

Report to DGXI, European Commission

**CONSTRUCTION AND DEMOLITION
WASTE MANAGEMENT PRACTICES,
AND THEIR ECONOMIC IMPACTS**

**Final Report
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Report by Symonds, in association with ARGUS,
COWI and PRC Bouwcentrum

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1. INTRODUCTION

The provenance of this Report

- 1.1 This is the Final Report of the study into 'Construction and Demolition Waste Management Practices, and their Economic Impacts' undertaken between January 1998 and March 1999 by The Symonds Group Ltd (from the UK) in association with ARGUS (from Germany), COWI Consulting Engineers and Planners (from Denmark) and PRC Bouwcentrum (from the Netherlands). The Terms of Reference (Technical Annex) for the study can be found in Annex 1. Although the Commission will make copies of this report available to interested parties, it does not necessarily endorse every opinion or conclusion as stated.
- 1.2 An Interim Report was delivered to the Commission in July 1998, and selected findings and data were prepared for circulation to the members of the Waste Management Committee prior to their meeting in October 1998. Progress meetings with the Commission were held on 30 January, 27 April, 19 August and 14/15 December 1998.

The structure of this Report

- 1.3 This introductory chapter seeks to put the issue of construction and demolition waste (C&DW) into some sort of context, as well as explaining the principal objectives of the study.
- 1.4 In Chapter 2 we address in much greater depth the typology and classification of C&DW, and the relationships between its origins and characteristics. We also deal with the question of hazardousness, and with other characteristics which make certain components of C&DW suitable for separate collection.
- 1.5 Chapter 3 sets out the major economic and administrative considerations which drive decisions on re-use and recycling of C&DW.
- 1.6 Chapters 4-6 deal with processes and best practice guidance related to different site types. We do not seek to reproduce details of best practice as such, but to identify where and by whom it has been documented, and thereby to provide a practical overview of the subject.
- 1.7 Chapter 7 presents our findings on the best available estimates of C&DW arisings in each Member State, and Chapter 8 summarises the measures which each Member State has taken to influence the level of re-use and recycling. The details supporting the conclusions set out in these two Chapters will be found in Annexes 5 and 6.
- 1.8 Chapter 9 presents practical findings and conclusions related to the economics of C&DW re-use and recycling.
- 1.9 Chapter 10 summarises our conclusions as to which interventions (at EU, national and local level) are most likely to result in predictable and positive outcomes.
- 1.10 There are 13 Annexes in total, the last of which provides definitions and descriptions of many of the technical terms used throughout this report, and explanations of the acronyms employed.

Construction and demolition waste: how big an issue is it?

- 1.11 Following the Council Resolution of 7 May 1990, which invited the Commission to establish proposals for action at Community level, the Priority Waste Streams Programme was initiated. C&DW was identified by the Member States as one such stream, even though at the time relatively little was known about the nature or volumes of the flows concerned.
- 1.12 The objectives of the Priority Waste Streams Programme respond to the waste management hierarchy, which prefers waste prevention or reduction to re-use, re-use to recycling or recovery (including the use of waste as a source of energy), and all of these to final disposal via landfill or incineration without energy recovery. Although not expressed in these terms in any of the key documents, the hierarchy is generally summarised as:

- (i) prevention or reduction (sometimes termed avoidance or minimisation);
- (ii) re-use;
- (iii) recycling or materials recovery;
- (iv) energy recovery;
- (v) disposal in a safe manner.

- 1.13 It was known that most C&DW had traditionally been landfilled, frequently in the same landfills as were used to dispose of municipal solid waste (MSW). Furthermore, it became clear that the volume of C&DW, most of which is inert, was roughly equal to that of MSW. Given the increasing scarcity of landfill space, and the increasing costs of improved environmental protection involved in modern landfill engineering and management, it was obvious that action to re-use or recycle C&DW would reduce the proportion going to landfill, thereby relieving the pressures on MSW disposal as well as respecting the hierarchy of waste management practices set out in the Framework Directive on waste (75/442/EEC as amended by 91/156/EEC) and the Fifth Environmental Action Programme.
- 1.14 At the same time some Member States were taking actions to relieve these pressures, and EU-wide programmes such as LIFE were addressing the issues raised by the waste hierarchy from the other end by looking for ways of designing structures in ways that reduce future waste flows, and by encouraging the use of secondary and recycled materials in new construction. Annex 10, Ref 11.1 provides an example of this work, which complements that of the Priority Waste Streams Programme. Similar initiatives were taken at national levels in several Member States.
- 1.15 As a direct result of the Priority Waste Streams Programme, a specially-convened project group met to advise the Commission on matters related to C&DW management between 1992 and 1995. The members of this 60-strong group included representatives from national, regional and local governments and agencies as well as the construction industry, the construction materials supply industry and the waste management industry. The Symonds Group and ARGUS acted as Technical Consultants to the project group. The project group's final report made recommendations for action on a range of issues, as discussed later in this Report. Among these were recommendations designed to tackle the widespread lack of reliable statistical data on C&DW arisings and practices noted by the working group.
- 1.16 Annex 2 provides additional information on the C&DW Priority Waste Streams Programme, in the form of Chapter 1 from the project group's final report. This helps to set this current study into a better overall context, and to explain why the Terms of Reference were drafted in the way that they were, with a considerable emphasis on identifying better and more consistent data.
- 1.17 We concentrate in this Report on what we have called 'core' C&DW. This is essentially the mix of materials obtained when a building or piece of civil engineering infrastructure is demolished, though we include under the heading those same materials when they arise as a result of construction. 'Core' C&DW excludes road planings, excavated soil (whether clean or contaminated), external utility and service connections (drainage pipes, water, gas and electricity) and surface vegetation.
- 1.18 Despite the factors which will affect the composition of 'core' C&DW in future (as discussed later), it is extremely likely that the inert (or decontaminated) fraction which is suitable for crushing and recycling as aggregate will continue to be the largest component. This can include materials such as glass which, although not directly comparable to primary aggregates, do not detract from the performance of the C&DW-derived aggregate if included in reasonable proportions.
- 1.19 One of the keys to maximising the yield of C&DW-derived aggregates is separation of materials at source, predominantly through selective demolition (see Chapter 4 and Annex 13 for a description of this activity) and good management of construction sites.

- 1.20 This study shows that, in the EU as a whole, arisings of 'core' C&DW alone amount to around 180 million tonnes each year (see Figure 1.1). This is over 480kg per person per year, and only about 28% across the EU-15 as a whole is re-used or recycled. Landfilling the other 72% (some 130 million tonnes a year) at a density of 1.0 requires the equivalent of a brand new landfill 10m deep and roughly 13 square km in surface area every year. To illustrate this, 13 square km is a circle with a diameter of just over 4km. Put another way, if central Paris (within the Boulevard Périphérique) were to be used, the level of waste would rise by roughly 1.3m every year. Adding construction waste, road planings and excavated soil and rock to this figure more than doubles the total weight and volume of material to be managed. Five Member States (Germany, the UK, France, Italy and Spain) account for around 80% of the total of 'core' C&DW, which is broadly consistent with the share of the overall construction market accounted for by these same countries. Data on the size and year-on-year changes in construction sector turnover and employment over the past decade can be found in Annex 3.

Figure 1.1: C&DW Arisings and Recycling (Summary Table)			
Member State	'Core' C&DW Arisings (m tonnes, rounded)	% Re-Used or Recycled	% Incinerated or Landfilled
Germany	59	17	83
UK	30	45	55
France	24	15	85
Italy	20	9	91
Spain	13	<5	>95
Netherlands	11	90	10
Belgium	7	87	13
Austria	5	41	59
Portugal	3	<5	>95
Denmark	3	81	19
Greece	2	<5	>95
Sweden	2	21	79
Finland	1	45	55
Ireland	1	<5	>95
Luxembourg	0	n/a	n/a
EU-15	180	28	72

Source: Annex 5

- 1.21 A high proportion of conventional demolition waste, and particularly the fraction derived from concrete, bricks and tiles, is well suited to being crushed and recycled as a substitute for newly quarried (primary) aggregates in certain lower grade applications, most notably engineering fill and road sub-base. This practice has been common (though not necessarily widespread) in several Member States for many years. The use of such C&DW-derived aggregates in new concrete is much less common, and technically much more demanding.
- 1.22 These materials therefore have the potential to displace equivalent volumes of primary aggregates, thus preserving non-renewable resources, with minimal need for landfill space. Reducing pressure on increasingly scarce landfill space is widely seen as one of the key benefits of C&DW recycling. In some Member States the volume of C&DW going to landfill exceeds that of household waste.
- 1.23 The only Member State where industry sources have expressed a concern that the supply of C&DW-derived aggregates may one day match the construction industry's capacity to substitute them for primary aggregates is the Netherlands. In general the volume of primary aggregates extracted and used in Member States is at least four times as great as the potential upper limit for C&DW-derived aggregates, and well above existing levels of production (see Annex 4). Nevertheless it must be acknowledged that, as things stand, by no means all of this primary aggregate could be displaced by C&DW-derived aggregate of an equivalent quality.
- 1.24 The largest single consumer of aggregates in most Member States is the road construction industry (including roads and car parks on housing developments, business and retail parks and industrial estates). This sector has generally led the way in accepting and using C&DW-

derived aggregates (as well as secondary aggregates such as pulverised fly ash and mine tailings).

- 1.25 However, road builders (and other construction companies) generally choose their materials on the basis of their suitability (sometimes referred to as their 'fitness for purpose', but also taking into account any applicable standards) and their price. In areas where quarries and/or sources of competing secondary aggregates are widespread and landfill costs are low, C&DW can find it impossible to compete on price.
- 1.26 These issues are considered in more detail in Chapters 3 and 9, but at this point it is worth drawing particular attention to the impact of marble (and other cut stone and china clay) quarries. Only about 10% of the material quarried is usually sold as marble blocks, and the remainder is broken up and sold (or even given away) as primary aggregate. This can substantially distort the market for aggregates in the local area around the quarries, though the impact declines when more urban areas are considered. The case for choosing these primary aggregates over C&DW-derived aggregates can be further boosted by the fact that quarry wastes ('scalpings') are not always in practice subjected to the full provisions of the Framework Directive on waste. The proportions (of primary material to waste) are different with china clay, but the effect of a large reservoir of very cheap competing material is the same.
- 1.27 Notwithstanding the above, there is evidence of a general trend for the price of both landfill space and primary (natural) aggregates to rise relative to transport costs. In general, the more valuable a product (in ECU/kg), the greater the distance over which it will be traded, and the greater the choice of suppliers from which individual users can choose. If landfill costs and primary aggregate prices continue to rise, both primary and C&DW-derived aggregates may in future tend to travel further. There is already a substantial cross-border trade in primary aggregates (see Annex 4), and this may well be emulated by C&DW-derived aggregates in future, making internal market considerations a bigger issue than at present. There is at least one instance (in the UK) of a former air base (the runways of which represent a very large source of high quality concrete) being recycled adjacent to a railway siding. The normal time pressures so often present on city centre demolition sites are also less severe under such circumstances. This is close to being an artificial quarry with low-cost transport, and other similar ventures could be developed in several Member States in future.

The environmental and amenity justification for C&DW recycling

- 1.28 Quite apart from depleting the stock of natural resources, the quarrying and processing of primary aggregates involves the generation of obvious environmental and amenity impacts, most of them limited to the local area surrounding the quarry. Transporting the aggregates to their final point of use generates a separate and more widely dispersed set of impacts common to those associated with bulk transport in general. Depots and bulk storage facilities (at railheads, for example) have their own associated impacts.
- 1.29 Considering first the impacts from quarrying, the scale and detail of the impacts depends to some extent on the product being quarried. Digging sand is a much quieter, less dusty activity than blasting and crushing hard rock, and marine dredging at a carefully selected location has the potential to cause substantially fewer problems than land-based quarrying. The main environmental impacts from terrestrial quarries are likely to include:
- (i) noise and dust;
 - (ii) some air pollution (from blasting, but more generally from the use of internal combustion engines);
 - (iii) vibration (from blasting, which can in turn open up fissures in the underlying rock, changing drainage patterns and allowing pollution to reach groundwater);
 - (iv) potential for pollution of surface and groundwater by fuels and lubricants used in plant and machinery;
 - (v) visual and aesthetic impacts;

- (vi) changes in land form (associated with both visual impacts and changes in surface water drainage);
 - (vii) changes to natural habitats and possible destruction of historical artefacts.
- 1.30 Some of these impacts are primarily environmental, but others depend on the presence of people, and can more correctly be termed amenity impacts. Quarries in remote areas cause fewer and less severe amenity impacts than those in urban or suburban settings. By contrast, remote quarries rely on transport links to deliver their aggregates to the final user. Transporting aggregates, whether by road or rail, generates further impacts in the form of noise, vibration, dust and air pollution, and contributes to the visual and severance impacts associated with existing infrastructure. It also uses up non-renewable energy resources. Delivery by boat or barge is generally less damaging, but is obviously limited in its application.
- 1.31 Where aggregates are supplied from quarries rather than from C&DW, the C&DW has to be dealt with in another way, which generally means landfilling it. A secondary impact from favouring primary aggregates is therefore additional landfilling. Although much C&DW is inert and the environmental impacts are therefore relatively mild, there are nevertheless adverse environmental impacts from the associated transport.
- 1.32 Changing from quarrying to C&DW recycling may avoid some of the above impacts, but it could introduce others. Moreover, because both C&DW arisings and potential locations for their re-use after processing are likely to occur in more urban settings, any impacts may well have the potential to affect more people. It should be stressed that these additional impacts do not include those associated with demolition itself, because the demolition process will occur whether or not the resultant waste materials are recycled.
- 1.33 The breaking up, crushing, sorting and stockpiling of C&DW-derived aggregates is likely to generate:
- (i) noise and dust;
 - (ii) some air pollution (from the use of internal combustion engines);
 - (iii) potential for pollution of surface and groundwater by fuels and lubricants used in plant and machinery;
 - (iv) visual and aesthetic impacts (particularly if the processing site is a green field or urban site);
 - (v) changes to natural habitats and possible destruction of historical artefacts (if the processing site is a green field site).
- 1.34 The transport and delivery impacts associated with C&DW recycling are essentially the same as those associated with primary aggregates delivered by road, unless the C&DW can be processed and used on the original site, in which case they are taken out of the equation altogether. In general rail transport is far less likely to be a practical proposition for C&DW recycling (which moves from site to site) than it is for quarrying (which stays in one place). There are exceptions to this statement (such as the city of Berlin), but they are few and far between.
- 1.35 The above arguments concentrate on the inert fraction of C&DW which can be processed into aggregates. However, C&DW includes non-inert materials, and the environmental case for re-using or recycling these rather than sending them for final disposal to either a landfill or an incinerator is clear, particularly in the case of the more hazardous fraction. However, despite the benefits of avoiding landfilling or incineration, it should be acknowledged that processing is not an impact-free activity.
- 1.36 More complex C&DW processing and sorting systems, such as are found at fixed C&DW recycling centres, may well generate additional impacts. Some of these impacts (such as noise) will be similar in nature but different in intensity to those listed above. Others will go

beyond those listed above, of which the most serious is likely to be potential pollution to the water environment as a result of the washing of C&DW-derived aggregates to remove unwanted fractions (such as wood and plastic). Such potential impacts can be mitigated, but at a cost which will be reflected in the recycling centre's gate price (defined in Annex 13).

- 1.37 We would suggest, therefore, that for a specific volume of aggregates used in construction (including landscaping), quarrying primary aggregates and landfilling the equivalent volume of C&DW is less environmentally desirable than recycling the C&DW into C&DW-derived aggregates.

The changing nature of C&DW

- 1.38 The nature of today's demolition waste is directly influenced by the building techniques and materials which were in vogue when the buildings, civil engineering structures and associated infrastructure being demolished today were built. This is considered in greater depth in Chapter 2.
- 1.39 The nature and volumes of demolition waste arisings also reflect the solidity and flexibility (and therefore the life expectation) of the structures themselves, and the balance in the economy and investment (between housing, industry and the service sector) of previous years. The nature and volume of today's construction waste, by contrast, reflects today's building materials and activity levels.

The objective of this Report

- 1.40 By agreement with the Commission, this Report is designed to be 'action-oriented'. It seeks to highlight practical measures which can be taken to encourage the re-use and recycling of C&DW. It does not seek to go into great detail on either a technical or an economic level, but rather to strike a balance between these factors. It seeks to distinguish between those measures which have been proven to be effective under one set of very particular national circumstances but which will probably not travel successfully, and those which can probably be applied widely and effectively.
- 1.41 Following the initial round of data collection, it was agreed with the Commission that more effort should be spent on improving the consistency of these data. Any process of economic modelling which relies on poor quality data has the potential to mislead more than it illuminates, so a more robust approach was agreed to be appropriate.

2. TYPES OF CONSTRUCTION AND DEMOLITION WASTE

Classification and recording of C&DW

The origins and nature of C&DW

- 2.1 The 'umbrella' term C&DW can cover a very wide range of materials. The most obvious categories are:
- (i) waste arising from the total or partial demolition of buildings and/or civil infrastructure;
 - (ii) waste arising from the construction of buildings and/or civil infrastructure;
 - (iii) soil, rocks and vegetation arising from land levelling, civil works and/or general foundations;
 - (iv) road planings and associated materials arising from road maintenance activities.
- 2.2 Cross-contamination and general mixing of materials is frequently observed on construction and demolition sites. This is of greatest concern if the mixing involves hazardous materials (using the term as defined in Directive 91/689/EEC). This applies to materials such as asbestos and to certain heavy metals (such as lead), solvents and adhesives.
- 2.3 Questions related to hazardousness and suitability for separate collection are dealt with at the end of this Chapter. In this context wastes which are suitable for separate collection include those that are hazardous, those that are valuable when separated, those that by any objective measure would be better separated, and those that are deleterious to the inert (or any other) fraction if mixed with it.

The current position on C&DW classification

- 2.4 The report of the C&DW Priority Waste Streams Project recommended (in its recommendation number 2) that:

"Member States should be encouraged to adopt the following classifications (taken from the European Waste Catalogue) as the framework within which future construction and demolition waste management planning will be undertaken, and waste arisings data collected and reported:

- *concrete, bricks, tiles, ceramics, and gypsum based materials (EWC code 17 01 00);*
- *wood (EWC code 17 02 01);*
- *glass (EWC code 17 02 02);*
- *plastic (EWC code 17 02 03);*
- *asphalt, tar and tarred products (EWC code 17 03 00);*
- *metals (including their alloys) (EWC code 17 04 00);*
- *soil and dredged spoil (EWC code 17 05 00);*
- *insulation materials (EWC code 17 06 00);*
- *mixed construction and demolition waste (EWC code 17 07 00)*

Hazardous components of construction and demolition wastes should also be identified."

- 2.5 Since that recommendation was made (in 1995) it has been decided that the EWC itself would be reviewed, and an expert working group drawn from Member States, DGXI and Eurostat is currently looking at this. We have been asked by the Commission, as part of this study, to comment on the advisability and implications of amending the EWC to make C&DW statistics more useful. We offer the following observations.
- 2.6 It has become apparent that different Member States interpret and record the EWC categories in slightly different ways. Some evidently record consignments of mixed waste according to their component elements, where these are known: for example 35% brick, 45% concrete, 15% timber and 5% plastic rather than 100% mixed waste. The former classification (by component) has the merit that it identifies those materials which may have potential for

re-use or recycling, though the latter may more accurately reflect the nature of treatment and disposal facilities required to manage the wastes.

- 2.7 A questionnaire was circulated by us to the members of an expert statistical working group to seek clarification on how materials are classified, and how statistics are recorded (and/or estimated) in different Member States. The findings from this survey are reported in Annex 8 to this Report. We have also drawn on the knowledge and experience of the study team members.
- 2.8 There are some specific matters worthy of note and further consideration in the context of EWC revision, particularly with regard to mixed concrete, bricks and other similar materials which can be crushed and used as C&DW-derived aggregates. It appears that:
- (i) in Germany and the Netherlands, for instance, a pile of concrete waste with comparatively small proportions of brick and gypsum mixed in with it would be recorded under 17 01 00;
 - (ii) in the UK, by contrast, the same material would probably be recorded as 17 07 00.
- 2.9 This difference in approach depends on whether the interpretation is what we have called 'top down' or 'bottom up'. 'Top down' classification involves finding the most appropriate top level classification and recording the waste there, whether or not it can be assigned to one of the sub-categories. 'Bottom up' classification involves finding the most appropriate sub-category, and calculating the totals of the top level classifications by adding the values for each sub-category. In an ideal world, of course, both approaches lead to a common result; in practice they seldom do.
- 2.10 In the specific context of C&DW classification, those who take the 'top down' approach assume that 17 01 00 includes any waste which only includes concrete, bricks, tiles, ceramics, and gypsum-based materials, whether mixed up together or not, whereas followers of the 'bottom up' approach treat 17 01 00 as being strictly the sum of its sub-categories. 'Bottom up' classifiers would assemble the total for 17 01 00 by adding the sub-totals for unmixed concrete (17 01 01), unmixed brick (17 01 02), unmixed tiles and ceramics (17 01 03), unmixed gypsum-based construction materials (17 01 04) and unmixed asbestos-based construction materials (17 01 05). The last sub-category does not include asbestos-based insulation materials, which are covered by 17 06 00. 'Bottom up' classifiers would place any mixtures of these (and other) materials into 17 07 00 (mixed C&DW).

Two alternative proposals for change

- 2.11 In developing the following proposals for changes to the EWC we have made reference to both the introductory notes to the EWC which describe its purpose, and to the waste hierarchy set out in the European Community policy document 'A community strategy for waste management (SEC/89/934(Final))' and reaffirmed in Chapter 5.7 of the Fifth Environmental Action Programme (COM(92)23).
- 2.12 Clause 5 of the introductory note to the EWC states "*The EWC is to be a reference nomenclature providing a common terminology throughout the Community with the purpose to improve the efficiency of waste management activities.*"
- 2.13 We have already summarised the waste management hierarchy (in Chapter 1) as prevention, re-use, recycling or recovery of materials, energy recovery and the safe disposal of waste which cannot be re-used or recycled, in that order. In particular Article 3 of the Framework Directive on waste (Directive 75/442/EEC as amended by Council Directive 91/156/EEC) requires Member States to "*take appropriate measures to encourage ... the recovery of waste by means of recycling, re-use or reclamation or any other process with a view to extracting secondary raw materials...*"
- 2.14 We have therefore started from the premise that one of the primary purposes for collecting C&DW statistics *per se* is to enable waste planners at all levels (local, national and EU) to plan accurately to meet the objectives of the hierarchy. It would therefore be desirable that the categories in the EWC should reflect as accurately as possible the potential for re-use

and/or recycling of the materials concerned, and identify the requirement for treatment or disposal, thereby providing meaningful data which planners can use.

- 2.15 In suggesting redefinitions of the classifications we have also tried to remove ambiguities which could lead to those recording the waste being faced with a choice of categories. Our aim has therefore been to produce a list of mutually exclusive categories which will provide a consistent approach and avoid potential 'double counting'.
- 2.16 EWC category 17 01 00 represents one of the major C&DW streams and is one which offers significant potential for the recycling of materials as construction aggregates. Accordingly if the statistics are to be as useful as possible to waste planners, then there is a reasonable case to be made for removing from 17 01 00 those materials which might be best kept out of C&DW-derived aggregates. This certainly applies to asbestos-based construction materials (17 01 05) which will release hazardous fibres to the atmosphere if crushed, and might also be considered to apply to gypsum-based materials, for two reasons:
- (i) gypsum adversely affects the quality of C&DW-derived aggregates;
 - (ii) some Member States, including Germany and the Netherlands, propose to ban gypsum from most landfills.
- 2.17 Category 17 02 00 contains three specific but unrelated materials (wood, glass and plastic), and it would be possible to argue that a further sub-category (17 02 04) might be added to record gypsum-based materials or mixed materials in which the gypsum content exceeds a certain level (which would have to be set by appropriate technical experts).
- 2.18 In a similar way, asbestos-based construction materials might be added as a new sub-category to 17 06 00, re-naming the main category as 'asbestos-based construction and insulation materials, and other insulation materials'.
- 2.19 At the same time it would be worth considering re-defining 17 01 00 as 'predominantly inert concrete, bricks, tiles and ceramic materials' and revising the remaining sub-categories to reflect more accurately their potential use as C&DW-derived aggregates. This would allow Member States either to record a single figure for 17 01 00 or to opt to collect statistics at a greater level of detail according to eventual destination. One proposal would be as follows:
- (i) 17 01 01 concrete (including reinforced concrete);
 - (ii) 17 01 02 bricks (possibly further broken down into 17 01 02 01 whole bricks and 17 01 02 02 broken or mixed bricks);
 - (iii) 17 01 03 tiles and ceramics (possibly further broken down into 17 01 03 01 whole tiles and 17 01 03 02 broken or mixed tiles and ceramics);
 - (iv) 17 01 04 any mixture of the above, plus an acceptably low level of other materials (contraries).
- 2.20 For each of the above sub-categories, guidance would have to be given (either by a Technical Adaptation Committee or by the Member States, reflecting national standards and practices governing the use of aggregates) on the maximum acceptable levels of:
- (i) gypsum;
 - (ii) other inert materials (including reinforcing metal and glass);
 - (iii) wood, plastic and other non-inert demolition wastes; and/or
 - (iv) hazardous wastes.
- 2.21 If followed to the fullest extent, this system would show waste planners the volumes of those materials (such as bricks and roof tiles) which can be re-used, as well as those materials which are suitable for crushing to produce good quality aggregates.

- 2.22 Taking up all of the above proposals would produce a 4-level classification as set out in Figure A9.1 in Annex 9.
- 2.23 Recognising that there may be some opposition to adding a fourth level, it would be possible to achieve most of the gains with limited loss of logic by using the alternative classification set out in Figure A9.2, which can also be found in Annex 9.
- 2.24 Some waste planners also need to estimate future flows of combustible C&DW, including uncontaminated wood, certain plastics, paper and cardboard. There is no obvious way in which the EWC could be amended to facilitate this. The same conclusion applies to hazardous waste fractions, which are identified only as hazardous wastes without reference to their origin in C&DW. Only a wholesale re-working of the EWC, which would have to be applied to all other wastes, not just C&DW, and which we do not recommend, would enable such fractions of the C&DW stream to be separately identified.

The different types of sites which generate C&DW

- 2.25 C&DW can arise from a range of different origins, or site types, as defined in Figure 2.1 below:

Figure 2.1: Site Types	
'Demolish and clear' sites	Sites with structures or infrastructure to be demolished, but on which no new construction is planned in the short term.
'Demolish, clear and build' sites	Sites with structures or infrastructure to be demolished prior to the erection of new ones.
'Renovation' sites	Sites where the interior fittings (and possibly some structural elements as well) are to be removed and replaced.
'Greenfield' building sites	Undeveloped sites on which new structures or infrastructure are to be erected.
'Road build' sites	Sites where a new road (or similar) is to be constructed on a green field or rubble free base.
'Road refurbishment' sites	Sites where an existing road (or similar) is to be resurfaced or substantially rebuilt.

- 2.26 There are five basic activities, some or all of which may occur on all of the above site types. In their simplest form these activities can be described as shown in Figure 2.2.
- 2.27 The linkages between the site types identified in Figure 2.1 and the five activities (and their sub-activities) identified in Figure 2.2 are then shown in Figure 2.3.
- 2.28 Some of the activities shown there as 'optional' (and particularly numbers 1 and 3a) might be considered to be 'best practice', to the extent that 'best practice' is likely to involve greater attention being given to these activities.

Figure 2.2: Basic Activities Found on Demolition and Construction Sites

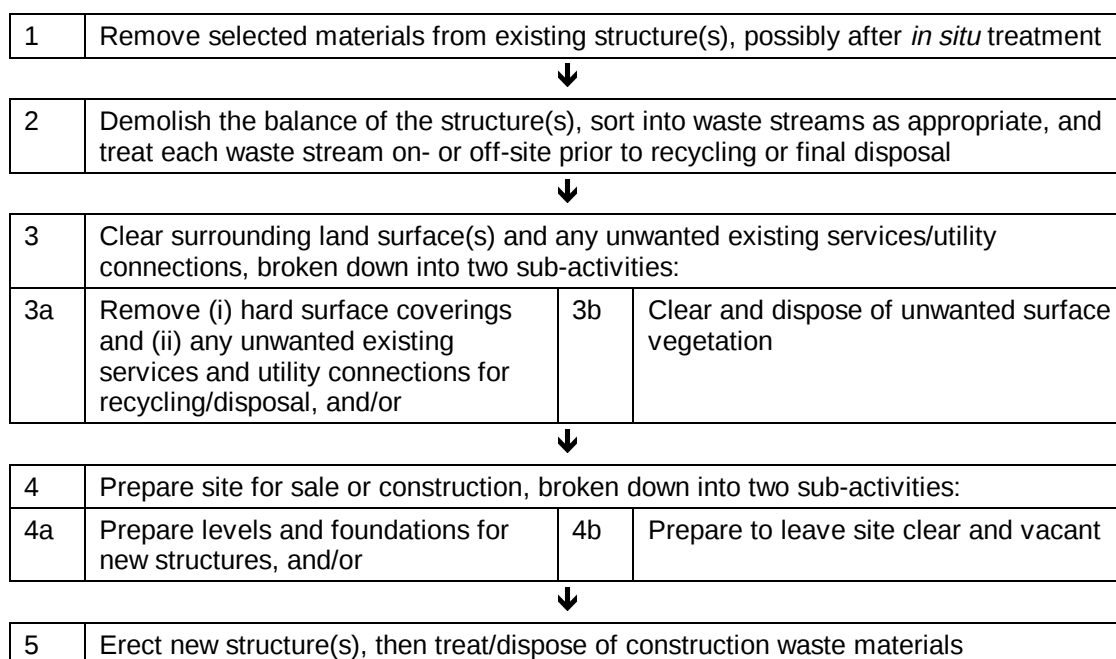


Figure 2.3: Linkages Between Site Types and Site Activities

	1	2	3a	3b	4a	4b	5
Demolish and clear							
Demolish, clear and build							
Renovation							
Greenfield							
Road build							
Road refurbishment							
Key:		Darker cells show unavoidable activities				Lighter cells show optional activities	

Destinations and uses to which C&DW may be put

- 2.29 There is a clear relationship between the possible destinations to which C&DW may be sent and the final fate of the waste materials concerned. It is possible to define a range of possible destinations/uses to which they may go once they have been collected on-site. These will include one or more of the following:

Re-use options

- (i) re-use on-site for the original intended purpose;
- (ii) re-use off-site for the original intended purpose;

Recycling options

- (iii) on-site processing to recover high value saleable materials;
- (iv) off-site processing to recover high value saleable materials;
- (v) recycling on-site for a low-value purpose (including non-essential land raising);
- (vi) recycling off-site for a low-value purpose (including non-essential land raising);

Incineration options

- (vii) off-site incineration with energy recovery;
- (viii) off-site incineration without energy recovery;

Landfilling options

- (ix) off-site landfilling of segregated waste materials;
- (x) off-site landfilling of unsegregated waste.

- 2.30 There is a general issue related to re-use (options (i) and (ii) above) which causes serious problems in some Member States, and which was discussed at length but not resolved by the Priority Waste Streams Programme C&DW Project Group. The issue is the interpretation of the definition of waste.
- 2.31 Although we deal with this in greater detail in Chapter 3, an example concerns the treatment of materials which the demolition contractor intends to re-use for their original purpose without any form of treatment, and which he treats and stores like a commercial product rather than a waste material. We believe that the Directive does not intend that these should be treated as waste, or recorded as such. This will apply to some unused construction materials (where new building is taking place) as well as to 'architectural salvage' and other valuable items (such as fireplaces, wood panelling, doors, sealed double glazing units, certain roof tiles etc) from demolition sites. Similar (but different) considerations apply to stockpiles of inert materials, particularly crushed materials which are then unsold C&DW-derived aggregates.
- 2.32 As far as the recycling options are concerned (see (iii) to (vi) above), it can be difficult in practice to draw a clear distinction between them, though they range from sending scrap steel to mini mills for processing into new steel to the breaking up (but not crushing) of concrete to produce material suitable for filling holes or creating noise bunds on the original site.
- 2.33 During the course of this study we found the distinction between 'high value' and 'low value' materials and uses to be confusing and unhelpful. This distinction was therefore abandoned. The main test which we used was whether the recycled product was saving a new material. There are certainly cases where excavated soil and poor quality C&DW-derived aggregates have been used to create 'low value' landscaping features and noise bunds that would not otherwise have been built, but obtaining any meaningful data on the basis of such a distinction is virtually impossible.
- 2.34 There is a whole range of techniques, and a great deal of research and technical literature, applicable to the recycling of road materials, and particularly the bituminous and asphalt-bound materials. In general these have nothing in common with those applicable to demolition waste from buildings and civil structures. This report is primarily concerned with 'core' C&DW, but Chapter 6 deals specifically with road maintenance and construction issues.
- 2.35 The incineration and landfilling options (see (vii) to (x) above) are self explanatory, and incineration only applies to a few wastes such as uncontaminated wood waste and some plastics (including some packaging materials). In theory it may be possible to landfill C&DW in dedicated landfills with a view to future processing and recovery when market conditions are more favourable. In practice this option has seldom been used to date.

Changes in material types over time

- 2.36 This issue was briefly raised in Chapter 1 under the heading 'The changing nature of C&DW'. The sort of considerations which affect the nature and volume of C&DW include the following:
- (i) individual family dwellings are predominantly built of blocks, brick and wood, with wood much more widely used in Scandinavia than elsewhere in the EU;

- (ii) the 1950s and 1960s apartment buildings which accommodated the flood of workers to post-war urban industrial centres in most Member States were generally built of reinforced concrete, with copper piping replacing lead;
- (iii) by the 1980s plastics (especially PVC double glazing units) were becoming widespread in pipes and window frames in all sorts of residential buildings;
- (iv) many industrial and commercial buildings erected since the 1980s have benefited from faster construction techniques based on steel frames, itself a reflection of lower demand for steel from heavy industry;
- (v) steel-framed structures lack the 'natural' fire resistance provided by concrete and brick, requiring much more fire proofing of beams and columns (often involving hydrocarbon-based materials) and fire fighting systems (often involving chemicals which may themselves be hazardous);
- (vi) the glass cladding which characterises many modern corporate headquarters buildings and shopping centres will in turn affect the composition of future C&DW arisings;
- (vii) city centres with strong conservation laws often require developers to preserve the original façades of buildings, re-building behind them;
- (viii) some cities built on suitable soils require new buildings to have underground parking facilities and/or civil defence shelters, greatly increasing the volumes of soil and rock which must be excavated and removed;
- (ix) irrespective of the primary materials from which they were constructed, older buildings are more likely to contain hazardous material such as asbestos, CFCs and PCBs, because controls on these materials have been tightened over time;
- (x) similarly, as controls have been imposed on the use of hazardous materials in commerce and industry, so the potential for contamination of the fabric of building structures from the products used or made in them, and from the wider environment, has decreased;
- (xi) the trend in fixatives, fillers and coatings has moved from nails, screws, plaster, mortar and emulsion paints to organic resins and solvent-based products which, although inert or at least non-hazardous in their final form, are made up on site from components which are often flammable and/or toxic, and whose residues and containers are therefore also potentially hazardous;
- (xii) bonding also makes full separation of waste streams more difficult;
- (xiii) the changing balance between road construction and maintenance (as well as associated infrastructure such as bridges and tunnels) affects the nature of recyclable material arisings, and the demand for other C&DW-derived aggregates.

Issues related to hazardousness and separate collection

Preliminary considerations

- 2.37 Many of the issues raised under this heading are driven by the imperatives of the waste hierarchy (see Chapter 1). This requires all materials to be moved up the hierarchy (from disposal towards re-use if they must arise at all), which in turn introduces a need for separation and separate handling, which we consider here. Issues related to recovery processes are dealt with in Chapter 4 and 5.
- 2.38 Council Directive 91/689/EEC establishes a list of criteria (in its Annex III) to be used when the hazardousness of wastes is being determined, and required the Commission to draw up a list of hazardous wastes. This list was subsequently published as Council Decision 94/904/EEC (the hazardous waste list).

- 2.39 Very few materials which may be classified as C&DW are invariably hazardous as defined in Directive 91/689/EEC or Decision 94/904/EEC. One of the most obvious examples of this small group, and certainly the one which is most frequently cited, is asbestos-based insulation. However, some other materials may be hazardous because they display one or more of the characteristics used in the Directive's Annex III to define hazardousness (such as toxicity or flammability). These characteristics may only be revealed under specific circumstances, and it may be possible to avoid those circumstances.
- 2.40 Furthermore, some other waste materials which are found in relatively small amounts in C&DW (such as paint and plastics), although not necessarily hazardous, are not inert either. For the sake of the much larger inert fraction, such materials should be kept separate from the inert fraction if at all possible. If they are not, it may not be possible to treat the main bulk of the materials as inert.
- 2.41 Finally, some inert materials (such as bricks and roof tiles) may be suitable for re-use, and therefore require separate collection if this is to become a realistic option.
- 2.42 Our general conclusion is that selective demolition (which greatly assists separate collection by separating materials at source) is a very desirable activity which should be encouraged, and possibly even required. Although local planners and regulators should take into account the availability of recycling and disposal facilities when encouraging or requiring selective demolition, they should also recognise that the two issues are interrelated. While they should not overwhelm local facilities by requiring them to deal with more materials than they can sensibly handle, they can by their decisions stimulate recyclers to expand their capacity by introducing a clear and consistent policy on selective demolition.
- 2.43 As a general point it is fair to say that control of hazardous wastes and others which should be collected separately ought to be easier on construction sites than on demolition sites (because the management's knowledge of the materials should be better, being under their control and of their choice). Economies of scale mean that organising and controlling hazardous materials should be easier on large construction sites than on small ones. On demolition sites, matters can be greatly helped if a proper pre-demolition survey is organised.
- 2.44 We deal in the remainder of this Section with matters relating to hazardousness, sorting and separate collection under the following sub-headings:
- (i) hazardous and potentially hazardous C&DW;
 - (ii) non-inert C&DW justifying sorting and separate collection;
 - (iii) inert C&DW justifying sorting and separate collection.

Hazardous and potentially hazardous C&DW

- 2.45 The key considerations related to hazardousness are summarised in Figure 2.4 below.
- 2.46 Annex 7 comprises a more detailed table of some potentially hazardous materials that may be encountered as a result of construction and demolition activities, including the refurbishment of existing buildings. It identifies those components which are potentially hazardous, the properties that make them potentially hazardous, and some of the options most likely to be considered for their treatment and/or disposal.

Figure 2.4: Types of Hazardousness in C&DW		
	Waste Streams	Examples
1	Some C&DW streams are hazardous because the materials originally used contained a high proportion of materials which were themselves hazardous.	Examples include asbestos, lead, tars, paint and preservative residues, adhesives, bonding agents and sealants and certain plastics.
2	Some materials become hazardous as a direct result of the environment in which they have existed for many years.	An example would be a factory where surface reactions between the originally non-hazardous building materials and chemicals carried in air (or water) pollution associated with the processes in or near the factory resulted in parts of the building's fabric becoming hazardous, and requiring special handling or treatment.
3	Some C&DW streams become hazardous if hazardous materials are left in them and/or subsequently get mixed with them.	The classic example concerns lead-based paint tins thrown onto a pile of bricks and concrete, making the whole pile hazardous waste.

- 2.47 On construction sites, a small number of building materials, such as asbestos sheet or insulation, may be hazardous in their own right. Others which are not themselves hazardous in their final form (including some adhesives, coatings and sealants) are either made up on site by a reaction between hazardous materials, or are supplied to site in solvent carriers. Any surplus pre-cursor materials and/or 'empty' containers with residual quantities of product which find their way into the C&DW stream are hazardous.
- 2.48 Specific hazardous and potentially-hazardous items that may occur on new construction sites include:
- (i) solvent-based concrete additives;
 - (ii) damp proofing chemicals;
 - (iii) adhesives;
 - (iv) tar-based emulsions;
 - (v) asbestos-based materials;
 - (vi) mineral fibres (insulation);
 - (vii) some paints and coatings;
 - (viii) treated timber;
 - (ix) resins;
 - (x) plasterboard;
 - (xi) empty or part empty gas bottles (from cutting, welding etc).
- 2.49 On demolition sites there are always likely to be some materials (such as asbestos and sodium/mercury vapour lamps) which are hazardous in their own right. Residues of hazardous substances manufactured, used or stored at the site may remain. Where possible these should be removed from the site prior to demolition activities commencing. If they have become impregnated into the fabric of the building it may be possible to neutralise or treat them *in situ* prior to demolition.

2.50 Some specific hazardous and potentially hazardous items that may be encountered on demolition sites are listed below. These include some (the first three and the last) which also occur on the construction materials list provided above:

- (i) asbestos-based materials;
- (ii) treated timber;
- (iii) mineral fibres (insulation);
- (iv) electrical equipment containing toxic components;
- (v) CFC-based refrigerants;
- (vi) CFC-based fire fighting systems;
- (vii) radionuclides;
- (viii) biohazards;
- (ix) empty or part empty gas bottles (from cutting, welding etc).

2.51 Refurbishment works are likely to produce a mixture of materials typical of both construction and demolition sites. Since the main fabric of the building is likely to be substantially untouched, the percentage of hazardous material is likely to be higher on refurbishment sites than on mainstream demolition or construction sites. Even so, experience (as reported by - among others - ADEME, see Annex 10, Ref 7.1) shows that it is unlikely to exceed 10% of the total.

Non-inert C&DW justifying sorting and separate collection

2.52 Some materials may be inert or relatively non-hazardous *in situ*, but could become hazardous depending on the disposal method. For example some treated or coated timber can give rise to toxic fumes if incinerated. Untreated wood, while eminently suitable for incineration if it cannot be re-used or recycled, should be removed from the inert fraction if at all possible, because its presence in a crushed aggregate material will detract from the value of that aggregate. The same applies to many plastic and textile wastes which can be found on most demolition sites.

2.53 Gypsum, when placed in a landfill can generate hydrogen sulphide, an acid gas. It can also detract from the quality of an aggregate if present in excessive amounts. There is no widely agreed figure for the maximum acceptable percentage of gypsum in C&DW-derived aggregate, nor are there widely agreed limit values for landfilling gypsum.

2.54 Other non-inert materials and products justify sorting and separate collection as a result of their economic (resale) value. Examples include carved wood panelling, doors, sealed double glazing units (especially those with hard wood or PVC frames).

Inert C&DW justifying sorting and separate collection

2.55 The main justification for sorting inert materials from the stream which will be crushed is economic. Metals have a well-established resale value, and in some areas and at some times materials such as bricks and tiles are in considerable demand. This is most likely to occur in urban areas with an established historical architectural and buildings materials style.

3. ECONOMIC AND ADMINISTRATIVE FACTORS AFFECTING RE-USE AND RECYCLING

Introductory comments

- 3.1 In this Chapter we look at the primarily non-technical barriers to greater re-use and recycling of C&DW. As well as the obvious economic considerations which are central to this study, we deal with three primarily administrative factors:
- (i) the way in which recycling can be discouraged or even rendered impossible by an unhelpful interpretation of the term 'waste';
 - (ii) land use planning and/or environmental controls on processing activities; and
 - (iii) questions related to those standards and norms which are applied to C&DW-derived aggregates.
- 3.2 Some of these administrative issues in particular have occupied many other study teams working on projects for DGXI, DGXII and Eurostat, and we have sought not to cover the same ground again in inappropriate detail.
- 3.3 In dealing with economic costs we have limited our consideration to internalised costs which can be expressed in monetary terms, and not sought to take environmental externalities (including issues related to the non-renewability of certain resources) into account. This is mainly because such externalities are hard to quantify, and there is no evidence (that we have found) of a broadly accepted position on their monetary valuation. This, we believe, is largely because such impacts are essentially site-specific and their financial costs subjective in nature, making generalisations potentially misleading.

Economic considerations

Economic modelling

- 3.4 Several years ago a macroeconomic model describing C&DW recycling was produced in the Netherlands, and published in CUR Report No.125 (see Annex 10, Ref 10.1.3). This model was subsequently used in a quantified assessment of the costs of selective demolition and re-use of secondary aggregates *versus* landfilling of unsegregated C&DW. This latter exercise was carried out by experts now with PRC Bouwcentrum and COWI (both participants in the present study), and the results were reported in the research report 'Recyclability in concrete of demolition refuses containing materials non-compatible to the traditional cement matrix' (see Annex 10, Ref 2.3).
- 3.5 The CUR model deals with the factors which drive decisions, and the factors which determine a material's value. Taking a very similar (but not identical) approach, we consider that, in the context of this project, there are two key decisions to be considered:
- (i) the potential user's decision whether to use primary aggregates or C&DW-derived aggregates; and
 - (ii) the demolition manager's decision whether or not to separate the various C&DW streams for individual treatment and/or use/disposal.
- 3.6 We consider these two decisions below. Although there is a case for following the flow of materials, and dealing with choices on the recycling site before considering how the recycled material may be used, in fact the whole process should be (and generally is) market-led. In other words, nobody willingly separates recyclable materials as a prelude to landfilling them, and the market demand for C&DW-derived aggregates, the largest recoverable component, largely determines the nature of the recycling process. We recognise, of course, that in some Member States it is now a legal requirement that C&DW be separated and treated rather than landfilled, so this option is not open to all.

The economics of construction

- 3.7 We are concerned here with the economic considerations which might lead a construction company or materials specifier to select C&DW-derived aggregates rather than primary or secondary materials (i.e. quarried materials, or waste materials such as pulverised fly ash).
- 3.8 Although some potential users of aggregates do choose recycled materials to enhance their 'green credentials', most can be assumed to act dispassionately, and (assuming that the two materials are equally capable of meeting their needs), to choose C&DW-derived aggregates whenever:

$$Q_p + T_q > E_r + R_{Cp} + T_r$$

where: Q_p = Price of newly quarried product at the quarry gate

T_q = Cost of transport from quarry to site

E_r = Any extra costs created by using C&DW-derived aggregates

R_{Cp} = Price of recycled product at the recycling centre gate

T_r = Cost of transport from recycling centre to site

- 3.9 Q_p can be assumed to be fixed by market forces. In the short term, and for the vast majority of users, Q_p will hardly be affected by individual choices whether or not to use C&DW-derived aggregates, though with greater market penetration there will be a general downward pressure on aggregate prices.
- 3.10 T_q and T_r will largely depend on distance, because with bulk materials loading and unloading costs are small. There is no obvious reason to assume that, in general, T_q will be significantly different from T_r (unless the C&DW-derived aggregates are re-used on their original site, in which case $T_r = 0$). Most primary aggregates are either quarried close to where they are used, or must find a low cost mode of transport (rail or water) if they are to travel significant distances. Although most urban areas are adequately served either by local landfills or by locations where a fixed C&DW recycling facility could be installed, the trend is for wastes to travel longer distances to disposal facilities, particularly in more densely populated areas.
- 3.11 E_r is made up of an 'objective component' and a 'subjective component', representing the price advantage which the user demands before buying C&DW-derived aggregates instead of primary material. The objective component may be quite small, but is likely to include additional storage and cleaning costs at the location where the aggregates are to be used, as a result of needing to maintain separate stockpiles and to switch machines over between batches. C&DW-derived aggregates sometimes also need to be wetted before mixing, unlike primary aggregates. The rest of E_r represents the 'subjective component', which is the value which the user places on the intangible benefits of using primary materials.
- 3.12 We assumed at the outset that the potential user makes his choice on the basis that the recycled and primary materials are technically interchangeable. In fact, of course, this is often not true. Recycled materials may well have slightly different mechanical, physical and chemical properties (which makes crushed concrete more cementitious than quarried gravel, for example). In such cases the decision maker may have to adjust the quantities of materials to be compared, but this does not change the essential structure of the decision-making process.
- 3.13 The same approach can also be applied to other choices between re-used or recycled and new materials (such as used *versus* new bricks, or plaster board using recycled *versus* new gypsum).

The economics of recycling versus disposal

- 3.14 The decisions which determine the style and detail of the demolition process may be taken by the original owner of the site, or by a new owner who is planning to erect a new structure on it, or by a contractor or consultant working directly or indirectly for either of these two parties. The discussion below deals with financial costs and benefits but excludes the environmental costs. Adding these in would complicate the discussion of the decision making process, not least because the costs and benefits fall on different persons, but it would not change the principles.

3.15 Under the simpler, more traditional model (in which the original owner employs the demolition contractor), the demolition contractor can advise the owner on the best way of organising the work, including options for selective demolition and materials recovery and recycling. Increasingly, though, site owners are tending to employ lead contractors who are responsible for managing the whole construction process from clearing the site right through to erecting and fitting out the new building. These contractors usually have strong financial incentives built into their contracts to complete the job as quickly as possible, which they will seek to pass on to their chosen demolition contractor.

3.16 Under this second model, although the demolition contractor may acquire the right to sell any materials derived from the site, unless the values are high enough to offset any time penalties set in his contract, he will inevitably seek to propose a methodology which goes no further than complying with all regulatory (or other) requirements regarding separation of waste streams.

3.17 We refer to whoever is driving the process (whether the owner, contractor or consultant) as the demolition manager. His decision can also be expressed as an equation. At its simplest, he can be assumed to choose selective demolition and separate handling whenever:

$$V_m(T_m + D_m) > V_1(T_1 + R/D_1 - SV_1) + V_2(T_2 + R/D_2 - SV_2) \dots V_n(T_n + R/D_n - SV_n) + E_s$$

where: V_m = Volume of unsorted C&DW
 T_m = Cost of transporting unsorted waste to disposal site
 D_m = Cost of disposing of unsorted waste
 V_1 = Volume of inert waste
 T_1 = Cost of transporting inert waste to recycling or disposal site
 R/D_1 = Cost of recycling or disposing of inert waste (including quality control costs)
 SV_1 = Sale value of recycled product (if relevant)
 $2 \dots n$ = Other sorted waste streams
 E_s = Additional costs of separate demolition and materials sorting

3.18 SV_1 as defined above is equal to RC_p from the first equation.

3.19 In general terms these expressions should be self explanatory. The complexity of the right-hand half of the equation will depend on the site and the extent to which separate handling is proposed.

3.20 Although it is highly unlikely to be structured in this very formal way (and our discussions with contractors confirm that it is not), the decision will take into account the costs of handling, transporting, processing and disposing of all the separated fractions, not just the inert fraction which can be converted into aggregate. This is one way in which our approach differs from the CUR model, which only considers the aggregate fraction.

3.21 The additional costs associated with separate demolition and materials sorting (E_s) will include any additional costs created by time and/or space constraints. On all sites they will be affected by the cost of labour, but more particularly by the costs of machinery. In order to try to compare the decision making process on different site types and in different Member States, the labour cost component needs to be expressed as an ECU wage rate and time and productivity factors. The same thing needs to be done for fixed and variable machinery costs to facilitate the asking of a series of different 'what if?' questions.

3.22 The results of this process are presented in Chapter 9.

3.23 The link between the two equations specified so far has already been identified as the returns from recycling (SV_1 or RC_p). Recycling will generally occur if these returns exceed the costs of recycling. Taking the relatively simple case of the demolition contractor with his own recycling centre, this means where:

$$SV_1 \text{ (or } RC_p) > D_c - D_f + T_1 + R/D_1 + L_{Fri} + T_{ri} + \text{recycler's profit margin}$$

where: D_c = Full on-site demolition costs not paid direct by the site owner,

including Es (previously defined)
 Df = Demolition fee (paid by site owner to demolition contractor)
 T1 = Transport costs (previously defined)
 R/D1 = Costs of crushing & sorting inert wastes (previously defined)
 LFri = Costs of landfilling residual (post-crushing) inert materials
 Tri = Costs of transporting residual inert materials to landfill

- 3.24 Dc will be heavily affected by the specific characteristics of the site, and the extent to which machinery can be used to demolish the structures there. Where the recycling process relies on a mobile crusher on the original site T1 will be zero. In general LFri and Tri will be small.
- 3.25 Some adaptation would be necessary to simulate the (rather simpler) decision facing a demolition contractor who had to pay an access fee to a recycling centre rather than using his own.

The economics of landfilling versus 'fly tipping'

- 3.26 'Fly tipping' is the practice of illegally dumping waste. This is usually done beside a road, or on open land, or in a wood. However, in some Member States (notably Spain and Portugal) there is a long tradition of unregulated but acknowledged waste dumps. Although these are being actively closed down as waste management practices improve (see Annex 10, Ref 11.3), some of these still receive MSW and C&DW with the local authorities' tacit approval.
- 3.27 Economic theory suggests that 'fly tipping' is likely to be more of a problem where landfill charges are high. Observation of real life does not support this view, suggesting that, where landfill charges are stable (whether high or low), the main determining factor is the expectation and consequences of being caught 'fly tipping'. Poor policing and limited sanctions appear to be more likely than high landfill charges to encourage higher absolute levels of 'fly tipping'. However, any sudden rise in landfill charges (as a result, for instance, of the introduction of a landfill tax) will inevitably produce increases in the level of 'fly tipping'. In the UK the Environment Agency has reported increases in general 'fly tipping' since the landfill tax was introduced in 1996, including many incidents of illegally-tipped builders' waste (according to the 'Surveyor', 13 August 1998). However, experience would suggest that once the industry has adjusted to higher charges, 'fly tipping' will revert to something like its previous level.

Administrative factors

The interpretation of 'waste'

- 3.28 The Framework Directive on waste (75/442/EEC as amended by 91/156/EEC) defines waste as "... any substance or object in the categories set out in Annex I which the holder discards or *intends* or is required to discard ..." (our *emphasis*). Annex I to the Directive contains 15 specific categories of waste (none of which refers to anything remotely like the inert fraction of C&DW, or to most other fractions either) plus a catch-all of "... any materials, substances or products which are not contained in the above categories."
- 3.29 In 1995 the report of the C&DW Priority Waste Streams Project recommended (in its recommendation number 6) that:
- "The Commission should review the definition of waste in Council Directive 75/442/EEC on waste, as amended by Council Directive 91/156/EEC, with the objective of developing a proposal whereby products and materials destined for re-use and recycling are not defined as waste."*
- 3.30 We were made aware during the course of our researches for this study that the demolition and recycling industries regularly experience cases where inert (and some non-inert) materials which neither the building's owner nor the demolition contractor nor the recycling centre ever *intend* to discard (and which require no processing before they are re-used) are being treated by waste regulators as waste.

- 3.31 The demolition and recycling industries' concerns (and desire for further detailed clarification) are also focused on those inert wastes which are destined to be crushed and recycled as C&DW-derived aggregates. These materials are waste before they are processed, but cease to be waste on successful completion of the recycling process.
- 3.32 By way of illustrating why there is concern, we would simply note that it is alleged that some officials (in the UK and possibly elsewhere) have threatened to prosecute users of C&DW-derived aggregates for illegal waste disposal because the aggregates they have used contain very small proportions of wood, plastics or similar 'contraries', even though the materials meet the technical requirements of the aggregate specification. The potentially serious consequences of losing a legal challenge have so far discouraged any recyclers from testing this point through the courts.
- 3.33 It would therefore be desirable, in our view, if a detailed guidance note on the interpretation of waste in the specific context of C&DW management could be issued at EU level. It is recognised that any change must provide adequate safeguards against abuse by those who simply wish to evade the provisions of waste regulation.

OECD guidance on deciding when a waste is no longer a waste

- 3.34 The Organisation for Economic Cooperation and Development (OECD) has recently issued a 'Final guidance document for distinguishing waste from non-waste' (see Annex 10, Ref 1.2.2). Although this guidance has been developed within the context of transfrontier movements of wastes destined for recovery operations, it provides some helpful pointers relevant to a discussion of when C&DW is and is not a waste, and when it becomes a non-waste product as a result of processing.
- 3.35 The OECD definition of waste is "...materials other than radioactive materials intended for disposal for reasons specified in Table 1." (Table 1 specifies 16 reasons why materials are intended for disposal by virtue of their condition. These reasons only differ in trivial ways from the 16 categories of waste listed in Annex I to the Framework Directive on waste). Disposal (in the sense used by the OECD) means any of the operations specified in their Table 2, which in turn is split into two tables dealing with final disposal operations and recovery operations. (These two tables, 2.A and 2.B, are very nearly identical to Annexes IIA and IIB to the Framework Directive on waste).
- 3.36 The guidance document observes that "... the intended destination of a material is the decisive factor in the OECD definition. However, it is not the decisive factor in many of the definitions enacted by many OECD Member countries." The Framework Directive definition of waste, by contrast, hinges on the concept of discarding. The guidance document observes that "... whilst the notion of discarding may differ from the OECD notion of disposing, both notions encompass the consignment of a material/waste to a recovery/recycling/reclamation process."
- 3.37 It is pointed out that "... when a waste material is subjected to a recovery process more than one material can be produced at the end of the process. It is likely that at least one of the materials ... could be a waste. The fact that a material meets a recognised national/international standard/specification when it is derived from an environmentally sound recovery operation may provide evidence that it has ceased to be a waste. However, the existence of a specification is not in itself sufficient." It is also stated that "... the simple sorting of a waste to meet an industrial specification is not considered, by many Member countries, to constitute an adequate means of recovery/recycling/reclamation."
- 3.38 The document concludes by suggesting that "... a waste ceases to be a waste when a recovery, or another comparable, process eliminates or sufficiently diminishes the threat posed to the environment by the original material (waste) and yields a material of sufficient beneficial use. In general the recovery of a material (waste) will have taken place when:
- (a) it requires no further processing by a Table 2.B operation;
 - AND
 - (b) the recovered material can and will be used in the same way as a material which has not been defined as waste;

AND

- (c) the recovered material meets all relevant health and environmental requirements.”

- 3.39 While recognising the potential problems embodied in the phrase “... all relevant health and environmental requirements”, it appears to us that a guidance document based on these principles would meet most if not all of the objections that we have identified in the specific context of C&DW. The potential problems to which we allude relate to requirements that are relevant to a recycled material but not to its primary ‘competitor’ (or *vice versa*). An example concerns leachates which may be produced by C&DW-derived aggregates but not primary materials.

Land use planning and environmental controls

- 3.40 One of the key challenges facing many would-be recyclers, and particularly those interested in establishing a fixed recycling centre, is identifying and securing a suitable site. The ideal site would be close to an urban area (where C&DW will both arise and be re-used, thereby keeping transport costs and associated environmental impacts down), but sufficiently removed from both non-human environmental receptors and housing to keep adverse environmental and amenity impacts (as discussed in Chapter 1) to an acceptable minimum.
- 3.41 Some large cities have official ‘green belts’ established around them. Requiring C&DW to go from the city through the green belt to a processing centre, and then back across the green belt in the form of C&DW-derived aggregate to a user in the city may well make recycling uneconomic. The attitude of the land use planning system to recycling can therefore be important, and local authorities can assist by identifying enough areas suitable for C&DW processing in their published plans, in the same way that they do other potential land uses. The Priority Waste Steams Project report (see Annex 10, Ref 1.1) makes various recommendations (notably numbers 14-19) which remain relevant in the context of waste planning, and which we endorse. Several are also pertinent to land use planning.
- 3.42 Environmental controls (primarily related to noise and dust) affect both on-site and off-site processing. Emphasising the temporary nature of impacts may favour on-site processing. This is comparable to the more lenient conditions often imposed on a construction site as compared to the process which will subsequently occupy the site.

Standards and norms for secondary and recycled materials

- 3.43 A specification is primarily a description of something to be made or done, produced with the aim of controlling the quality of materials, their production and use. It allows a contract to take place and gives confidence to the parties to the contract by controlling the risks. National and international specifications have been produced to assist designers and specifiers by defining parameters considered to be acceptable to all parties to a contract. The standardisation of specifications therefore removes the need for their individual preparation for each construction project.
- 3.44 However, specifications depend on accepted practice, and their widespread use reflects the generally conservative nature of designers and specifiers. Using an existing specification saves time (and possibly money) at the design stage, but can inhibit innovation, simply because specifications will not include new or untried materials.
- 3.45 While national and international specifications are routinely used in construction for convenience, they are not a prerequisite. Alternative mechanisms for controlling risk, such as bespoke specifications and externally verified quality certification, can be used provided they are acceptable to both parties to the contract. The requirement on designers and specifiers is to identify the properties and qualities required of materials appropriate to their proposed use, and to satisfy themselves and their clients that the materials proposed will meet these.
- 3.46 Much attention has been paid to the need for technical standards applicable to recycled C&DW and there is a universal acceptance in the construction industry that properly formulated performance specifications can safely permit the use of products derived from secondary and recycled materials.

- 3.47 This whole subject area, and the role played by RILEM (the Réunion Internationale des Laboratoires d'Essais et de recherches sur les Matériaux et les constructions) and CEN (the European standards body) was reviewed in a 1997 report on a Brite-EuRam project entitled 'Use of Recycled Materials as Aggregates in the Construction Industry' (see Annex 10, Ref 2.1).
- 3.48 In practice most national bodies are waiting for CEN Technical Committee 154 ('an *ad hoc* group for recycled aggregates'), whose remit in respect of construction materials requires the development of performance specifications that permit the use of products derived from recycled materials. Inevitably this is a lengthy process, and the conclusion of most experts who have dealt with this issue in any depth is that the industry cannot wait the many years which it will take for formal standards to be adopted, and that interim measures are required to fill the gap in the meanwhile.
- 3.49 While there is agreement on the need for appropriate specifications, there is a difference of opinion in the industry as to whether such specifications need to be developed specifically for secondary and recycled materials, or whether specifications should permit the use of all materials irrespective of their source. This debate stems primarily from the need for particular issues to be addressed which relate solely to secondary and recycled materials. For example, the potential for leaching of contaminants is an issue not addressed by traditional 'recipe' based specifications. 'Recipe' based specifications define the physical constituents of a material rather than setting performance criteria which it must meet.
- 3.50 The unresolved nature of this debate is reflected in the differing approaches adopted by the various Member States (as reported in Annex 6). Austria, Denmark, Germany and the Netherlands have all developed some standards specifically for secondary and recycled materials with the Netherlands also adopting performance specifications. The UK and Ireland make limited provision for the use of some secondary and recycled materials in road construction. The UK also has one national standard 'BS 6543: 1985 British Standard Guide to the Use of Industrial By-products and Waste Materials in Building and Civil Engineering'. France, Italy, Portugal and Finland do not make specific provision for the use of secondary and recycled materials. In the UK, Italy, Spain and Belgium, externally verified quality certification systems covering both materials and recycling plants have been adopted to facilitate the use of recycled materials. If such national systems diverge and become entrenched, it is almost inevitable that they will create market barriers to cross-border trade in recycled aggregates.
- 3.51 The demand for materials for particular uses also needs to be given careful consideration. In general, even if all C&DW was re-used or recycled, the quantities are such that they would only meet a comparatively small proportion of the demand for construction materials (see Annex 4). Primary materials will therefore continue to have to meet the bulk of the demand for the foreseeable future.
- 3.52 C&DW-derived aggregates provide a good illustration of the appropriate use of recycled materials. Road and car park construction is an activity where properly quality controlled C&DW-derived aggregates can meet the technical and environmental requirements for this comparatively low grade use. Structural concrete on the other hand requires higher strengths and a greater degree of consistency. Given that a high level of demand for road construction materials is likely to be sustained it must be questioned whether the effort required to produce concrete-quality recycled aggregates can be justified other than in exceptional circumstances.
- 3.53 While there may be local circumstances where access to primary materials is limited, and the use of secondary and recycled materials for high grade use is therefore cost effective, unless there is a very significant downturn in the demand for new infrastructure, it is not considered that this will become widespread.
- 3.54 In view of the attention being given to this topic in other fora, it seems unlikely that a further initiative on standards and norms would be appropriate or even helpful. However, to avoid the continuing uncertainties surrounding technical specifications, pressure should be applied to the participants in the RILEM and CEN working groups to resolve the issues as soon as possible.

4. PROCESSES AND BEST PRACTICE GUIDANCE: DEMOLITION, RENOVATION AND RECYCLING SITES

Processes commonly found on demolition and renovation sites

- 4.1 In Chapter 2 we identified a series of activities likely to be found on any demolition site (see Figure 2.2). Most of these (such as demolition of the main structure, clearance of the site and disposal of the residual materials) are unavoidable, because if they are not carried out, then demolition cannot be considered to have occurred. The one more 'optional' activity, and the one which has the greatest influence on the extent to which materials are re-used and/or recycled is, by common consent, selective demolition (Activity 1).
- 4.2 Selective demolition (which also applies to sites which are being renovated) can be considered to comprise a series of sub-activities, as set out below in Figure 4.1. Although these sub-activities can take place in any sequence (or even concurrently), they will generally be organised in roughly the order shown.

Figure 4.1: Component Elements of Selective Demolition

	Sub-Activity	Materials	Comment
1a	Selective removal of accessible materials with obvious sales value.	Valuable architectural salvage (such as fireplaces, stained glass, carved doors and wall panelling, some decorative wrought iron and tiles), some sorts of roof tiles, some sealed double glazed window and door units, some electrical fittings, some metals (such as lead off the roof and easily accessible items such as copper pipes and wiring).	If the owners of the site do not manage this process, 'informal recyclers' (i.e. thieves) may do it for them.
1b	Selective removal of accessible materials which, if not removed, will cause the C&DW to be treated as hazardous.	Asbestos and other hazardous materials (see final Section of Chapter 2).	This will reduce the proportion of C&DW that has to go to hazardous landfill.
1c	Selective removal of materials which, if not removed, will depress the value of the remaining C&DW when crushed.	Other accessible wooden items, other accessible plastic items, excessive volumes of glass. Even plaster (gypsum) may be removed for this reason.	This will raise the value of the C&DW-derived aggregates subsequently produced.
1d	Chemical treatment <i>in situ</i> of those exposed parts of the building fabric which have become contaminated during the life of the building, followed by removal if appropriate.	Surface materials (roofing, walls, floors) which have undergone chemical changes.	This is a relatively new concept/ activity. It is only likely to be appropriate in the case of industrial structures.

Figure 4.2: Activity Flow on Construction Sites

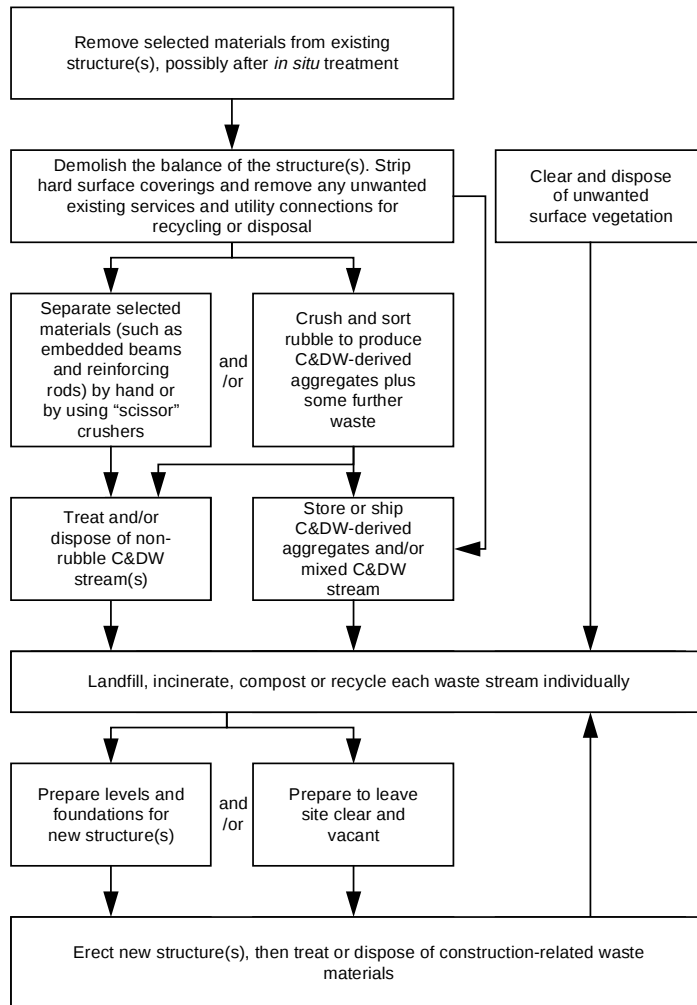
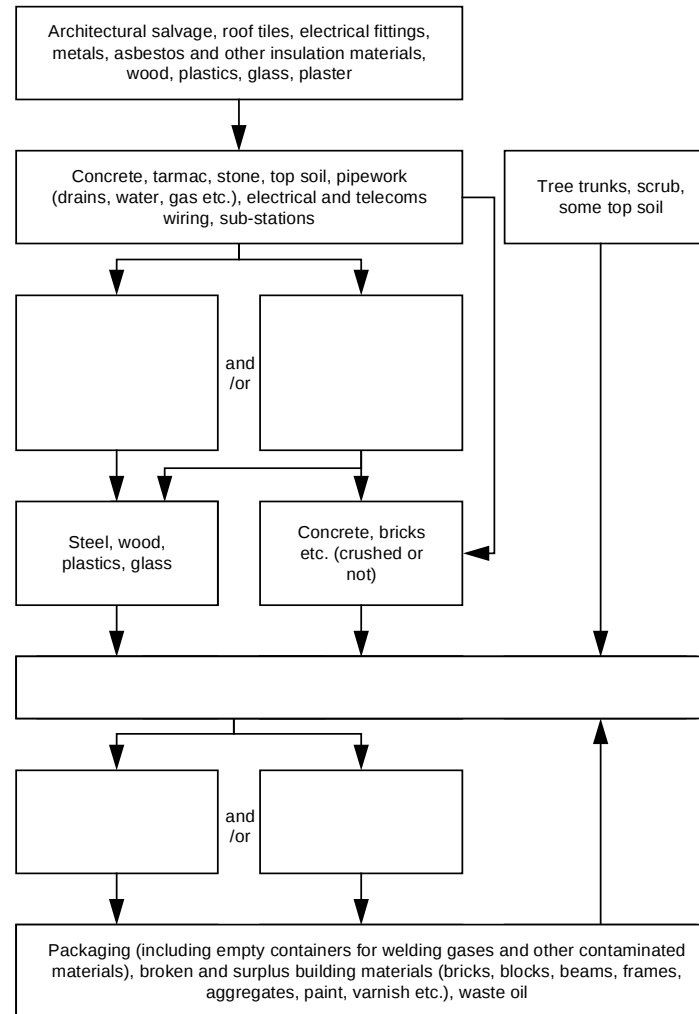


Figure 4.3: Arisings of Waste Materials Related to the Activities in Figure 4.2



- 4.3 In all cases, the decision whether or not to undertake any or all of these sub-activities will be driven by a combination of regulation (of demolition and waste management activities) and market forces.
- 4.4 After whatever selective demolition is decided on has taken place, and after the resultant shell of the structure has been demolished (whether by controlled explosion, mechanically or manually), there are further stages/sub-activities to be considered, particularly within Activity 2 (which covers the demolition of structures and the treatment and disposal of rubble and other wastes). The latter stages of Activity 2 are similar in nature to the latter stages of Activity 3 (the clearing of surrounding land surfaces and utility connections), in that they both potentially involve the sorting and manipulation of materials which have become unavoidably mixed.
- 4.5 In fact, Figure 2.2 can be presented in a more complex way, with a rather more detailed set of sub-activities, which we have done in Figure 4.2. It should be stressed that Figure 4.2 represents the flow of activities, not of materials. The equivalent material flows (i.e. the arisings of C&DW streams) are shown in Figure 4.3. Comparing Figures 4.2 and 4.3 shows which waste streams are associated with each of the site activities.
- 4.6 Demolition and its related activities (which appear in the upper half of Figures 4.2 and 4.3) result in the greatest volumes of C&DW (other than soil), and this is the point where policy initiatives, whether relating to demolition, recycling or disposal, can have the greatest impact. This is therefore the stage on which it has been agreed with the Commission that greatest attention should be focused.
- 4.7 After the structure has been demolished it is normally possible to remove further steel (or possibly wooden) beams which were part of the basic structure (and therefore could not be removed previously). By using heavy duty mechanical 'scissor' crushers (described in Annex 13) to break open reinforced concrete members, some of the steel reinforcing bars can also be removed. Some insulation materials which were inside walls can also be removed by hand (or, possibly more accurately, by non-automated processes).
- 4.8 If all of these actions have been taken, there will now be a largely inert waste stream which is predominantly made up of concrete, bricks, some ceramic materials and (possibly) gypsum. If this is not required on site for engineering fill or landscaping (thereby avoiding transporting onto the site primary aggregates or other clean soil), then it can be mechanically crushed and sorted.
- 4.9 This waste stream can be further treated using a mechanical ('jaw' or impact) crusher and sorter. Such crushers and sorters fall into one of two categories: smaller mobile machines (primarily intended for on-site use, but sometimes used off-site at waste transfer stations or recycling centres) and larger fixed machines (which are more likely to incorporate more sophisticated sorting technology which can remove further remaining traces of other wastes through a variety of techniques, including air sorting and washing). We describe a 'state of the art' recycling centre below.

The choice between on- and off-site processing

- 4.10 The choice as to whether crushing and sorting should be done on- or off-site is complex, and depends on many factors including:
- (i) the availability (and ownership) of different machines;
 - (ii) the quality of aggregate required on the demolition site itself;
 - (iii) the space and time available on the demolition site;
 - (iv) the haul distances between the site, the nearest available fixed processing site and other treatment and disposal sites.
- 4.11 In practice, the answer will tend to reflect national and local practice and licensing (including land use planning and environmental controls), and market forces (which we consider in

greater detail in Chapter 9). Once the rubble goes off-site for crushing, it becomes less likely that it will be re-used on the original site.

- 4.12 Figure 4.4 summarises the key factors associated with a choice between on- and off-site crushing and sorting facilities. These factors have been brought to our attention and/or confirmed on the basis of existing knowledge during discussions with operators of C&DW recycling facilities.

Figure 4.4: Pros and Cons of On- and Off-Site Crushing and Sorting	
Advantages of on-site crushing and sorting: • lower materials handling and transport costs • lower machinery capital costs • less transport disruption to surrounding areas (if recycled materials can be used on-site)	Disadvantages of on-site crushing and sorting: • conflicts between site operations and space demands for materials and machinery • higher machinery operating costs per tonne of C&DW • more local noise and dust nuisance • less flexibility about where/when recycled materials can be used • construction may be delayed
Advantages of off-site crushing and sorting: • easier to reduce and/or mitigate adverse environmental impacts on surrounding areas • more practical to use a wider range of higher capacity equipment • lower machinery operating costs per tonne of C&DW • easier to control quality of recycled materials • possible to hold stocks, thereby making positive marketing of recycled materials easier	Disadvantages of off-site crushing and sorting: • proper control of demolition process essential (to avoid arrival of unknown quality materials) • higher materials handling and transport costs • higher machinery capital costs • fixed costs of recycling the site (land etc)

- 4.13 The point about quality control (in the lower left hand cell of Figure 4.4) appears to be very important. Even in those Member States where C&DW-derived aggregates are already relatively widely used, the main barrier to greater market acceptance appears to be potential buyers' doubts about their quality and consistency rather than a lack of formal standards for recycled materials. In some countries there is now a move among C&DW-derived aggregates producers to institute external quality verification procedures (typically involving cooperation with an independent materials testing laboratory), thereby allowing their products to benefit from a quality mark.
- 4.14 The International Recycling Federation (FIR) has recently compared some existing national quality systems for recycled materials (including those of Germany, France, the Netherlands and Austria), and made recommendations as to the structure which such systems should follow. Their recommendations are summarised in Figure 4.5. In general, better product management tends to lead to a better final product which can be used in a wider range of applications.

Figure 4.5: Quality Systems for Recycled C&DW (Based on the FIR Recommendation)

Heading	Sub-Heading	Notes
1 - Resources	- Determination of sources of input materials - Avoidance of contamination/purity	- Sources might include unbound C&DW, hydraulically bound C&DW, bituminously bound C&DW, industrial by-products or incinerator bottom ash - To be attained by selective demolition and collection of mineral and other C&DW
2 - Storage	- Pre-treatment storage - Post-treatment storage	- Raw materials should be stored separately to achieve good product quality - Treated materials should be stored separately according to quality classes
3 - Preparation	Achieving the required properties	Preparation should be carried out in such a way as to ensure that the material(s) fit specified quality classes
4 - Type (quality classes)	Classification according to the envisaged end use	Recycled materials should be classified according to their intended use(s)
5 - Engineering tests	- Particle size distribution - Frost resistance - Stiffness - Compactability	These and any other tests should (for the time being) be conducted according to national standards
6 - Composition	- Percentage of other minerals - Mixing ratio - Detrimental components - Dangerous components	- Other minerals would be those which differ from the main product (i.e. concrete in asphalt granulate) - Mixing ratio gives the variability of percentages of different mineral products in the granulate mix - Detrimental components are materials which adversely affect the mechanical behaviour of the material - Dangerous components are organic or inorganic contaminants which create a risk for the environment
7 - Environmental acceptability	Leachability	For recycled materials the parameters and limit values should be defined according to the quality class
8 - External monitoring	Determination of parameters and frequency of testing	To be conducted by a laboratory or testing organisation licensed or recognised by the Government
9 - Internal monitoring	Determination of parameters and frequency related to volume of production and quality classes	To be conducted by either an in-house laboratory or an external organisation

Source: Based on the study team's own unofficial translation of an FIR document

- 4.15 Larger off-site crushing and sorting facilities can operate much more like conventional aggregates quarries, building up stocks of different specification materials which enable them to supply larger contracts without delay. Some operators blend primary and C&DW-derived aggregates, and there is increasing evidence of primary aggregates operators now entering the C&DW recycling sector in the UK, in Italy and in Spain.
- 4.16 Off-site facilities can also take long enough over the processing to ensure that the amounts of wood, plastic wastes and other contaminants getting into the final products are kept to an acceptable minimum. Operators of on-site crushers are often under pressure to treat whatever materials are placed in front of them, and to make the resultant C&DW-derived aggregates available for the construction process as quickly as possible.
- 4.17 Off-site crushing and sorting plants which accept C&DW from third parties may well have a problem with irregular and unpredictable raw materials (which may or may not contain hazardous or at least non-inert fractions as a result of the professionalism with which the structure was demolished, irrespective of the nature and content of the original building). Some plant owners overcome this by controlling the demolition process (if it is done by third parties) through close on-site liaison with the demolition contractor. Others rely mainly on careful, and sometimes multiple, inspections of the incoming materials prior to and during processing. Others simply use a central facility to deal with the waste from all their own local demolition sites, rather than operating mobile plants at each, and do not accept any C&DW from third parties.

'State of the art' C&DW processing equipment

- 4.18 The following description draws heavily on a paper presented to a meeting in the UK (the 1997 AAS Seminar, May 1997, London) by representatives of Deutag Remex (now just known as Remex), the leading German operator of C&DW recycling centres, and on technical information provided by manufacturers of C&DW crushing and sorting equipment.
- 4.19 There is a general acceptance that German C&DW recycling centres provide a good proxy for 'state of the art' technology. Remex do not act as demolition contractors, but accept C&DW from many such contractors.
- 4.20 The incoming inert fraction is weighed and inspected, and placed onto one of a series of separate stockpiles for:
- (i) broken bricks and tiles;
 - (ii) reinforced concrete;
 - (iii) non-reinforced concrete;
 - (iv) mixed C&DW.
- 4.21 Broken bricks, tiles, reinforced concrete and non-reinforced concrete are screened through a pre-sieving process to remove the 0-45mm fraction (divided into 0-4mm and 4-45mm). The remaining material then goes to an impact crusher (see below). Material coming out of the impact crusher passes through a magnetic separator to remove ferrous metals before being sieved to divide it into 0-45mm and >45mm. The >45mm fraction is placed onto a temporary stockpile for re-crushing, while the 0-45mm fraction is sieved into sub-fractions of 0-4mm, 4-8mm, 8-16mm, 16-32mm and 32-45mm. These sub-fractions can be re-combined into mixes defined by the end user, or into proprietary (branded) mixes.
- 4.22 The choice of an impact crusher over a 'jaw' crusher reflects the fact that it produces a more consistent and predictable aggregate, with sharper edges on the individual granules. Impact crushers use a high speed rotor inside a container into which the material to be crushed is fed. There are typically four or six 'hammer plates' mounted on the rotor which break the material against 'face plates' set at operator-determined positions on the inner surface of the container (see Annex 13 for an illustration). The 'cutting' action is very like that on a conventional cylinder lawnmower (for cutting grass). The throughput is greatly affected by the

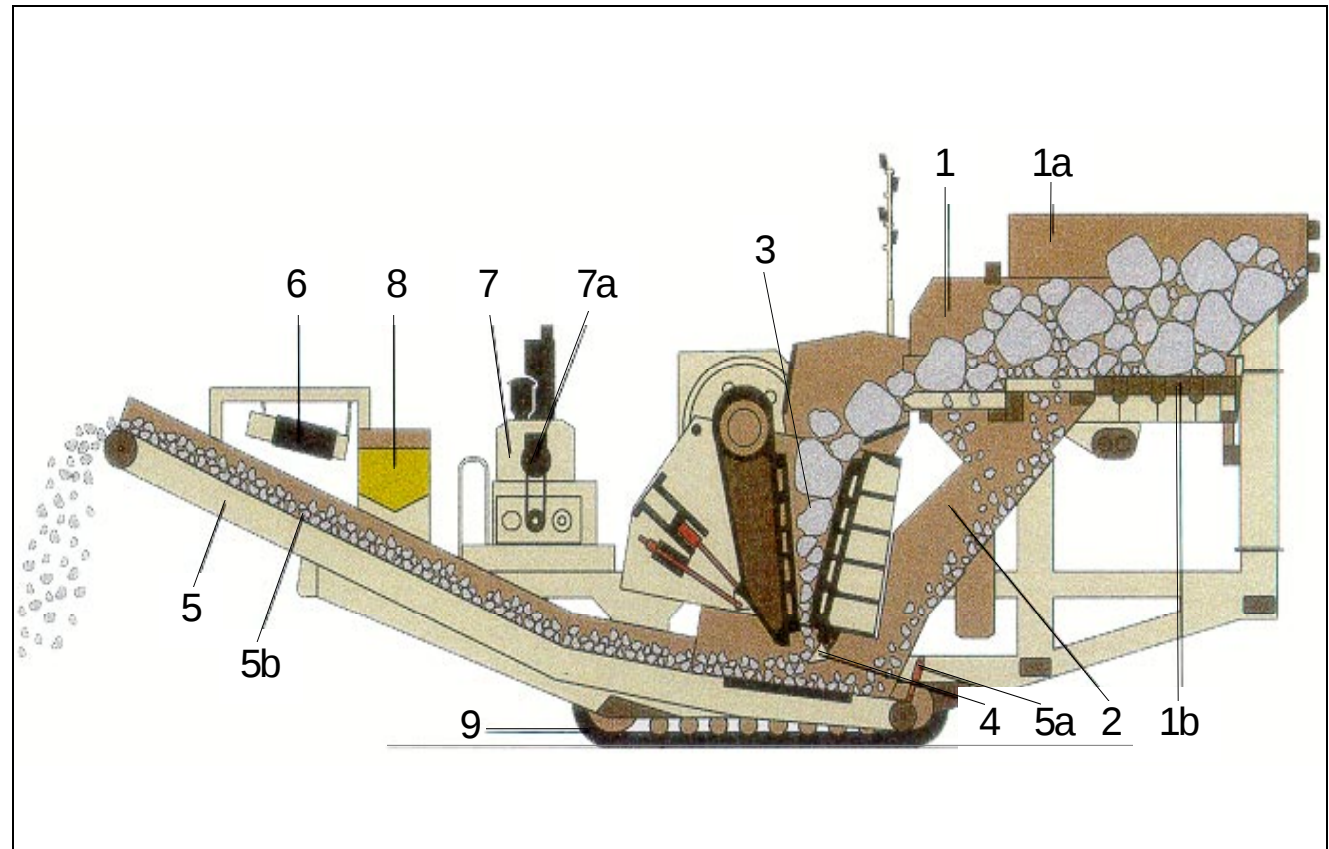
clearance between the rotating 'hammer plates' and the fixed 'face plates', and the rate of wear on the plates varies greatly according to the hardness of the material being processed.

- 4.23 'Jaw' crushers are typically shaped like a wedge, in which one of the faces moves relative to the others, producing a 'chewing' action which grinds the material into progressively smaller pieces as it passes towards the narrow end. Material is fed in at the wide end (the top), and falls out at the narrow end (see Annex 13 for an illustration). The narrow end can be set to a range of openings to determine the nature of the resultant material.
- 4.24 The choice between an impact crusher and a 'jaw' crusher is the operator's, and very much depends on the use to which the crushed material will be put. Impact crushers produce an aggregate with a smaller range of sizes, and although they are substantially cheaper to buy on a size-for-size basis, their running costs are much higher, particularly with very hard materials like some reinforced concretes. In general impact crushers tend to be designed for higher throughputs than 'jaw' crushers.
- 4.25 Figure 4.6 is a drawing of a relatively sophisticated mobile plant fitted with a 'jaw' crusher. Although very similar to this in most respects, fixed plants are likely to have higher processing capacities, and to be provided with hydraulic legs rather than crawler tracks or wheels.
- 4.26 The throughput achieved with recycled aggregates can be as low as half of that achieved with primary materials, and seldom exceeds three quarters of the nominal output. Performance is better with asphalt, but still not as high as for primary materials.
- 4.27 On emerging from the crusher, instead of being sieved into the sub-fractions described above, the 0-45mm fraction can be passed through an air classifier, washed, passed through a further metal separator and screened through either a vibrating screen or a free-fall screen. This produces a range of washed, sorted and quality-graded materials. Any oversize materials (which are more common with 'jaw' crushers than with impact crushers) can be sent back to the crusher for re-processing.
- 4.28 In the Remex system, mixed C&DW is generally subjected to hand sorting even before it is screened and passed through a magnetic separator for the first time. This is followed by further manual (or in some cases automated) sorting to remove plastics, paper, wood and other non-ferrous metal wastes.
- 4.29 The mixed C&DW is then passed through a 'jaw' crusher and magnetic separator before being passed through an air separator which removes light materials (small pieces of paper and plastics which escaped the earlier sorting processes and the 0-4mm fraction of the inert material. The 4-45mm fraction can then be sieved or screened, as with the brick, tile and concrete waste (see above).
- 4.30 Some recycling centres also have wood processing plants or composting facilities. Even without these facilities, the equipment plus necessary infrastructure described above costs roughly ten times as much as a good quality mobile crusher.
- 4.31 The closer a recycling centre is to neighbouring properties, the more likely it is to have to invest in noise and dust controls, including buildings to contain some of the equipment. This will make it harder for the recycled materials produced to compete in the market.

Figure 4.6: Cross Section of a 'Jaw' Crusher Mounted on a Mobile Chassis with Associated Equipment

Key:

- 1 Feed hopper, with extension (1a) and 'grizzly' feeder (1b)
- 2 By-pass chute
- 3 'Jaw' crusher
- 4 Belt protection plate
- 5 Main conveyor, with hydraulic controls (5a) and reinforced belt (5b)
- 6 Magnetic separator
- 7 Engine unit, with generator (7a)
- 8 Fuel and oil tanks
- 9 Tracks



Acknowledgement: The illustration above is reproduced by kind permission of Nordberg

Best practice guidance on demolition and renovation site management

General guidance

- 4.32 Although the manager of a demolition site never knows with absolute certainty what he will find as structures are broken open, much uncertainty can be removed by carrying out a pre-demolition survey to identify materials and select appropriate techniques. Further uncertainty is inevitably associated with processes such as controlled explosions, but computer controlled systems have significantly increased the predictability of such demolition methods.
- 4.33 In Annex 6 we provide details on measures taken by the various Member State governments to encourage C&DW re-use and recycling. These have included research, development, pilot and demonstration projects on selective demolition and written guidance (including training materials) on best practice for officials, building owners and demolition contractors.
- 4.34 By reference to Annex 6 it can be seen that the Member States which have done most in this regard are Germany, the UK, France, the Netherlands, Belgium and the Scandinavian countries.
- 4.35 When it comes to identifying best (or at least good) practice, two reports of particular interest (because they are in French and English, and therefore widely accessible to native speakers of several other Member States) have recently been published by ADEME and CIRIA respectively. Both of these references can be found in Annex 10, along with many other technical references.
- 4.36 Although many of the references in Annex 10 are in English, we have included some others on topics of particular interest (such as selective demolition) in other languages (such as Catalan).
- 4.37 Given the complexity of the selective demolition process it is not well suited to regulation by conventional legislation. It is notable that several Member States (including Germany, the Netherlands, Belgium, Austria and Denmark) have turned instead to Voluntary Agreements (VAs) to promote best practice. The UK has established two VAs related to the use of HCFCs (hydrofluorocarbons, which are greenhouse gases) in fire fighting systems and insulation foams, both of which may in future show up in C&DW.

Material-specific guidance

- 4.38 To avoid repetition, we deal with guidance linked to specific waste streams once only. This information will be found at the end of Chapter 5 below.

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5. PROCESSES AND BEST PRACTICE GUIDANCE: CONSTRUCTION SITES

Processes commonly found on construction sites

- 5.1 This Chapter is limited to matters which are specific to construction (and re-construction) sites. Demolition-related issues relevant to 'demolish, clear and build' and 'renovation' sites are dealt with above in Chapter 4.
- 5.2 One major difference between construction waste and demolition waste is that the construction manager knows (or should know) exactly what materials are brought onto a site, and has some control over both the stocks and flows of such materials. He can therefore plan with some confidence for the management of all waste flows. Only ground conditions represent an area of potential surprise.
- 5.3 The construction manager needs to maintain sufficient stocks of materials to enable work to go ahead without undue delays, which means that he must carry some stocks at all times. Relying too heavily on 'just in time' deliveries carries risks of delays in an industry which is still dependent on the weather, because when one site can boost its work rate and therefore wants extra supplies, so can all others in the area.
- 5.4 Building sites are also messy places with difficult working conditions, particularly at the early stages of construction. Some damage to building materials (as well as some mixing and/or contamination) inevitably occurs, which both generates some waste and reinforces the need for the site manager to order more materials than are actually required.
- 5.5 Construction waste therefore falls into four main categories:
- (i) damaged materials;
 - (ii) excess materials left over at the end of the job;
 - (iii) 'intermediate' and 'pre-cursor' waste products; and
 - (iv) packaging waste.
- 5.6 The first two of these categories are self-explanatory. Both are susceptible to good site management practices, in that efficient storage facilities, good stock control, proper training of the labour force and effective control of sub-contractors can reduce damage and reduce over-ordering. Having an internal accounting systems which enables undamaged surplus materials to be returned to the supplier or transferred to another site would also help. A surprisingly large volume of good quality construction materials goes to landfill as mixed waste.
- 5.7 Part-used gas bottles (from welding and cutting gear), sealants, paints and other similar items also fall under the heading of excess materials left over at the end of the job.
- 5.8 In the final Section of Chapter 2 we dealt with hazardous and potentially hazardous C&DW. This included several 'intermediate' and 'pre-cursor' materials, which are used to make up a material on site. 'Intermediate' wastes would also include products like waste oil which are generated by the construction plant and equipment found on a typical site.
- 5.9 There will also be a considerable volume of packaging waste. A survey carried out in France and reported in a study for ADEME (see Annex 10, Ref 7.1) estimated that the volume of packaging waste which arises on construction sites represents about 2% of the total waste arising from construction and rehabilitation sites, and much more when the inert fraction of C&DW is excluded.
- 5.10 Of the 296,000 tonnes of packaging waste in the ADEME survey, 42% was wood, 24% was metal, 22% was cardboard, 10% was polypropylene and polyethylene, and 4% was 'other'.

Best practice guidance on construction site management

General guidance

- 5.11 A major recent research project carried out in the UK for CIRIA (see Annex 10, Ref 12.9) has resulted in a series of best practice guidance publications aimed at:
- (i) site owners;
 - (ii) construction managers;
 - (iii) site labourers.
- 5.12 Although the message (which concerns waste avoidance and best practice related to handling) is consistent across the different documents, the details and the style varies considerably.
- 5.13 Similar best practice guidelines have been published in most other Member States, and details can be found in Annex 10.

Material-specific guidance

- 5.14 This Section deals with recycling process applicable to all types of C&DW, not just construction waste. The information has been gathered into one place to avoid repetition.
- 5.15 The same ADEME report referred to above includes an overview of recommended practice on how to deal with the major C&DW fractions, namely:
- (i) wood;
 - (ii) paint;
 - (iii) asbestos;
 - (iv) plaster;
 - (v) the inert fraction; and
 - (vi) plastics.
- 5.16 In 1995 similar information was also collected for the C&DW Priority Waste Streams Project. This information came from European associations and federations, and was collected through questionnaires issued to Project Group members in 1993 and 1995. Where appropriate, this was supplemented by published data. Inclusion of these materials in the Project Group's report was stated not to imply "... any judgement as to their significance but was determined by the replies to the questionnaires ...". It was included in that report as Appendix 6 under sub-headings dealing with:
- (i) aluminium products;
 - (ii) asbestos products;
 - (iii) asphalt;
 - (iv) clay bricks and tiles;
 - (v) concrete;
 - (vi) glass;
 - (vii) glasswool, stonewool and slag wool;

- (viii) gypsum-based construction materials;
 - (ix) iron and steel;
 - (x) plastics;
 - (xi) plastic foam insulation; and
 - (xii) textiles.
- 5.17 During the course of this project we re-contacted the same European associations and federations that had contributed to that report to identify any new material or research. A considerable amount of new information has been produced on gypsum recycling. This is brought together in the proceedings from Eurogypsum's XXII Congress in the Hague in May 1998 (see Annex 10, Ref 3.2). An important finding of that work is that recycling can only work in relatively densely populated areas, where the collection costs are not too high. Collection costs are heavily influenced by economies of scale (which means having collection points which can attract enough material to make regular collection worthwhile, and distances between collection points and the processing centre which are short enough to keep transport costs down).
- 5.18 A third source of information on a very wide range of secondary and recycled materials will become available in mid-1999 when CIRIA publish 'The Reclaimed and Recycled Construction Materials Handbook (see Annex 10, Ref 12.9.3). This substantial handbook, running to some 200 pages, is intended to provide guidance and information on both the approach of the UK construction industry to using reclaimed and recycled materials and on the available materials (including products) themselves.

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6. PROCESSES AND BEST PRACTICE GUIDANCE: ROAD MAINTENANCE AND CONSTRUCTION

Road maintenance processes

Introductory remarks

- 6.1 Road reconstruction has conventionally consisted of the excavation of existing materials, and their replacement by new. This requires significant quantities of materials to be brought in, traditionally from primary sources. It also requires the existing material to be taken away for disposal. There are therefore two sets of transport-related environmental impacts. The recycling of existing materials can result in both cost savings and reduced environmental impacts compared to conventional techniques.
- 6.2 Although the recycling of road by-products shares many overlapping theoretical considerations with more mainstream C&DW re-use and recycling, the context within which it occurs, the processes used, and the very particular nature of the bituminous surfacing used on most roads, are so specific and individual that road recycling should be considered separately from other C&DW recycling and from new road construction using recycled materials.
- 6.3 The two principal techniques are known as *in situ* and *ex situ* recycling. These are briefly discussed below, but any interested reader should refer to a 1997 report (see Annex 10, Ref 1.2.1) from the OECD entitled 'Recycling strategies for road works' which reviews the techniques and the experience of 14 OECD Member countries including Austria, Belgium, Denmark, Finland, France, the Netherlands, Sweden and the UK.
- 6.4 Before that, we reproduce some data from the European Asphalt Pavement Association (see Annex 10, Ref 3.3, which show just how much material is currently used on Europe's roads and motorways (Figure 6.1), and how much recycling is currently going on (Figure 6.2).

Figure 6.1: Statistics on Road Construction Materials ('000 tonnes)			
Member State	Hot Mix Asphalt Production 1997	Cold Bituminous Mixes 1997	Bitumen Consumption in the Road Industry 1997
Germany	65,000	n/a	2,680
UK	27,500	n/a	1,810
France	38,600	1,500	2,900
Italy	39,800	n/a	1,950
Spain	23,900	1,450	1,320
Netherlands	7,900	26	330
Belgium	4,600	0	220
Austria	6,100	50	320
Portugal	8,100	240	580
Denmark	3,500	24	180
Greece	5,200	2	370
Sweden	5,300	700	320
Finland	3,800	1,000	250
Ireland	2,400	120	210
Luxembourg	n/a	n/a	n/a
EU-15	241,700 ⁽¹⁾	5,112 ⁽¹⁾	13,440 ⁽¹⁾

Source: Asphalt in Figures, 1997 (European Asphalt Pavement Association)

Notes: n/a = not available

(1) excluding n/a

Figure 6.2: Statistics on the Recycling of Road Construction Materials ('000 tonnes)			
Member State	Material Available for Recycling	% Used in Warm Recycling	% of New Production Containing Reclaimed Materials
Germany	15,000	80	18
UK	≈5,000	n/a	10
France	>1,000	≈25	<3
Italy	1,200	50	5
Spain	700 ⁽¹⁾	n/a	n/a
Netherlands	3,000	50	20
Belgium	≈1,500	10-40	15
Austria	500	25	5
Portugal	67	n/a	n/a
Denmark	160	67	37
Greece	600	n/a	n/a
Sweden	900	8	2
Finland	300	50	5-10
Ireland	n/a	n/a	n/a
Luxembourg	n/a	n/a	n/a
EU-15	29,927 ⁽²⁾	n/a	n/a

Source: Asphalt in Figures, 1997 (European Asphalt Pavement Association)

Notes: n/a = not available

(1) all used in cold recycling

(2) excluding n/a and treating >, < and ≈ as actual numbers

In situ recycling

- 6.5 *In situ* recycling of roads generally involves the remediation of worn carriageways by the reprocessing of the existing road construction materials and the incorporation of a binder material. This requires several passes of specialised machinery. The technique has been used extensively in the Scandinavian countries. A 50km stretch of the main highway between Zaragoza and Lérida (in Spain) was renovated in this way as a trial. In some other Member States (such as the UK) its use has generally been restricted to minor urban and rural roads.
- 6.6 The process normally follows the following sequence:
- (i) the existing road construction materials (including the wearing course, base course and sub-base) are broken out and mixed by one pass of a rotary pulveriser;
 - (ii) a binder is mixed into the pulverised material with a further pass of the machine (where cementitious binders are used, water is also added);
 - (iii) the resultant mix is graded (levelled) as necessary and compacted using conventional equipment;
 - (iv) the surface is sealed with bitumen and grit as preparation for the laying of a new wearing course.
- 6.7 Before the process begins, core samples are taken from the existing road pavement to enable the depth of treatment and type and percentage of binder to be determined. Following the first pass of the rotary pulveriser, material often has to be removed in order to allow a new wearing course to be put into place without adversely affecting the final level of the road surface.
- 6.8 The binders used in the process are generally cement, mixes of cement and lime, fly ash or foamed bitumen.

- 6.9 The advantages of the process compared to traditional methods are as follows:
- (i) the existing road material is reclaimed, thus reducing the demand for brought-in (normally primary) aggregate;
 - (ii) fewer lorry movements are required;
 - (iii) the process is quicker, thereby reducing disruption to traffic;
 - (iv) costs are usually lower than for traditional construction methods.

6.10 The disadvantages of the process are:

- (i) services (gas, water, telephones etc) close to the surface can be disrupted;
- (ii) manhole covers have to be lowered and sealed prior to the process, and then raised again.

6.11 The time saving benefits were quantified on one trial project in the UK where the existing road surface was badly degraded. Using conventional methods it was estimated that the road would have to be closed for a month, whereas using *in situ* recycling it was closed to the majority of traffic for just five days, and buses and essential local traffic were able to continue using the road throughout. The total duration of the works, including lowering and reinstating manhole covers, was approximately eight days.

Ex situ recycling

6.12 *Ex situ* recycling involves the excavation and removal of existing road construction materials to a stockpile, from where it is processed by grading and mixing with appropriate binders prior to being re-compacted to form the new road.

6.13 The *ex situ* approach allows greater control over material quality than *in situ* recycling (see above), and more engineering control during the construction operation. It more easily provides a consistent construction material which experience has shown to be suitable for heavily trafficked road surfaces.

6.14 *Ex situ* recycling has the following characteristics:

- (i) the recycling plant is easily transported and can be established on the chosen site in a few hours;
- (ii) the plant itself is comparatively smokeless, odourless and quiet;
- (iii) the location for the recycling plant can be chosen to reduce environmental impacts and to enable them to be mitigated;
- (iv) environmental impacts at the reconstruction site itself can be reduced to a minimum;
- (v) a wide range of materials can be processed including road planings, crushed concrete and masonry;
- (vi) the materials can be crushed and screened to fit a predetermined grading 'envelope', before being mixed with a binder;
- (vii) all materials are processed in a controllable environment, resulting in the production of a quality controlled product;
- (viii) graded materials can be stockpiled until they are needed;
- (ix) bound materials, if correctly stored, can be used for up to four weeks after production;

- (x) the excavation of the road and its replacement can be undertaken using conventional plant and equipment;
 - (xi) secondary aggregates (such as fly ash) can be incorporated into the new road, further reducing the need for primary aggregates.
- 6.15 Where indigenous aggregates are of poor quality, a specialist proprietary binder can be used in the recycling process. Such an approach has been widely used for a number of years in Canada.

Road construction using other recycled materials

- 6.16 Road construction (as well as the construction of car parks and similar areas of hard standing) offers by far the main outlet for C&DW-derived aggregates throughout the EU. It can be stated with some confidence that where C&DW-derived aggregates are not accepted by the relevant highway authorities (as is the case with both JAE and BRISA, the major highway authority and toll motorway operator respectively in Portugal) there will be little or no C&DW recycling.
- 6.17 The same OECD report as was mentioned above (see Annex 10, Ref 1.2.1) deals with the use of a wide range of waste and recycled materials, including C&DW-derived aggregates. As it points out they are used primarily as sub-base material and in embankments and as general engineering fill. Although a relatively low grade use, this nevertheless avoids the need to quarry significant volumes of primary materials.
- 6.18 Annex 10 contains a large number of references related to road reconstruction and construction using recycled materials.

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7.1