Construction and Demolition Waste, its Variability and Recycling in Brazil

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1 CDW GENERATION RATE IN BRAZIL

There are few consistent studies on construction and demolition waste (CDW) generation rates in Brazil. However, the available data does allow suggesting that the amount of CDW is probably higher than the amount (w/w) of Municipal Solid Waste (MSW). A typical Brazilian per capita CDW generation rate for some cities is above 500 kg/year (Table 1).

Table 1 CDW Quantity, population and some generation rates in Brazil (Pinto, 1999).

<table>
<thead>
<tr>
<th>City</th>
<th>State</th>
<th>Population (Inhab.)</th>
<th>CDW Quantity (ton/year)</th>
<th>CDW per capita (kg/year)</th>
<th>Data from year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santo André</td>
<td>São Paulo</td>
<td>625,564</td>
<td>369,745</td>
<td>591</td>
<td>1997</td>
</tr>
<tr>
<td>Vitória da Conquista</td>
<td>Bahia</td>
<td>242,155</td>
<td>113,150</td>
<td>467</td>
<td>1998</td>
</tr>
<tr>
<td>Ribeirão Preto</td>
<td>São Paulo</td>
<td>456,252</td>
<td>380,695</td>
<td>834</td>
<td>1995</td>
</tr>
<tr>
<td>São José do Rio Preto</td>
<td>São Paulo</td>
<td>323,627</td>
<td>250,755</td>
<td>775</td>
<td>1997</td>
</tr>
</tbody>
</table>

These values are consistent with reported international generation rates. The reported CDW participation in the total MSW varies from 13% (Bossink; Brouwers, 1996) to 67% (Lauritzen, 1994). A study conducted by the European Union reports a variation of the per capita generation from 136 kg/year up to 3359 kg/year (EU, 1999). A significant portion of the variation in CDW generation rates is a direct result of CDW definition. Other sources of variation are the differences in the industrial structure and the degree of development as well as the characteristics of the building technologies used in each country, etc.

2 ORIGIN OF CDW

Like most developing countries, Brazil is still under construction. The construction related business is about 15% of the Brazilian GNP. Because of the relatively high production of construction waste at building sites, CW represents approximately 50% of the total CDW generated (Pinto, 1999). In more developed countries, like those of Europe and the USA, the construction activity is responsible for about 1/3 of the total CDW produced (Lauritzen, 1994; Peng et al, 1997)
In Brazil, construction waste quantities are increased due to high rates of material wastage at building sites. Table 2 presents selected wastage rates measured at about 63 new building sites in Brazil (Souza et al., 1999). This data is valid only for the formal construction industry. Until now, there has been no data about material wastage for the informal (do-it-yourself) construction sector, which produces most of the low-cost houses in Brazil.

Table 2  Material wastage in new building sites and estimations of construction waste (Souza et al, 1999; Andrade, 2001).

<table>
<thead>
<tr>
<th>Materials</th>
<th>Wastage (%)</th>
<th>Waste (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Minimum</td>
</tr>
<tr>
<td>Concrete</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Steel</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Blocks and bricks</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>Ceramic tiles</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Mortar (screed)</td>
<td>42</td>
<td>8</td>
</tr>
</tbody>
</table>

3  CDW TRADITIONAL MANAGEMENT IN BRAZIL

As a rule, municipal policy towards CDW residues has been to ignore them. The only strategy towards CDW traditionally adopted by local authorities has been to repeatedly clean fly tipping areas and, sometimes, operate a CDW landfill or accept CDW dumping in the municipal solid waste landfill. Nevertheless, the landfill never succeeds in attracting more than a fraction of the total CDW generated and fly tipping is the most common private solution adopted for disposing of CDW. The landfill operated by the city of São Paulo attracts only 15% of the total CDW generated in that area (Schneider, 2002).

Fly tipping areas can be streets (Figure 1), parks, private areas and creek banks. The environmental impact associated with this kind of dumping is important. The proliferation of pests (rats and poisonous insects, among others), traffic hazards and landscape destruction are part of this issue. The city of São Paulo estimates that illegal dumping in public areas is as high as 20% of the total CDW (Schneider, 2002).

Removing this illegally dumped CDW is also very expensive. In city of São Paulo, the local authorities report spending about R$45 million a year (about US $19 million) removing illegally dumped CDW (Schneider, 2002) from the “one” official CDW landfill.

(a)            (b)
Figure 1 Illegal dumping sites in city of São Paulo. (a) Street used as dumping area just after being cleaned by the local authorities (2002-08-30) (b) the same area after two months (2002-11-04).

Most middle-sized and big cities do have private CDW landfills. Most of these landfills operate without a license. Environmental licensing is very difficult because there are no consolidated regulations. Also, private dumping sites do not have any design that ensures stability and there is no practical control over the waste dumped, leading to great risk of environmental contamination. It is known that one illegal C&D landfill collapsed about 10 years ago in São Paulo, killing 13 persons.

As a consequence, CDW management is a profitable business, with revenues estimated to be higher than US $40 million/year in the city of São Paulo alone (John; Agopyan, 2000). Most CDW in Brazilian middle-sized and big cities is collected and transported by specialized private companies, using open containers (chain lift skips).

In big cities like São Paulo, there are no longer so many places suited to be landfills. So the landfill prices are increasing. Also a significant part of the CDW generated in São Paulo is, at present, being “exported” to other municipalities within the metropolitan area and illegally dumped there. This additional distance adds to the cost of transport and disposal. The price for removing and dumping a 4m³ container (including the renting fee for up to a week) can be as high as US $30,00 in São Paulo.

There are some companies that recycle CDW as rendering mortar using a small rotating mill installed at the building site (Miranda, 2000). Grigoli (2000) reports other uses of CDW in-site.

4 TRENDS ON CDW MANAGEMENT IN BRAZIL

Management of CDW is changing very fast. In the next few years most municipalities are expected to develop specific policies towards CDW.

Some municipalities, such as Belo Horizonte, have already implemented successful systems to manage CDW and others are in the process of doing the same. This system includes registration of companies that transport CDW, a well-located network of CDW deposit sites which attract most of the CDW and a recycling plant, which produces aggregates and gives proper destination to the metallic and organic fraction. Education is an important component of the system as well as an effective structure to prevent and punish fly tipping. In big cities, like São Paulo, stations sort the waste and transfer it to bigger trucks, making the system cheaper and reducing the impact of transporting the CDW in urban area.

The CDW recycling plant belongs to the municipality, which consumes most of the aggregates as road base. Very frequently, political changes halt the entire system. São Paulo, Londrina and São José dos Campos are examples.

The National Council for the Environment (CONAMA) is in the process of approving a directive on CDW management that will require all municipalities and building contractors to set up management schemes. This directive has been negotiated with the community. Additionally, the CDW Task Group of the Environmental Chamber of the Construction

1 Exchange rate US $1 = R$2.4
Industry of the State of São Paulo is drafting drafts of technical standards related to the use of recycled aggregates as well as proposals of regulations for licensing CDW landfills and transfer stations.

As a result of these efforts, recycling construction demolition waste is expected to become an important business in Brazil in the near future.

5   RECYCLING PLANTS TECHNOLOGY

Brazilian CDW recycling plants are simple and stationary. As in Europe, most of plants are derived from mining engineering but do not apply any better technological equipment or new ways of more elaborate separation and concentration (Hendriks, 2000). As a rule, these plants consist only of manual pre-sorting system, crushers, manual sorting that removes contamination, conveyor belts and screenings (Figure 2). A magnetic separator is used in some plants such as the ones in São Paulo and Belo Horizonte. There is no systematic control of the arriving material although there is visual inspection. Likewise, there is no systematic quality control of the delivered aggregates.

Figure 2  Typical Brazilian CDW recycling plant (City Municipality Vinhedo – São Paulo state) aggregates for road base.

Most of the aggregates produced by the recycling plants are used as road base in urban paving activities. Some tentative applications of selected recycled aggregates for concrete component production (concrete blocks and paving blocks) have been made, in the cities of Vinhedo, Belo Horizonte and Santo André. However, in at least one case, the cement consumption rate was at least 30% higher that the required for natural aggregates.

6   CDW, ITS VARIABILITY AND RECYCLING POSSIBILITIES

6.1 Sources of composition variability

CDW is a mixture of the materials used in the building (Figure 3 and Figure 4) and the composition is highly variable. In Brazil, the typical building waste is a mixture of ceramic or concrete blocks, mortar, reinforced concrete, steel, plastic, asbestos cement and wood. The use of gypsum as plasterboard or plaster is on the rise and is expected to become a significant part of the waste in a few years’ time.
Construction waste, which is about 50% of the Brazilian CDW, is considered to be more mixed and variable because there is less discipline in waste discharge. This is due to the wide variety of contractors, the high cost of waste separation, insufficient areas for waste discharge and different waste period production in building sites (Hendriks, 2000). In Brazil, demolition waste also tends to be a mixture of all phases, because sophisticated selective demolition techniques are only applied to very old residential buildings, where the bricks, windows, etc have a high market value.

As most of the CDW containers are parked in the streets or in front of the building site, neighbours often place additional litter in the containers, further increasing the contamination (Figure 3).

So, without changes in CDW management at both construction and demolition sites, it will be very difficult to classify the arriving waste as predominantly concrete or masonry, as specified by European countries (Rilem Recommendation, 1994; Hendriks, 2000).
6.2 Composition variability

As can be seen in Table 3, the composition of Brazilian CDW recycled aggregates is highly variable. Angulo (2000) presents results of the most comprehensive investigation about the variability and quality of CDW aggregate produced in Brazil. While studying the operation of an experimental recycling plant in Santo André (São Paulo Metropolitan Area), the author took hourly samples during 12 working days. Zordan (1997) results are after three random samples.

Table 3 Reported composition and its variability for some Brazilian CDW aggregate recycling plants.

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Av</td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Concrete</td>
<td>23</td>
<td>44</td>
<td>62</td>
<td>32</td>
</tr>
<tr>
<td>Gravel</td>
<td>3</td>
<td>23</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Mortar</td>
<td>10</td>
<td>28</td>
<td>61</td>
<td>15</td>
</tr>
<tr>
<td>Ceramic</td>
<td>0</td>
<td>4</td>
<td>13</td>
<td>33</td>
</tr>
<tr>
<td>Soils</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>Wood &amp; Organic</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Others</td>
<td>0.0</td>
<td>1.2</td>
<td>4.6</td>
<td>4</td>
</tr>
<tr>
<td>City</td>
<td>Santo André</td>
<td>São Paulo</td>
<td>Salvador</td>
<td>Ribeirão Preto</td>
</tr>
</tbody>
</table>

6.3 Variability and recycling

The high variability of the composition is in itself a major problem when recycling, even when considering its use as road base aggregate.
Angulo and John (2002) compared the aggregates’ characteristics (mortar + ceramic maximum content, maximum water absorption, density, maximum content of contaminants and filler content) with those specified in the RILEM recommendations and the Dutch Standard (Rilem Recommendation, 1994; Hendriks, 2000). None of the 36 samples studied complied with the standards for use in structural concrete. And only 10 samples did comply with the Dutch rules for demolished masonry aggregate, suitable for use in non-structural concrete applications. The major reasons for non-compliance with non-structural applications were filler content and the presence of contaminants as well as mortar plus ceramic maximum content. The contaminants most frequently detected were asphalt, glass and wood. No evaluation for sulphate control was made.

Zordan (1997) investigated the effect of the variation of the composition of the CDW in concrete. It was found that compressive strength is reduced 30% for 1:3 (cement/aggregates proportion) and w/c (water/cement) relation of 0.5 when the composition varies (see Table 3).

Miranda (2000) studied the influence of CDW composition variability on performance rendering mortar. Laboratory produced waste was analysed to determine what influence the content of concrete blocks, ceramic blocks and mortars have in the properties of fresh and hardened mortar samples. An increase in mortar content generated a higher incidence of cracking on rendering caused by higher water/cement relation.

So, at present, road base aggregate seems to be the only market for recycled CDW aggregates. However, in most cities, the municipal consumption of road base aggregate is not enough to consume the total available waste (Pinto, 1999).

Consequently, long-term development of a market big enough to recycle all CDW will demand new and more valuable applications. To achieve this goal it will be necessary to (a) introduce changes in CDW management for construction, demolition and transportation, (b) to significantly improve the recycling plants.

6.4 Improving Brazilian recycling plants
One possibility for improving CDW recycling plants is the adoption of equipment to classify the waste based on its specific gravity, like jig (Jungmann; Quindt, 1999; Ancía et al., 1999). This kind of technology allows separating the densest aggregates that can be, potentially, recycled in more valuable applications, like concrete production. Results from Angulo (2000) confirm that this technology can be very useful in the Brazilian market (Figure 5).
Another option is the adoption of homogenisation piles, especially when combined with jigs, because they drastically reduce the variability of composition, density and water absorption. Simulations with the data from Angulo et al (2001) show that piles, which were accumulated during 3 or more weeks of production presented stable compositions, water absorption and specific gravity. Considering the typical production of a recycling plant to be above 300 ton/day, the homogenisation pile would require a relatively large storage area, which would reduce the recycling site options and increase the site cost. Combining the homogenisation technique with jig classification can reduce the time necessary to get a stable composition.

Developing a fast and cheap methodology to control the quality of recycled aggregates is also vital to the development of more sophisticated markets for the aggregates. Such techniques must be precise enough to allow certification of the composition and other quality relevant requirements of the generated aggregate.

7 CONCLUSIONS
C&D Waste is a relevant problem in Brazilian society. The generation rate is high, being around 500 kg/year per capita. Illegal dumping is a current practice, with considerable social and environmental impact. Nevertheless, CDW management is a prosperous business in most cities.

At present, the amount of recycled waste is very small and the resulting product is used as road base. The technology of the recycling plants is very simple. There is no systematic quality control of the resulting product. It results in aggregates with high variable compositions and with a high content of ceramic and mortar materials. A small fraction of the resulting aggregate is suitable for more valuable applications like producing concrete and concrete components.

The ongoing changes within the institutional framework, especially the national regulation on CDW, technical standards and the development of municipal policies will greatly increase the demand for recycling in the near future.
In order to increase recyclability and attract private investments to the recycling market, both waste management practices and recycling technology must be improved. Homogenisation piles combined with density based classification systems (jig) are interesting options for the technical improvement of recycling plants.

8 ACKNOWLEDGEMENTS
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9 REFERENCES


