction of low level structures and the loading of skip and lorries. Due to demand throughout the 1990’s major plant manufactures started to produce bespoke demolition machinery with attachments made for specific demolition activities. By 1999 the first free standing, three piece boom demolition rig capable of working down a structure, standing at ground level, of 42 metres height was in use. Mainly due to the H&S legislations bought in to protect workers from injuries and accidents, the demolition industry is highly mechanised today. The most often used tools and methods used for demolition and dismantling work are detailed below:

**Pneumatic and Hydraulic Breakers**

Often used in concrete demolition projects involving bridge decks, foundations and pavement, hand-held or boom mounted pneumatic and hydraulic breakers are currently the tools of choice. The amount of work accomplished using these methods depends on the hammer size, strength of the concrete, the amount of steel reinforcing used in the concrete, and working conditions.

**Pressure Bursting, Mechanical Bursting and Chemical Bursting**

Pressure bursting can be used in cases where relatively quiet, dust-free, controlled demolition is preferred. Both mechanical and chemical pressure bursting split the concrete, either with a splitting machine operating on hydraulic pressure provided by a motor in the case of mechanical bursting, or through the insertion of an expansive slurry into a pre-determined pattern of boreholes in the case of chemical bursting.

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The split concrete is then easily removed, either by hand or by crane. Hydraulic and chemical pressure bursting break up concrete structures with a minimum of noise and flying debris. Both methods work by applying lateral forces against the inside of holes drilled into the concrete, and can do virtually any job other demolition methods are capable of. However, rather than shattering the concrete into bits as dynamite and impact tools would, the lateral forces build up over time to crack the concrete into smaller sections.

**Ball and Crane for Demolishing Masonry and Concrete Structures**

One of the oldest and most commonly used methods for building demolition, the ball and crane uses a wrecking ball weighing up to 13,500 pounds to demolish concrete and masonry structures. During the process, the ball is either dropped onto or swung into the structure that is to be demolished. The ball and crane, however, is not suitable for all demolition applications. Some limitations:

> While the concrete can be broken into rather small pieces, additional work in the form of cutting rebar may be necessary;

> Only highly skilled and experienced crane operators should be used on ball and crane demolition projects -- smoothness in controlling the swing of the ball is important since missing the target may tip or overload the crane and a mild swing-back may cause the ball to hit the boom;

> The size of the building that can be demolished with this method is limited by crane size and working room, including proximity to power lines;

> This form of demolition creates a great deal of dust, vibration and noise.

**Explosives**

Explosives are generally used for removing large volumes of concrete via insertion of explosive devices in a series of boreholes:

**Mechanical Demolition & Dismantling**

The intricacy of the demolition process is a function of the size and complexity of each project. For the times when explosive demolition is not appropriate, mechanical methods are applied. Small scale demolition projects involving low-rise structures can be carried out using ordinary machinery, methods and equipment. Larger structures and complex projects require more extensive planning as well as specialised procedures, equipment and machinery.

When valued assets are present at the demolition site it is essential to recover these items in order to lessen the cost of demolition to the client. This often involves careful dismantling of plant and equipment to recover the assets or internal fixtures for reuse by the client.

Issues for future consideration

This section considers a number of issues that may have an impact over time on the amount and management of demolition waste arising.

Modern methods of construction

Energy and resource efficiency is high on the political agenda with construction methods and materials that satisfy reduced carbon emissions and resource efficiency requirements already in demand. Modern methods of construction are essentially seen by Government as a means to increase the rate at which private and public sector affordable homes are constructed. In 2003 the term 'Modern Methods of Construction' came into common use to refer to a range of innovative technical solutions for construction, of which Off Site Manufacture (OSM) is a subset. 24 For example bathroom pods manufactured in a factory environment ‘off site’ and then transported to a site to be installed in building are building components using OSM practices. MMC construction can refer to construction methods using different OSM elements within a building or structure.

There are a number of perceived advantages of using a Modern Method of Construction (MMC). 25

> Traditional building methods are reliant on a contracted labour force with skill levels varying from site to site and between regions. Labour employed for factory-built housing components has the advantage of controlled recruitment and encourages employers to initiate training schemes with the potential to lower staff turnover.

> By building much of the frame in factories, the selection and training of labour used is more easily controlled and consequently the consistency of the product quality is likely to be better than on site. On site construction is also less predictable than off site given the vagaries of the weather.

> The more predictable offsite methods can help with compliance of recent stringent building regulations where the emphasis is increasingly on thermal and acoustic performance, rather than the more traditional emphasis placed upon health and safety on site.

> Environmental performance – both before and after construction - is becoming a major focus for the Government and material wastage is a key issue with regard to on site manufacture with little or no incentive to the contractor to economise on material usage. The materials are usually part of bulk orders and both waste and surplus materials are very often discarded via the skip. Procurement of materials for factory manufacture is controlled and waste is minimised. Construction noise, dust and traffic normally associated with on site construction are also reduced when components are factory built.

Since 2000 the use of MMC is on the increase. A market research study undertaken by AMA Research Ltd on the ‘Timber Frame Housing Market’, forecasts the growth in house building using MMC in England.  

The use of traditional brick and block construction is still significant however; house builders are under increasing pressure to ensure that they make significant progress in achieving the targets set by the Government for both carbon zero homes and more new dwellings by 2016. This driver aimed at house builders would suggest an increase in the number of homes being built using MMC.

There is little knowledge in the house building sector regarding the future recyclability of the materials encased in buildings using MMC. It is predicted that when these houses reach the end of their life, which is defined as 60 years using the whole life costing accounting methodology, then it is likely that some of these materials cannot be easily recycled. A recent study undertaken by BRE as part of the WRAP funded case study called the “Tangible Benefits of Off Site Manufacturing”, looked at the difference between MMC and brick and block construction. The main focus of the study was to find out if MMC construction was more resource efficient in terms of speed of construction and materials used.

As part of this study a pre-demolition audit of a timber frame (OSM) house was undertaken. A comparison was made with a traditional brick and block house to compare the materials arising from future demolition activities. This demonstrates how the composition of the demolition material quantities and types could change in the future dependant upon the type of house built.

To make this comparison previous pre-demolition audit findings of a traditional brick and block house have also been used in this study. Figure 7 (next page) presents the findings of the pre-demolition audit.

Figure 6. Housing Completions Forecast England – By Volume and materials (Brick & Block, Timber Frame, Steel / Concrete) – 2000-2012

![Graph showing housing completions forecast for England from 2000 to 2012.](chart)

When comparing the quantity of materials present in a 100 m² floor area of traditional brick and block house as opposed to a timber frame house the study showed that the traditional house had 15% more materials encased in the building. The material composition of the OSM house was similar to the traditional house as both houses used concrete and bricks in their construction. The difference was in the quantities of the materials used. The traditional house had more inert materials encased within the building than the OSM house. Conversely the OSM house contained more timber, plasterboard and insulation within its structure and walls. This study highlights that demolition contractors are likely to encounter more materials in the future that cannot be as readily recycled as ceramics and concrete. Recyclability and recovery of materials need attention for the future in terms of researching and developing new technologies to divert these materials from landfill.

**Plasterboard**

Gypsum is the main component in the manufacturing of plasterboard. Plasterboard offcuts can be recycled and reprocessed if they are free from contamination. This requires segregation at source. The gypsum core needs to be separated from the paper liner to which it is bonded – this requires investment (normally by the plasterboard manufacturer) in expensive specialised equipment. All of the plasterboard manufacturers have or are setting up plants to enable plasterboard waste to be recycled back into plasterboard. Some of these recycling sites are managed by a third party and do not accept certain types of plasterboard waste. For instance, laminated and foil backed boards cannot be recycled owing to their composition. The schemes typically work on reverse logistics and collection charges are made. Take-back schemes for recycling of plasterboard waste from new build have been in existence since 2002. The take-back schemes are dependent upon the quantity and quality of plasterboard waste produced.
and currently manufacturers will only take back their own plasterboard products. Return load haulage is used wherever possible, but the logistics of hauling scrap material are quite different to those of moving pallets of plasterboard. In England, Northern Ireland and Wales, as of 1 April 2009, the Environment Agency and Northern Ireland Environment Agency have revised their policies for disposing of gypsum waste to landfill. Previously, waste containing less than 10% gypsum could be sent to landfill. The environment agencies have removed this guideline value. This means that demolition contractors need to segregate the gypsum waste on site and send it for recycling and/or mono-cell landfill disposal.

**Insulated Panels**

Building foams are a significant store of Ozone Depleting Substances (ODS) in the UK and occur in a wide range of building products. For example, some foam will be in the form of panels in cold stores or refrigerated warehouses. Additionally, foam may be present as insulation panels and materials contained within some brickwork. Despite the phase-out of the use of CFCs in developed countries in 1995 many insulation panels contain (ODS). CFCs and HCFC were used to provide bubbles in building foams as they are good insulators and have fire resistance properties. The lifetimes of the foams are tied to the lifetimes of the building and the EU has suggested that this will be between 30 – 70 years. It has been estimated that an excess of 350,000 tonnes of CFCs are still contained in insulated panels use globally. The use of these panels has been prevalent since the 1960 with products likely to enter the waste stream from 2010 (although some are entering now). This has implications to the demolition sector, as they will play a part in the future recovery of this material. The recovery of ODS from building foams is currently covered in Article 16(3) of the of the (EC) No 2037/2000 Regulation, which states that ODS ‘contained on products, installations or equipment’ to be recovered for deconstruction if practicable.”

The UK Government has introduced specific legislation to ensure that ODS from fridges is captured using fridge recycling plants however there is no legislation to explicitly require the capture of ODS from building foams or to specify treatment routes. The ODS Regulations are currently under review with the proposal that Member States require the recovery of building foams where technically and economically feasible.

Recovered insulation panels from buildings are more expensive to treat than the recovery of fridge panels as the two thin metal sheets that surround the insulation foam in the middle does not contain much metal, rendering this process as not economically viable. Although, Kingspan have carried out research in this area and has successfully re-processed panels from four separate sites in 2007 using existing refrigerator recycling plants. A research paper (by Kingspan) has shown that the plant had to be slowed from its normal production rate to cope but a mixed stream of refrigerators and panels could overcome this. With no technical/practical barriers to the procession of panels through a standard refrigerator plant, provided they are cut to size before processing, mixed streams would be required for plant optimisation. To ensure that blowing agent retention within foam dust is kept below 0.5, and recovery levels of 55% are demonstrated, real recovery levels are expected to be higher. With the cooperation of the NFDC it would be useful to undertake a trial study on recovering insulation panels from demolition sites to find out the ease of recovery from the building structures.

Other materials that may be difficult to recover at the end of their life include:

**Composites –**

Composite materials used in buildings and structures can refer to:

> Materials mixed together using adhesives
> Laminated composites
> Polymer composites
Materials mixed together using adhesives
Oriented Strand Board (OSB) is a wood based panel that uses cut wood wafers that is bounded together under heat and pressure with powdered phenol-formaldehyde resin. This product is increasingly being used in OSM timber frame buildings. The comparative pre-demolition audit report produced as part of the WRAP funded “Tangible Benefits of Off Site Manufacturing” project looked at the difference between the end of life options using OSB and traditional brick and block construction. As already discussed, demolition contractors are likely to encounter more materials in the future that cannot be as readily recycled as inert materials. Treated timber products use adhesives, which hinders their recyclability.

Particle board or chipboard is another product that is widely used in MMC for example most timber frame houses have chipboard. About 2 million cubic meters of particleboard (chipboard) are consumed each year in building applications in the UK. Particle board manufacturing uses recycled timber in the manufacturing process. These products are used for flooring, stairs, timber frame structures, timber interior and exterior fixtures and fittings. Fibreboards are boards made from timber fibres. The resin of the timber is sometimes used to bind the fibres together under pressure. Medium density fibreboard (MDF) has many applications, as it is easily shaped and can have plastic veneer glued to its surface. MDF is commonly used as kitchen cabinets and architrave. Another common type of fibreboard is hardboard also called High density fiberboard (HDF). It is similar to particle board and MDF but is denser and harder because it is made out of exploded wood fibres that have been highly compressed. It is used to manufacture kitchen and bathroom built in cabinets. Particle board products using additives in the manufacturing process, currently prevents these materials from being recycled.

Laminated composites
Types of laminated timber include plywood, blockboard, and laminaboard. Many laminated boards are covered with a decorative veneer, which is glued to the surface. These laminates are used for kitchen surfaces and specialist surfaces in shops and offices. For example formica is a type of laminated timber product.

Polymer composites
Today, most plastics are produced from petrochemicals the by-product of the oil industry. The first step in plastic manufacturing is polymerization. Chemical additive can be used in the manufacture of plastics to achieve creation characteristics. These additives include:

- Antioxidants to protect the polymer form degradation by ozone or oxygen
- Ultraviolet stabilisers to protect against weathering
- Plasticisers to increase the polymer’s flexibility
- Lubricants to reduce friction problems
- Pigments to give plastic colour
- Flame retardants
- Antistatics

Plastics are often manufactured as composites. This is achieved by adding reinforcements such as glass or carbon fibres to plastics, increasing their strength and stability. PVC is the second largest commodity plastic after polyethylene. PVC materials are widely used by the construction sector most often as PVC U window frames and PVC pipes. High density polyethylene (HDPE) is used to manufacture construction products such as chemical drums, cable insulation and low density polyethylene (LDPE) is used to manufacture gas and water pipes and heavy duty sacks. Some Polypropylene (PP) is utilised by the construction sector, most notable as domestic drainage pipes and as flexible and rigid packaging materials. Glass reinforced plastic (GRP) are used in a
variety of applications such as cooling water, drinking water and waste water systems. It can also be used to construct brick effect panels that can be used in the construction of composite housing.

The recycling of PVC-U windows and pipes is in its infancy and only occurs via a specialist recycler. It is possible to make the recycling of plastic PVC-U windows and pipe offcuts economically viable to transport to the recycling facility but this would mean a requirement for large quantities of offcuts. The quantities of plastics generated on most sites is not enough to make it worthwhile to transport it long distances. The situation regarding collection and recycling of PVC-U is gradually improving due to the Recovinyl scheme introduced in the UK as part of the Vinyl 2010 voluntary commitment. Currently, the economics of PVC recycling are finely balanced against disposal to landfill. Recovinyl provides financial incentives (currently £50 per tonne) to those who collect and deliver post-construction PVC waste to a Recovinyl accredited recycler or waste recovery firm.

Demolition and refurbishment contractors indicated that not only the material compositions and characteristics make the above products difficult to recycle at the end of their life but also the segregation, transportation as well as the current unattractive end of life markets.

**Design for deconstruction**

The concept of Design for Deconstruction (DfD) gained international recognition when in 1999 Task Group 39 of the International Council for Research and Innovation in Building Construction (CIB) was formed. The aim of TG39 was to produce a comprehensive analysis of, and a report on, worldwide building deconstruction and materials reuse programs that address the key technical, economic, and policy issues needed to make deconstruction and reuse of building materials a viable option to demolition and landfill.

**TG39 adopted a range of tasks including.**

1. **Design of New Buildings**: Assess the potential for Design for Deconstruction that is, changing architecture and building products to allow easy disassembly of buildings. This task included designing buildings to allow partial disassembly for renovation, retrofit, or remodelling and the reuse and recycling of components and materials.

2. **Design of Future Components and Materials**: Apply the principles of natural systems ecology and industrial ecology to foster the development of building products and materials that are designed for disassembly and designed for recycling.

3. **Technical Issues of Deconstructing Existing Buildings**: Examine the technical issues of deconstructing existing buildings such as disassembly techniques, tools (existing and required), risk assessment, and safety.

4. **Deconstruction Assessment**: Develop methods for rapidly assessing the content of existing buildings scheduled for demolition for their economic value, to include total and partial deconstruction.

5. **Reuse and Recycling of Extracted Building Components and Materials**: Assess the barriers to reusing materials and components from existing buildings in new buildings to include general acceptance, building codes, testing, liability, and certification. Determine how to optimise the recycling of extracted materials.

6. **Economics of Deconstruction and Materials Reuse**: Examine the existing economic feasibility of deconstruction and component reuse. Assess market opportunities and potential new business structures. Perform cost/benefit analysis of using reused versus new components and materials. Develop economic models to determine deconstruction feasibility and for performing breakeven analyses.
7. Marketing and Sales of Used Building Materials: Examine the use of information networks, on-site auctions, establishment of used materials centres, and the need for new infrastructure to support materials reuse.

8. Social Issues of Deconstruction: Examine the affects of deconstruction and materials reuse on communities and local government, to include new jobs creation, reduced landfill demand, and lowered environmental impacts.

9. National Policy Impacts on Deconstruction: Determine the affects of national policies and regulations on building deconstruction and materials reuse.


11. Other Tasks: Quantify the environmental benefits of deconstruction and materials reuse.

Over a 10 year period the practice and issues surrounding deconstruction had been moved forward by innovative building projects. Not all tasks that were set out by the TG 39 group had been achieved as researching and finding alternatives to the demolition of buildings for the future involves natural system and industrial ecology; concepts that need to be behind all design of buildings for the future.

To move the vehicle of deconstruction forward, some of the tasks have been well advanced. For example, the Deconstruction Assessment outlined in Task 4 has been developed by BRE’s SMARTWaste pre-demolition audit and the Institute of Civil Engineers’ Demolition Protocol methodologies. Roads have also been made for setting up reclamation and reuse centres around the country and the advertising of specific salvage items on www.salvo.co.uk or low value materials on www.salvomie.co.uk had been initiated. The tasks to progress will remain on the agenda for a long time, as this is a constantly ongoing process.

How to better manage demolition arisings

Unlike construction waste, it is not possible to minimise the quantity of demolition arisings. Minimising the quantity of demolition arising entering the landfill and finding higher grade applications via reuse and recycling activities contributes towards the better management of demolition waste.

Reuse

On demolition contracts a soft strip of the building is undertaken 90% of the time, during which time items that have reclaim value are taken out of the building and usually sold to reclamation yards. Due to the tight timescale given to the demolition contractors to demolish a building, there is limited time to recover items that do not have high value (such as Victorian and period style fixtures and fittings). Moreover, the health and safety requirements placed on demolition contractors hinder them in recovering lower value items for reuse. The demolition process is highly mechanised partly to remove the workforce from the demolition face of the project. As a result demolition contractors do not invest time into cleaning up demolition materials and components as this would result in workers being put in closer proximity to the demolition work areas. Not investing in this type of recovery reduces the risk of injuries, such as trips, falls and cuts. The increasing transport costs, storage facilities available to store reuse items and the distance between the different demolition jobs presents a barrier to reuse lower value items. Strict material specifications also govern the reuse of different building components in a new building or structure.

Having more lead time to recover and advertise the reusable items on material exchange websites such as www.salvomie.co.uk would encourage more reuse activities. Reclaiming materials on demolition projects and using these products in the construction of new buildings have less environmental impact than using recycled materials, as the energy used to manufacture

those products would be retained. Using the Building Research Establishment (BRE) life cycle analyses environmental profiling technique to evaluate the environmental impact of a building product or component when comparing reclaimed with virgin materials shows an environmental impact reduction of 96% when using reclaimed steel and 79% for reclaimed timber when compared with new. If a new steel product (beam) has a recycled content of 40% i.e. 40% of the material melted down to be formed into sections is recycled scrap. The smelting process uses energy and produces carbon emissions. The re-use of reclaimed steel sections saves all the reprocessing energy and so has a 96% lower overall environmental impact.

Recycling
The on and offsite recycling of demolition arisings have been well established within the demolition sector. Concrete is readily separable at demolition sites, easily recycled, with good quality assurance. Very often the problem with recycling demolition arising is that the crushed materials are downcycled. To achieve higher grade recycled aggregates that can be specified for use in other buildings or structures the concrete should be segregated from other inert materials, and sent for screening and certification. It is routine practice on all demolition sites to segregate metals and send them for offsite recycling. However, the site segregation and the recycling of plasterboard is a relatively new occurrence on demolition sites, since the ban on plasterboard entering landfill unless it is put in engineered monocells.

Energy recovery
The recovery of energy from waste is advocated by the government mainly for residual municipal waste. For the demolition industry there is an opportunity to send wood materials that are not suitable for recycling to energy from waste plant. Recent research showed that of the estimated 7.5 million tonnes of waste wood arisings in the UK, out of which 80% is landfilled, 16% or (1.2 million tonnes is reused and recycled with energy being recovered from just 0.3%. Carbon benefit from recovering energy form waste can only be recognised from non-reusable and recyclable wood waste if there is sufficient combustion facilities for clean and/or contaminated wood that satisfies the Waste Incinerator Directive standards.

Other demolition arisings that generate in smaller quantities are insulation products. These materials are difficult, if not impossible, to send for recycling from demolition sites due to the fact that insulation materials take up lots of space and transporting them long distances would not be economically viable. Polymer-based insulation (e.g. polyurethane foams) can be incinerated in order to recover energy and reduce its volume (to approx. <1%). Polymers have a high calorific value and can be burned to recover this energy, proper management of the processing can allow for toxic fumes to be collected, minimising any environmental damage. There is currently insufficient energy-from-waste infrastructure in the UK to deal with insulation waste. It is also expensive to transport these lightweight wastes over long distances, which potentially negates any environmental benefit from energy recovery. However, it may ultimately be one of the most favourable solutions for polymer-based insulation waste, particularly in the short –to medium term. The material would still need to be recovered and segregated at end of life, however it would be less important if the insulation offcuts were soiled since they would be sent for energy recovery as opposed to recycling whereby only clean or lightly soiled insulation offcuts are suitable.

Measurement
To forecast the demolition arisings available as a resource in place of using virgin materials it is important to measure and report on all the different materials that enter the demolition waste stream. Currently, the NFDC members report on the quantity of the inert material

42. Source: BNIW01: Insulation industry, product and market overview
arisings and their waste management options used to process this material. The quantity of materials sent to landfill and the hazardous waste materials segregated by the NFDC members are also recorded. Other demolition material types are not reported on. Site Waste Management Plans (SWMP) would be an appropriate vehicle to encourage demolition contractors to report on the tonnages of materials produced on sites as a result of demolishing a building and how these materials are going to be dealt with so that the disposal routes take into consideration the waste hierarchy principle. Undertaking a pre-demolition audit of a building whereby the different material streams are quantified would be a useful tool for the demolition contractors to systematically record and report the tonnages of materials arising. This information could be an important part of the SWMP submitted by the demolition contractors at the tender stage.

**Main contractors**

Main contractors also have an influence on ensuring that demolition contractors improve resource efficiency on site by ensuring that the waste targets set by the client are met by the demolition contractors and demolition information is inputted into the SWMP.

It is essential for contractors to monitor the following:

> Type of waste being generated
> Amount of waste being generated
> Waste management routes
> Checking “Duty of Care” documentation
> Diversion from landfill target

**Clients**

Clients commissioning the demolition of a building or structure have the highest influence in requiring the demolition contractor to implement the highest level of material segregation on site. The clients’ requirement on resource efficiency can be written in the tender documentation in the form of sub-contractor clauses. Targets for sending materials for reuse and recycling will also serve as a performance target against which the demolition contractor can be assessed. These can be set based on data from pre-demolition audits. A useful method of measuring demolition contractors’ performance could be implemented by requesting the demolition contractor to report the quantity of demolition arisings via an independent waste monitoring system such as the SMARTWaste plan tool that is suitable to use by the demolition and refurbishment sectors.
Case studies for demolition

Four case studies are summarised below which are based on BRE’s pre-demolition audit findings, three of which were funded by the Construction Resource Efficiency (CoRE) project which is funded by Defra under the Business Resource Efficiency and Waste programme (BREW) in 2006 to 2007. The Borough Council of Wellingborough commissioned the fourth case study in 2007.

Wellingborough Swimming pool

Borough Council of Wellingborough commissioned the construction of a new swimming pool and as a result the old swimming pool (see Picture 1) used by local residents had to be demolished as it came to its end of life. The planning department of the Borough Council wanted to ensure that prior to demolition work starting on site, a pre-demolition audit would be undertaken so that the material arisings would be managed efficiently, ensuring that the principle of the waste hierarchy is implemented throughout the project.

Project details

The swimming pool was built in the 1960’s using red bricks as its building envelope. The building has a 25 m adult pool and a smaller teaching pool. The two pool areas are set in heavily reinforced concrete that can withstand the water’s pressure. The seating area that was devised for watching swimming competitions is based on the second floor of the building. The building has a flat roof that is covered with metal sheeting material. The foundation of the building was excavated, as there are plans to turn the swimming pool site into a parkland area.

Contractual agreement

The Borough Council of Wellingborough appointed BCLA consulting engineers to manage the demolition work package. The demolition work package was put out for competitive tender to the Borough’s demolition framework suppliers. One of the requirements was the implementation of SWMP during the demolition work on site. The demolition contractor also had to reach a material recovery target - at least 85% by weight - that was set in the pre-demolition audit undertaken by BRE. On the basis of reaching these requirements, C. Jackson and Sons demolition contractor was selected to undertake the job.

Pre-demolition audit findings

The pre-demolition audit findings estimated the quantity of the different materials encased in the building (see Figure 8). Materials that could be diverted for reuse were also identified.

Figure 8. Material types and quantities

> Several fixtures and fittings were suitable to reuse;
> The report identified that 95% of the overall tonnes of materials were suitable to recycle;
> The remaining 5% of the materials was only suitable for landfill disposal.
Table 3 summarises the actual tonnes and waste management options of demolition arisings. The demolition contractor recycled the concrete, ceramics and inert materials on site. As the site did not need this material for landscaping these materials were crushed to produce Recycled Aggregate for sale off site.

**Conclusion**

This was a successful project that has exceeded the aspirations of the client and design team with regards to the amount of site waste that was recycled. The use of a pre-demolition audit helped to ensure the success of the project in terms of resource efficiency.

**Kings Crescent Estate, Hackney**

This case study was produced by BRE as part of CoRE London project. The Kings Crescent Estate (see Picture 2) redevelopment was chosen to become an exemplar project in the London region due to the high level of commitment London Borough of Hackney committed to implement resource efficiency practices throughout the demolition and refurbishment phase of the project. This includes, undertaking pre-demolition audits on selected projects.

**Project details**

The London Borough of Hackney Council is regenerating a number of estates within the Borough. Most of the Council’s stock is to be upgraded within the Decent Homes programme. In the specific case of
Kings Crescent Estate the report described it as an estate that was poorly designed and did not meet the Decent Homes standard. For these estates, the report recommended the Council adopt a comprehensive redevelopment approach.

The estate comprises of 404 units in a range of 5, 6 and 7 storey blocks arranged around the edges of the site, with the interior a number of two storey dwellings, open spaces, community facilities and car parking areas. The accommodation was a mixture of low rise housing, 1 and 2 bedroom flats, and 3 and 4 bedroom maisonettes. The linked blocks were of masonry and concrete construction with felt covered flat steel roofs. The family accommodation in the middle and upper floors has no access to private gardens or amenity space. There are a number of sealed-off semi-submerged underground car parks.

**Contractual agreement**

As part of the Sustainable Appraisal (SA) of the new development the saving of resources was one requirement that had to be fulfilled on the project. As a result when the demolition work was sent out for competitive tender it was stipulated in the tender documentation that the at least 85% of the total quantity of demolition arisings had to be reused or sent for off site recycling on the project. This recycling rate was based on the pre-demolition survey that was undertaken by BRE as part of the London CoRE programme. The tender documentation also asked from the demolition contractors to supply a SWMP for the proposed demolition work. SWMPs set out practices and procedures for the handling and management of site waste arisings. SWMP is a tool for improving overall environmental performance, meeting regulatory requirements and optimising the reuse and recycling of site waste. SWMPs can also reinforce other policy areas such as health, safety and sustainability on the project. Clifford & Devlin was selected to undertake the demolition work on the Kings Crescent Estate.

**Pre-demolition audit findings**

The pre-demolition audit findings anticipated the quantity of the different materials generated as a result of demolition. During the site survey the reuse and recyclability of the materials encased in the buildings and structures were assessed as shown by Figure 9.

**Figure 9. Waste management option of the different demolition material arisings.**

- 93% of the overall quantity of materials such as concrete and bricks were identified as suitable to use as Recycled Aggregate (RA) on site;
- 5% of the overall materials mainly in the metals and timber category were suitable for off site recycling;
- 2% of the overall quantity of materials was identified as only suitable for landfill disposal.
Demolition arisings processed by the demolition contractor
The demolition contractor Clifford & Devlin arrived on site in July 2007 to undertake the demolition of Codicote Terrace and the 2 storey buildings including demolition of the underground garage on Bramfield Court. The demolition work finished at the end of December 2007. Table 4 outlines the quantity of demolition arisings and their management implemented on the project.

Method of demolition
The demolition of the buildings was carried out by soft stripping, using the traditional removal of all hazardous materials first followed by the structural demolition of the buildings using low-rise machines with demolition attachments such as breakers and hammers.

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SWMP
A SWMP developed for the demolition work was based on the pre-demolition audit findings and SWMP template supplied by BRE as part of the CoRE project. It was a good opportunity to implement practices and procedures for the handling and management of site waste arisings so that in the future the preparation of SWMPs will become a routine requirement on all new demolition works planned under London Borough of Hackney’s forthcoming regeneration programme.

Table 4. Actual tonnes of demolition arisings

<table>
<thead>
<tr>
<th>Product</th>
<th>Tonnes</th>
<th>Percentage</th>
<th>Waste Management Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled Aggregates</td>
<td>2,680.0</td>
<td>89.0</td>
<td>On site recycling / reuse</td>
</tr>
<tr>
<td>Metals</td>
<td>136.3</td>
<td>4.5</td>
<td>On site recycling</td>
</tr>
<tr>
<td>Timber</td>
<td>120.6</td>
<td>4.0</td>
<td>Off site recycling</td>
</tr>
<tr>
<td>General waste</td>
<td>38.5</td>
<td>1.3</td>
<td>Landfill</td>
</tr>
<tr>
<td>Asbestos</td>
<td>27.0</td>
<td>0.9</td>
<td>Asbestos hazardous waste disposal</td>
</tr>
<tr>
<td>Plasterboard</td>
<td>8.9</td>
<td>0.3</td>
<td>Off site recycling</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>3,011.3</strong></td>
<td><strong>100.0</strong></td>
<td><strong>98% of materials recycled.</strong></td>
</tr>
</tbody>
</table>
The demolition contractor recycled the inert materials on site for reuse as backfill for the underground garage space and for landscaping purposes (see Picture 3).

**Picture 3. RA used as backfill and landscaping material on site.**

**Conclusion**

The support provided by the CoRE project helped the London Borough of Hackney to implement waste reduction principles and practices at the beginning stages of the site’s re-development. The pre-demolition audit provided the first step on the route to resource efficiency on the development. The project team used the recommendation given on achieving at least 85% overall recycling rate on the site and included this waste reduction clause in the demolition company’s tender documentation.

The demolition contractors’ selection process at the tender stage considered the economic, environmental and social credentials of the companies tendering for the job with equal weight. As a result the demolition contractor who was given the contract diverted 98% or 2,946 tonnes of the overall quantity of demolition arisings form landfill. The actual recycling rate 98% for the works surpassed the 85% recycling target stipulated at the start of the project.

This project demonstrated that early inclusion of waste minimisation clauses in the contract and monitoring of demolition raisings throughout the demolition phase can achieve a high recycling rate. The implementation of the SWMP on the demolition phase of the project also enabled the London Borough of Hackney’s regeneration team to have a better understanding of the SWMP requirements. This understanding will enable the regeneration team to oversee the implementation of the SWMPs during the construction of the social housing units on the Kings Crescent Estate development.

**Pre-refurbishment audit of Reading University**

This case study was based on a pre-refurbishment audit that was undertaken at the University of Reading as part of the CoRE South East project. This project addressed the potential for reusing and recycling components and materials generated as a result of refurbishment activities.

**Project details**

The estates management of the University of Reading undertook a phased refurbishment of some of Buildings 4 & 7 of the London Road campus in 2007. Buildings 4 & 7 are low rise red brick buildings that were built in 1908 and used as artists’ studios (see picture 4). No building work has been undertaken on the buildings after 1947 and refurbishment work had to be done in order to bring them in line with new building and safety standards. Thereafter the buildings are to be used as offices for the university’s estate’s management.

The building works undertaken were:

- Removal of doors;
- Removal of some of the internal partitions;
- Removal of heating system;
- Removal of existing wiring; and
- Re-roofing.
Buildings 4&7 are adjacent to each other and are connected by a corridor. All the walls in the buildings are made up of red bricks.

**Picture 4. Buildings refurbished.**

**Pre-refurbishment audit findings**

The aim of the audit was to provide an informed targeting of Key Refurbishment Products (KRP) for, reclamation and recycling (in that order of priority). The building included Victorian period style fittings and building materials. Figure 10 summarises the quantities of materials removed from the buildings. After inspecting the building internally, 3 products were chosen for a reclamation valuation and 3 products were identified as suitable for recycling. Table 5 represents the recovery options assigned for the surveyed materials. Criteria set for selecting these key demolition products include, economic value, the number of units and viability of deconstruction.

**Figure 10. Quantities of refurbishment materials removed from the buildings.**
Table 5. Material quantities by recovery option.

<table>
<thead>
<tr>
<th>Product</th>
<th>Reclaim (t)</th>
<th>Recycle (t)</th>
<th>Reclamation valuation (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slate Roof Tiles</td>
<td>92</td>
<td>-</td>
<td>£46,000</td>
</tr>
<tr>
<td>Timber Doors</td>
<td>0.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cast Iron Radiators</td>
<td>22</td>
<td>-</td>
<td>£14,400</td>
</tr>
<tr>
<td>Red Bricks</td>
<td>-</td>
<td>12.9</td>
<td>-</td>
</tr>
<tr>
<td>Ceramics</td>
<td>-</td>
<td>1.9</td>
<td>-</td>
</tr>
<tr>
<td>Cast iron Piping</td>
<td>-</td>
<td>7.5</td>
<td>£262</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>115</strong></td>
<td><strong>22</strong></td>
<td><strong>£60,662</strong></td>
</tr>
</tbody>
</table>

**Reclamation**

> The audit recommended the recovery of the slate roof tiles to be taken down and reclaimed. The roof tiles covered approximately 1,300 m² and to advertise the slate tiles free of charge on www.salvo.co.uk. At the time of the audit there were 20 entries on the SALVO website from businesses and individuals who wanted to source slate roofing tiles. For example, a roofing company Bethesda Slate Company in Wales pays £500 / tonne of reclaimed slate roofing tiles.

> Cast iron radiators can be sold via architectural salvage yards. At the time of the audit the price per reconditioned small radiators was £270. Using a conservative estimate of £120, since the radiators had to be reconditioned before selling on, the project could realise approximately £5,400 for 45 x no. radiators.

> It was recommended to take out the pine doors with their frame and ironmongery intact for reclamation via the SALVO Website.

> As the bricks were laid using cement mortar, it would usually be too labour intensive to clean up individual bricks for reclamation. Since small quantities of bricks were removed from the wall areas and the bricks were of a high quality it was suggested that it would be reasonable to spend time cleaning them and sell these off as reclaimed bricks.

**Recycling**

> In the case of the bathroom, sinks and toilets cannot be sold on. However, these items could be sent off to a local company who takes in construction and demolition waste for processing into recycled aggregates;

> The cast iron pipes were suitable for off site recycling. Rates payable for mixed steel was £35 / tonne.
Conclusion
This project identified 6 KRPs and identified extensive potential to divert refurbishment waste from landfill, with over 95% by weight available from quick wins, (bricks ceramics and metal recycling) and selling off the architectural salvage items such as cast iron radiators and slate roofing tiles. It was estimated that the economic potential of the selected 6 KRPs could realise an income of £60,662.

Eastern CoRE – Stoney Hall, Stevenage
This pre-demolition audit was carried out by BRE at the request of Wilmott Dixon Housing under the Eastern CoRE programme. This pre-demolition audit addressed the potential for reusing, reclaiming or recycling components and materials from the Stoneyhall Estate in Stevenage whereby Wilmott Dixon carried out a phased rebuilding of this social housing estate.

Project details
The buildings on this estate were low-rise blocks of two to four storeys of assumed concrete crosswall construction, faced in brick. They contained a total of 43 housing units, principally flats with 6 two-storey maisonettes in Blomfield House (see picture 5), Bates, Bertram and Edwards Houses share a similar layout with two main entrances and stairwells each, and each flat having a balcony with metal railings. Blomfield House has a different design, with each unit having its own entrance, and a pitched roof. There are a total of 30 brick garages in 4 separate blocks. Windows are generally single-glazed metal frames and entrance and internal doors mostly timber, though there are some replacement UPVC units, particularly at the rear of Bertram House.

Picture 5 Stoney Hall social housing estate.

Pre-demolition audit findings
This pre-demolition report aimed to provide quantities of demolition arisings as a result of demolishing the main structure and the remaining internal components.

Figure 11 Materials contained in within the buildings.
Figure 11 shows the volume of materials present in the buildings on the Stoney Hall Estate. Knowing the volume of materials arising within the building helped better planning of vehicles and containers needed to process and transport the materials on this phased demolition project. Figure 12 shows the volume and tonnes of the different material types surveyed within the buildings of the Stoney Hall estate.

**Figure 12 Material group by overall volumes and tonnes.**

Converting the material volumes into tonnes enabled the project to estimate the value of materials on the recycling market. Knowing the worth of materials helped the project to prepare the tender documentation for the demolition works. This information also helped the project team to set material recovery targets within the tender document.

The report identified that recovering the ferrous and non-ferrous metals from the buildings and structures would gain the project approximately £30,000.

**Environmental Valuation**

Aluminium is the most cost-effective metal to recycle: recycled aluminium saves 95% of the energy costs and CO2 emissions associated with virgin production. Recycling 1 tonne of aluminium saves 10 tonnes of raw materials and 14,000 kWh of energy.

1 tonne of recycled steel saves 2 tonnes of raw materials and 70% of the energy required to produce virgin material.

**Reclamation**

The social housing estate was built in the 1960’s so the items that were identified as suitable for reclamation are generally not considered as ‘high value’, as it is the case with architectural salvage items for example. Nevertheless it is always worthwhile to make an effort to reuse as much building products if there is an opportunity and possibility to do so.

Items identified as suitable for reclamation were:

> Decorative wrought ironwork on ground floor balconies (4 x No panels) (see picture 6);
> Hardwood timber main entrance doors to the buildings (4 x no) (see picture 7);
> Entry system (Videx door panels 6 x No, Videx handsets x 34 No);
> Fire alarm and lighting systems;
> Electricity meters (43 x No). Each flat had its individual electricity meters;
> Timber internal doors (265 x No) (see picture 8), and cupboard doors on built-in wardrobes in similar numbers;
> Emergency light fittings on stairwells.
Reclamation values on key demolition products were not given since these are entirely dependent upon finding a market for the right items at the right time. Experts advise that a long lead-in time and maximum exposure are required. The best chances for use, with the best environmental and economic benefits, are as near to site as possible:

- Used in the redevelopment;
- Used by the same client locally;
- Sold or given away locally.

The following recommendations may assist in maximising the reclamation potential of KDPs:

- Consider setting aside storage on site for segregation of salvage items;
- Advertise specific salvage items for free on www.salvo.co.uk or low value materials on www.salvomie.co.uk;
- Contact local architectural salvage merchants about specific items. Salvo publishes a directory on their website. Local options listed on BREMAP www.bremap.co.uk.

**Conclusion**

- The pre-demolition report identified 11 key demolition product groups and identified extensive potential for diverting demolition waste from landfill, with over 95% by volume available from quick wins (concrete & brickwork and metal recycling) making sound economic sense. If time and space allows, serious consideration should be given to reclamation. All of these actions will reduce the environmental impact of the demolition process.
Conclusion and recommendations

The demolition Industry in Britain is represented by the NFDC with a current membership of 167 demolition contractors. The demolition industry has grown significantly in the last decade demonstrated by the increasing value of work undertaken and workforce employed, that showed a 7% increase between year 2006-07.

On behalf of the demolition contractors, the NFDC collects annual demolition arisings for inert and hazardous waste and their management method from its members, which accounts for 80% of the contract value of the work that is carried out nationally. Using this information it is possible to provide annual demolition arisings processed by both the NFDC and non-NFDC members. In 2007 the demolition industry processed 32.7 Mt of demolition arisings. Approximately 88% of the inert materials handled by the demolition contractors are either recycled and used on site or recycled on site and then sold and sent off site. Currently the Industry is not reporting on the non-aggregate materials such as timber, insulation, plasterboard, and plastics. To establish compositional data for demolition arisings, BRE’s pre-demolition database was utilised. Based on the pre-demolition audit compositional data, except concrete and inert demolition waste, the quantity of metals (10%), timber (7%) and plasterboard (1.4%) were the most prevalent non-aggregate waste streams.

There are many regulatory and technological drivers affecting the demolition industry in Britain today. The aims of these instruments are to ensure that the workforce adheres to safe practices as a result of the stringent Health and Safety regulations. There is an increasing level of environmental regulation being implemented to drive the industry towards sustainable waste management practices for its own sake and also for the sake of the construction Industry that uses the reprocessed materials recovered by the demolition contractors.

BRE offer the service of pre-demolition audits during which the building and the components within it are audited to determine what the key demolition products are and make recommendations for their reuse (on and off-site), recycling or final disposal. The main aim of these audits is to maximise materials available for reuse and recycling and to minimise materials going to landfill. The findings of 4 pre-demolition audits have been written up as best practice case study examples, to provide guidance to the construction and demolition industry of how to achieve resource efficiency targets that are becoming more imperative when re-development and refurbishment projects get the green light. Three case studies were based on the Construction Research Efficiency (CoRE) project funded by Defra under the BREW (Business Resource Efficiency & Waste) programme, which aimed to recycle landfill tax receipts into targeted resource efficiency support for business. The pre-demolition audit reports prepared for the clients demonstrated that involving the project team and bringing all parties together early on in the development can result in increased reuse, and recycling of materials and minimise the quantities of demolition arisings entering landfill. A pre-demolition and pre-refurbishment audit is the first step to raise awareness of resource efficiency issues on site.

Issues for future consideration by all parts of the construction supply chain include:

- The increasing use of MMC and the potential for other types of demolition waste arisings which could be harder to recover;
- The requirements to design with deconstruction in mind;
- Usage and selection of materials as end of life choices;
- Allowing time within the demolition process to ensure the value of demolition waste is fully realised;
To investigate recovery options for difficult demolition wastes such as insulation containing ozone depleting substances.

**Recommendations**

**Measurement**

The demolition industry needs to be more transparent about the type and quantity of waste they produce on an annual basis. Annual tonnages of inert and hazardous waste materials are disclosed by the NFDC members. Other waste streams however are either not being monitored, or not disclosed. Site Waste Management Plans (SWMP) would be an appropriate vehicle to encourage demolition contractors to report on the tonnages of materials produced as a result of demolishing a building. The SWMP will also identify disposal routes that take into consideration the waste hierarchy principle. Undertaking a pre-demolition audit of a building whereby the different material streams are quantified would be a useful tool for the demolition contractors to systematically record and report the tonnages of materials arising. There is potential for this information to be an important part of the SWMP submitted by the demolition contractors at the tender stage. However, it would also be necessary for clients to routinely request this information from the demolition contractors so that, apart from requesting price information for a particular job, information on waste disposal routes are also factored in to fully assess the best candidate to undertake demolition work. BRE’s SMARTWaste plan monitoring tool would be a suitable way to implement this.

**Future recyclability of materials**

This study highlighted that with the increase in the MMC predicted for the future it is also likely that the use of composite materials will be more prevalent in the new build and refurbishment sectors. Research on new recycling or recovery technologies that could efficiently deal with the rising quantities of specialist building products such as insulation panels, timber products and composite building elements would be beneficial for the future.

**Difficult demolition waste streams**

Products that reached the end of their life may be classed as ‘difficult’ wastes. These can include ozone depleting insulation panels, WEEE items, batteries, smoke alarms and certain flooring products. They are termed as ‘difficult’ waste as they may be problematic to recover, which could be due to their material composition, techniques of demolition / strip out, contamination and value of recovery and as a result are likely to end up in landfill. It would be beneficial to carry out further research on those building products that fall into this category by establishing how much of these materials are encased in buildings now, and in the future, and determining the difficulty of recovering these products from buildings.

**Raising the client’s awareness**

A key issue is to ensure that the client is fully aware of the importance of the demolition stage of a project for resource efficiency. The industry cites the lack of time for demolition as a problem, which means there is less time to reclaim materials for reuse and separate materials for higher value recycling. Pre-demolition audits are a useful means for the client to understand the value of the demolition materials and set targets on the demolition contractor; they also feed into Site Waste Management Plans.

**Environmental assessment**

The demolition industry recovers a high proportion of waste generated from the demolition of buildings’ and structures. From an environmental perspective, it would be useful to quantify the reduction in environmental impact from diverting this waste from landfill and replacing raw materials including savings in embodied carbon. This could be included within pre-demolition audits and Site Waste Management Plans.
PROJECT PARTNERS

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