ABSTRACT: Recycling in Portugal is a fairly new business, especially when it comes to construction and demolition waste (CDW), where recycling efforts are minimal, although gaining momentum. Efforts to determine the quantity of nationally produced CDW have resulted in huge discrepancies, which highlight the necessity to further pursue a more precise account of this generation. Nevertheless, a few recycling facilities have started working in some regions, even without specific legislation concerning CDW recycling, which means that there is a great profit potential for this industry. Although the output material is not of great quality (aggregate mix with several contaminants), it can be used in applications as secondary road base or undemanding building groundfloors. The legislation frame related to CDW is almost non-existant although seen as crucial to a proper development of the CDW recycling business.

1 INTRODUCTION

The construction industry in Portugal does not have a tradition in re-using or recycling wastes which are generated in construction and demolition activities. While other industries have started collecting and recycling their products, as plastic and paper industries, mainly due to stricter environmental legislation referring to Municipal Solid Waste (Portugal has only recently finished banning open-air dumps), construction and demolition companies are still allowed to dump their waste in landfills, when not illegally at the road-side (Fig. 1). Although mainly inert, CDW amounts to enormous quantities and, if not recycled or re-used in some way, contributes to the ongoing depletion of natural resources (stone, sand, oil (plastics), wood) and exhausting of landfill space. Just as a reference, Municipal Solid Waste (MSW) generation in Portugal amounts to about 4,550,000 ton/year (derived from Waste Institute information), while CDW production rises up to 6,440,000 ton/year (a national projection of the amount presented in (Pereira 2002)). This means that, at least in terms of quantity, CDW is a greater problem, in Portugal, than MSW.

Although the overall picture is not bright, efforts have been undertaken in favour of recycling CDW, as seen from the work of starting recycling plants in several parts of the country. These facilities basically collect non-dangerous mixed CDW (collecting different fees at the entrance, depending on the waste mix level and its density), separate it mainly by hand labour and crush into several grain sizes the resulting material. Although this output product is of low quality, most materials that enter the facility are actually sent to be recycled (paper, cardboard, wood, plastics (some varieties), metals, glass), after receiving companies (legally operating recyclers, as listed in (National Directory of Environment and Natural Resources 2006)) have been contacted and established which quality condition applies for each material to be recycled.
This paper aims to give an overview, as accurate as possible, of the CDW recycling activities in Portugal, in order to expose the existent barriers but also to identify the opportunities that lay on its path. A short insight on recent attempts to quantify CDW generation, followed by a description of two recycling facilities and their working process, an overview on some CDW management operations in several parts of the country and comments on the Portuguese legislative frame concerning CDW management constitute the main chapters which this paper is composed of.

2 QUANTIFICATION OF CDW GENERATION

Although some attempts have been made to quantify CDW in Portugal, variations are too great to reach any conclusive figure. Consulted studies present values are as different as 235,774 ton/year (Salinas 2002), 7,691 ton/year (Carvalho 2001) and 2,132,600 ton/year (Pereira 2002), the latter only for the Portuguese northern region. European estimations have attributed to Portugal about 3,200,000 ton/year, calculated from a CDW capitation of 325 kg/person/year, with a 9.9 million population (Symonds Group Ltd., 1999). Other estimates have resulted in 95 kg/person/year (CDW without soil content) and 190 kg/person/year (CDW with soil content), reported has having been deposited in legalized sites (FCT Project POCTI / ECM / 43057 / 2001, 2004). From the referred figures, the one presented in (Pereira 2002) is considered by the authors, up to this moment, as the most realistic number, since it actually relied on a systematic direct and indirect contact survey of private and public institutions, namely through personal interviews, email enquiries and telephone contacts.

There are several reasons that account for such differences in the presented numbers. One is the generalized ignorance, as far as CDW is concerned, from producers, transporters to municipalities, which tend not to keep records of quantities produced, transported, landfilled, recycled or reused, although this procedure is a part of the Portuguese law, concerning these matters (see chapter 5). Another reason is the illegal discharging that is still occurring by all agents, namely contractors, transporters and municipalities as well, although there are already a few legalized industrial inert waste landfills in the country (DECRETO-LEI n.º 152/2002), which remain, however, underused (Jornal de Notícias, in press, 2006). Other reasons might be related with what is considered CDW, since, for example, soils constitute a large share of the average composition of CDW if included, although not quite representing a waste (recent legislative efforts have already acknowledged this fact, see chapter 5), since it is not a transformed material (contaminated soils, however, are rightly labelled as waste, which must be treated in order to return to the natural environment).

Other attempts to quantify CDW generation, as already in progress by the authors, follow the same logic as in (Pereira, 2002), aiming at the collection of as much in situ information as possible (mainly from construction and demolition contractors and CDW recyclers), not only on global CDW amounts but also on specific waste flows (concrete, masonry, wood, plastic, met-
als and so on) and trying to associate these with their origin (residential, non-residential and from construction, renovation and demolition activities).

3 EXISTING RECYCLING PLANTS

3.1 Description and location

Up to this date there is only one recycling plant working on CDW, already active (since beginning of 2006). This plant is owned by TRIANOVO, located in Torres Vedras (TRIANOVO recycling plant – Location: Casais da Serra, 2560-057 A-dos-Cunhados, Portugal). Another one, inaugurated in April 2007, is called ECOLABOR (http://ecolabor.paginas.sapo.pt/ (in Portuguese)) and will receive CDW from Sintra region, although it is still not fully active.

TRIANOVO is a basic collecting, separating and crushing plant, which sells separated materials to other recyclers (plastics, wood, paper, metal, glass) and supplies graded fill aggregate, mainly composed by crushed concrete, brick and mixed fines. Mixed CDW are deposited in a central area where large pieces of contaminants are first separated and oversized concrete blocks are reduced to fit in the crusher input opening. Then materials are transported up the separating belt (Figure 2), which runs at an average speed of 0.2m/s, where medium size contaminants are separated by hand by one worker per separate fraction. The resulting aggregate fraction is then conducted to the crusher belt, passing through an overhead magnet, which picks up medium sized ferrous metals. The crusher plant has three separate crushers, tuned to deliver several aggregate sizes. The plant receives around 250 ton/day of CDW, half of which is composed by mixed soils.

ECOLABOR (Figure 3), although not processing CDW until very recently, is equipped with an air blower (to separate the light materials from the heavy aggregates), a jig table (to isolate different grain sizes) and a portable fine separator (mounted on an excavator). This equipment will speed up the separating process, while enhancing the output materials quality.

3.2 Input materials

Generally, input materials are all mixed, which of course results in a more expensive separation process and lower final product quality. However, the recycling plant guarantees profitability by charging accordingly to the input mix level, using the values stated in Table 1 (which may vary). For contaminated mixed aggregated, which belongs to a certain category between

Figure 2. Separating belt feed at TRIANOVO recycling plant

Figure 3. General view of ECOLABOR recycling plant
Table 1. Prices charged for incoming materials at TRIANOVO recycling plant

<table>
<thead>
<tr>
<th>CDW type</th>
<th>Price charged, €/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soils</td>
<td>1</td>
</tr>
<tr>
<td>Clean mixed aggregates</td>
<td>2</td>
</tr>
<tr>
<td>Contaminated mixed aggregates</td>
<td>only with high density wood and/or ferrous metals</td>
</tr>
<tr>
<td></td>
<td>with any kind of low density non-hazardous contaminants</td>
</tr>
</tbody>
</table>

High density wood and ferrous metal contaminants and any kind of low density non-hazardous contaminants (as for instance plaster/plasterboard and low density wood), a price between 4 and 60€/ton is charged. The great difference in prices has to do with the level of contamination, which is associated with waste density, or in other words, the less dense the mix waste is, the more likely it is to be harder to separate and the lower quality it will have as an output material, which will result in financial losses for the recycler. This way the recycler defends itself from higher treating costs and at the same time encourages source separation.

The plant accepts all aggregate materials containing concrete, bricks, tiles, rock and soils, which all together build up to over 99% of the input weight (Mimoso 2006). Mixed with the aggregates are also plastics, wood chips, paper, glass, ferrous metals, non-ferrous metals and other contaminants (such as gypsum), which represent only about 0,5% of the total weight (Mimoso 2006). 0,03% corresponds to the rejected materials (for instance, certain kinds of plastic that are not accepted by local recyclers), which cannot be sent to other recyclers and are unsuitable to remain in the aggregate fraction. This last fraction is sent to a controlled landfill. Bituminous concrete is accepted under strict conditions, although presently it is not being recycled. Hazardous materials are generally not accepted, which means the central rejects the discharge if these materials are detected (for instance asbestos, tar, paints, industrial oils and contaminated soils). This means that the producers of hazardous waste must separate them at the source and transport them to specialized recyclers, not to common CDW recycling plants.

Recycling initiatives in other parts of the country will most probably receive similar input products, which may vary depending on the demolition works taking place at that region (buildings age being demolished) and any source separation initiative (which is, however, unlikely).

3.3 Output products

Combining highly mixed input materials with lack of machinery to completely separate them, especially the fine fraction, output quality is not high. Therefore, the output aggregate can only be used for unspecific fills. Furthermore, there is no quality control over the final product, which also results from insipient national regulation on recycled construction products (although there are already four LNEC standards, see Chapter 4).

It is clear, however, that producing output products to be used in concrete or in top road layers (bituminous concrete), over which recent standards focus, is out of reach for the kind of recycling facilities emerging nowadays in Portugal. The industrial process to obtain such high quality materials (that may compete on a technical basis – let alone economical - with virgin materials) is much more complex, expensive and relies on strict quality control procedures (Xing 2004). These conditions and the lack of acceptance of recycled materials by both the Portuguese road construction and concrete industry, makes it almost impossible that such an initiative takes place today.

This high recycling level, as a matter of fact, has not been common, not even in the most developed countries (examples: Netherlands, Germany, United Kingdom, Denmark), in what concerns CDW management, due to the still large market for using recycled aggregates in road construction (especially in base and sub-base layers), which results in low recycled aggregate usage in concrete production.

3.4 Management options

In spite of low CDW recycling tradition in Portugal, some experiments have already been conducted, from which a few management options can be derived.
In the demolition of three concrete structures in the north of the country (in 2004) – south part of Boavista football stadium, FC Porto stadium and a factory (Hipólito et al. 2004) – fermentation factory in Matosinhos – basic demolition, separation and crushing techniques were used in order to recycle the majority of the demolished materials. In each of these three cases, source separation was conducted, removing non-structural materials as plastic, wood and metals, pillaging them separately and sending them to independent recyclers. This was done rather easily because these are relatively uncladded structures, which means there were few finishing layers and small amounts of other materials such as cables, isolation, window frames and floor coverings (when compared to the global amount of concrete). As a result, concrete demolition was conducted on rather stripped structures, which allowed crushing clean concrete rubble (with a mobile crusher/screener), after taking out the reinforcement with hydraulic scissors. Still, the resulting recycled aggregates were not used for new concrete production, being used, instead, in low grade pavement fills.

Another case study was reported, in 2001, for the José de Alvalade stadium, in Lisbon, were selective demolition was performed on all concrete support structures. Demolition, separation and crushing techniques were similar to those cited above. However, a more in-depth study was conducted, in order to determine the technical feasibility of using the recycled aggregates in new concrete (dos Santos et al. 2004). The results were rather promising, with 100% recycled aggregate concrete showing good mechanical properties (compressive strength, flexural strength and modulus of elasticity) when compared with natural aggregate concrete, although demanding somewhat a greater amount of mixing water, mainly due to the higher recycled aggregate water absorption.

Still another case, presently ongoing, accounts for the (partial) selective demolition of Estoril-Sol Hotel, in Estoril, Portugal (Figs 4-5). This reinforced concrete building constructed in the 1960’s has been targeted to demolition as it no longer serves the modern functional and financial purposes of its owners. The demolition bid, however, has been won by Ambigroup, a Portuguese group of companies dedicated to waste management, developing in recent years capabilities in large CDW management operations, namely in technical and logistic aspects.

This specific case has involved locating, separating and sending to treatment facilities (which may not recycle these materials, but only landfill them in a controlled way) of hazardous materials as asbestos and mineral oils; selective removal of carpets, wood frames, glass, doors, metal frames, sanitary, electrical cables and insulating materials; unselective demolition of remnant materials – reinforced concrete, masonry, tiles, plastic pipes and gypsum boards and source separation of all valuable metallic materials (reinforcement and steel joists and plates). All metals were sent for recycling, as well as glass, since there is a well established market for recycling these materials. Combustible materials as wood doors, carpets, wood frames and cables have been incinerated at Secil-Outão cement factory, as alternative fuel. Finally, all other materials (over 90%, in weight, of all materials taken from the building), which had lime and silica content (concrete, masonry and tiles), were sent to the main clinker burner at the same mentioned cement factory. Overall, although the actual recycled material percentage was low, in total weight, dumping was avoided in almost every material fraction, allowing instead for energy recovery (alternative fuels) and secondary raw material use (ceramic minerals for clinker production).

Figure 4. Concrete, masonry and ceramic materials after demolition and size reduction, at Estoril-Sol working site
As far as CDW management options are concerned, the Portuguese situation is not much different from those encountered in other countries, which means there is great recycling potential, even with basic equipment and mainly low-grade recycling applications.

4 PORTUGUESE LEGISLATION FRAME CONCERNING CDW

The Portuguese legislation frame concerning CDW has been developing, especially in recent years. In Table 2, an overview of these documents is presented, in chronological order.

<table>
<thead>
<tr>
<th>Legislation reference</th>
<th>General description</th>
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<tbody>
<tr>
<td>Portaria nº 15/96, 23rd of January, 1996</td>
<td>Approves waste management operations</td>
</tr>
<tr>
<td>Portaria nº 335/97, 16th of May, 1997</td>
<td>Establishes rules for waste transportation</td>
</tr>
<tr>
<td>Portaria nº 818/97, 5th of September, 1997</td>
<td>Approves the European list of wastes (all kinds)</td>
</tr>
<tr>
<td>Decreto-Lei nº 239/97, 9th of September, 1997</td>
<td>Establishes general rules for waste management</td>
</tr>
<tr>
<td>Portaria nº 961/98, 10th of November, 1998</td>
<td>Legislates authorization processes in managing industrial, urban and other kinds of waste</td>
</tr>
<tr>
<td>Portaria nº 792/98, 22nd of September, 1998</td>
<td>Approves the non-hazardous industrial waste map</td>
</tr>
<tr>
<td>Decreto-Lei nº 321/99, 11th of August, 1999</td>
<td>Regulates the installation and management of non-hazardous industrial landfills</td>
</tr>
<tr>
<td>Decreto-Lei nº 516/99, 2nd of August, 1999</td>
<td>Approves the Strategic Plan for non-hazardous industrial waste</td>
</tr>
<tr>
<td>Decreto-Lei nº 152/2002, 23rd of May, 2002</td>
<td>Regulates the installation, use, closure and post-closure procedures for landfills</td>
</tr>
<tr>
<td>Portaria nº 209/2004, 3rd of March, 2004</td>
<td>European waste classification list</td>
</tr>
</tbody>
</table>

In spite of all the waste management legislative effort undergone since 1996 (even though the first published law over waste management, in Portugal, goes back to 1985, with DECRETO-LEI nº 488/85), there has not been published, up to this moment, a specific law concerning CDW management. However, a draft legislative document is under preparation since 2005, to address this specific waste management issue. This document calls for certain definitions and actions/management options, which can be summarized as follows:

- Non-contaminated soils are excluded from the CDW stream - an important issue, since soil can take up a considerable percentage of total CDW waste, if considered. This is based on the average Soil/Total CDW relationship calculated for several European countries (values presented in (Pereira, 2002)), which is around 60%;
- Focuses on reduction as the basis of CDW management, with reuse and recycling as the preferred options, after generation;
- Defines the responsibility chain, in CDW production and management;
- Calls for previous CDW generation study for each construction project, which must always be a part of the bid process, stating the Owner as its responsible;
- Obliges the Owner to pay previously to the municipality a certain amount (3 or 10% of the contract amount, depending if this contract involves only construction/retrofit or only demolition) to guarantee CDW management in case of improper or inexistent plan of action;
- Non-compliance with its basic principles involves payment of fines and/or losing the right to exert (construction or demolition) activity.

In order to positively influence sound CDW management, this legislative draft also defines incentives, to be applied during the bid processes, which shall incorporate CDW management good practices as one of the decision parameters (in winning or losing a bid).

It is also worth mentioning that the National Civil Engineering Laboratory (Laboratório Nacional de Engenharia Civil – LNEC) has recently produced four recycling standards, one for structural concrete – Guide for the use of recycled coarse aggregates in concrete, E469-2006; another for bituminous concrete – Guide for the production of recycled hot mix asphalt, E472-2006, a third one for pavement layers – Guide for the use of recycled aggregates in unbound pavement layers, E473-2006; and, finally, the last one for embankments and capping layers – Guide for the use of construction and demolition recycled materials in embankments and capping layers, E474-2006. Although the relevance of such standards is undeniable, if high level recycling is to be done in the Portuguese construction industry, there is, at the moment, little possibility in doing so, due to lack of advanced CDW recycling technology and source separation actions (which render high level recycled output construction products – as structural concrete or bituminous top layer concrete - uneconomical).

5 CONCLUSIONS
A general presentation of the CDW management situation in Portugal has been reported in this paper. Although still insipient, a CDW market is developing, along with shortage of dumping sites, higher tipping fees and longer distances to legalized landfills. Effort has been applied in developing legislation concerning waste production, transport and treatment in Portugal, although a dedicated CDW standard is still unpublished.

However, even lacking specific legislation, some industrial initiatives have been started (TRIANOVO, ECOLABOR) and a few companies (AmbiGroup) have been investing in logistics and machinery for conducting selective demolitions (dismantling), while setting up commercial networks between transporters, recyclers and cement factories (in the cited example, Secil-Outão). These initiatives show that there is a high lucrative potential in CDW recycling activities, since generated quantities are very significant, a recycling market already exists for some important CDW fractions – steel/metals, wood, plastics and paper – and there is a high demand for unspecified filling materials, base foundation layers and road bases and sub-bases.

Although the general quality of CDW recycled output materials is low, mainly due to highly mixed input flow, low tech recycling equipment, lack of quality control and non-existent demand for recycled high-value products (such as recycled structural concrete or bituminous concrete), the developing of new recycled material standards (for instance, LNEC E469-2006, E472-2006, E473-2006 and E474-2006) and specific legislation under preparation will certainly create better conditions to backup recyclers, incentive producers to reduce and manage their CDW and help clients to better understand and learn to trust recycled materials.

6 FUTURE RESEARCH
More accurate and categorized CDW quantification is needed in Portugal. Therefore, a case-driven data gathering initiative is crucial, in order to give recycling investors, clients, contractors and designers previous knowledge of the generated quantities per type of building and/or
predictions per material flow, which allows them to take management decisions and allocate funds.

Thorough information gathering on CDW recycling technology is also needed, in order to organize in a systematic way all the technological possibilities in mobile and fixed recycling operations, for different material inputs and desired output quality. A complete study on selective demolition is also important, to allow a direct comparison in material and financial terms between selective and traditional demolition practice.

Finally, a profound operational and economical analysis of a fixed recycling industrial facility is of great importance, since this can help to better understand the complexities of the CDW recycling industrial system, its optimization and ways to render it as lucrative as possible. This also generates background knowledge for future CDW recycling investors, helping them to overcome some market barriers and explore current possibilities.

7 ACKNOWLEDGMENTS

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