**CODE 011-0171**

# USE OF CONSTRUCTION AND DEMOLITION RESIDUES IN NEW MATERIAL FOR CONSTRUCTION

**Fábio José Esguícero** – Universidade Estadual Paulista –UNESP. Rua Chanés, 512 – Lençóis Paulista – SP. E-mail: fabioeconomia@ig.com.br Phone (14) 3263-3325

**Jair Wagner de Souza Manfrinato** – Universidade Estadual Paulista –UNESP. Av. Eng. Luiz Carrijo Edmundo Coube, 14-01 – Bauru –SP. E-mail: jwsouza@feb.unesp.br – Phone (14) 3103-6122

**Benedito Luiz Martins** - Universidade Estadual Paulista –UNESP. Av. 09 de Julho, 972 - Lençóis Paulista – SP. E-mail: martins_bl@hotmail.com. Phone (14) 3269-7054

POMS 20th Annual Conference
Orlando, Florida U.S.A.
May 1 to May 4, 2009

## Abstract

Construction sector is responsible to great amount of residues generation in the whole production chain, from natural resources extraction to disposal of remains during life-cycle of products, causing social and environmental problems to cities. Due the exposed problem, this work presents a study about reuse of CDR (Construction and Demolition Residue) in new material to construction. Recycling CDR can generate sand and stone, which can be used to manufacture concrete with no structural purpose, concrete artifacts such as pipes to water galleries, blocs, including reuse in basis and sub-basis to asphalt. With recycling, CDR has an environmental correct solution, and also decreases natural resources extraction through construction chain in resources purchase.

**Key-words**: Resources, Recycling, CDR.

## 1. Introduction

The civil construction industry generates high volumes of solid waste in its entire production chain.  The sector is responsible for the extraction of non-renewable natural resources and consumes larges amounts of energy from the exploration of mines to the transportation of materials. This generation of residues continues with waste in carrying out private, commercial interest or public undertakings, leading to problems as to the correct disposal of such waste. It thus becomes an environmental problem for society with few practical alternatives and a lack of studies in Brazil.

When deposited in improper locations and without controls by public authorities, the waste can cause environmental pollution and harm the urban landscape.

In the 1990s, concern with the generation of household waste became the object of several studies, leading to practical solutions that are being implemented in some Brazilian cities such as selective collection and composting. But Construction and Demolition Residue (CDR), when monitored by public authorities, is frequently sent to special landfills without the techniques and investments that enable recycling and this hampering the return of CDR to the production chain. Without monitoring, these residues are deposited at clandestine sites and can cause health problems for the population as well as environmental pollution such as flooding and silting of rivers and streams (ZORDAN, 2005).

The recycling of construction and demolition waste provides cities with an option that minimizes the environmental problems generated by CDR and their proper disposal, corroborating with resolution number 307 of the National Council on the Environment (CONAMA) of 2002, which prohibits disposal in landfills. This resolution aims at sending as much residue as possible for recycling and reuse. This way, this treatment model for CDR provides sustainable and economically correct solutions for the problem.

## 2. Methodology

The methodology used for development of this work was based on bibliographical research, divided in three stages. Initially had been identified the norms that establish the criteria and the necessity of the recycling of the CDR in function of the ambient problems observed by the generation of these residues.

In the second stage, had been identified the existing statisticians regarding the volume of CDR generated in Brazil and the exterior.

In the final stage had been searched the diverse forms of reusable of CDR existing in literature its acceptance technique, as well as the diverse forms of job of these materials in the industry of the civil construction.

## 3. Classification and destination of construction residue

Resolution 307 of July 5, 2002, of the National Council on the Environment (CONAMA) standardizes the civil construction residue management process, classifying them and establishing their economic, social and environmental relations:

> "Whereas the technical and economic feasibility of production and use of materials from the recycling of civil construction residues; and whereas the integrated management of civil construction residues should provide social, economic and environmental benefits, decides to: Art.1 Establish criteria and procedures for civil construction residues, controlling necessary actions in order to mitigate environmental impacts..."

Tenório & Espinosa (2007) affirm civil construction residues could be classified as urban waste. Due to their characteristics and volumes, they are normally classified separately.

Civil construction residues come from constructions, renovations, repairs and demolitions of civil construction works and those resulting from preparing and excavating land, such as: bricks, ceramic blocks, concrete in general, soil, rocks, metals, resins, glues, paints, wood and compensated wood, sheathing, mortar, drywall, tiles, asphalt pavement, glass, plastics, piping, electric wiring, etc. (CONAMA, 2002). The residues are classified as follows:

a) Class A – reusable or recyclable residues such as for construction aggregates (sand and stone) like: from construction, renovations and repairs of pavement and other infrastructure works, including soil from landscaping.

Construction, renovations and repairs of buildings, such as ceramic components (brick, blocks, tile, sheets of cladding, etc.), mortar and concrete;

Manufacturing and/or demolition process of pre-molded parts in concrete (blocks, tubes, curbs, etc.) produced at job sites.

b) Class B – recyclable residues for other destinations such as: plastics, paper/cardboard, metals, glass, wood and others;

c) Class C – residues for which economically feasible technologies or applications have not been developed, which permit their recycling/recovery, such as drywall products;

d) Class D – hazardous residues from the construction process, such as: paints, solvents, oils and others, or contaminates from demolitions, renovations and repairs of radiology clinics, industrial installations and others.

CONAMA resolution 307 emphasizes the need for recycling and reusing residues, establishing the following criteria:

a) Class A residues must be reused or recycled as aggregates or sent to civil construction landfills and disposed of in a manner that permits future use or recycling;

b) Class B residues must be reused, recycled or sent to temporary storage areas and disposed of in a manner that permits future reuse or recycling;

c) Class C and Class D residues must be stored, transported and disposed of in compliance with the product's specific technical norms.

**4. Measuring residue volume**

It is very difficult to measure the volume of CDR generated in a city because most of them use information obtained from CDR collectors by means of the so-called "buckets". According to the Urban Solid Residue Management Diagnosis (2004), the records of data regarding the operations of these companies seems precarious and do not permit establishing the existence of characteristic residue behavior.

According to John & Agopyan (2000), international estimates range from 130 to 3,000 Kg/inhab. per year. In Brazil, estimates for the cities of Jundiaí, Santo André, São José dos Campos, Ribeirão Preto, Campinas and Vitória da Conquista range from 230 Kg./inhab. per year to 760 Kg/inhab. per year.

In the city of Lençóis Paulista, with a population of approximately 61,000 inhabitants, an average daily volume of 127.0 cubic meters of CDR has been established. According to data from the Waste Recycling Plant of the City Hall of São José do Rio Preto, the specific mass of CDR is approximately 1.3ton/m³. This results in a daily volume of 165.1 tons. (Monday thru Friday). The city estimate is 670 Kg./inhab. per year, similar to the volumes estimated for other locations observed in Table 1 and the volume in weight shown in Figure 1:

TABLE 1 - Estimates generate of CDR

| Location | Volume Kg./inhab.per | Source |
|---|---|---|
| Sweden | 136 - 680 | TOLSTOY, BORKLUND & CARLSON (1998) |
| Italy | 600 - 690 | LAURITZEN (1998) |
| Brazil | 230 - 660 | PINTO (1999) |
| Jundiaí- SP | 760 | PINTO (1999) |
| Lençóis Paulista - SP | 670 | Author |

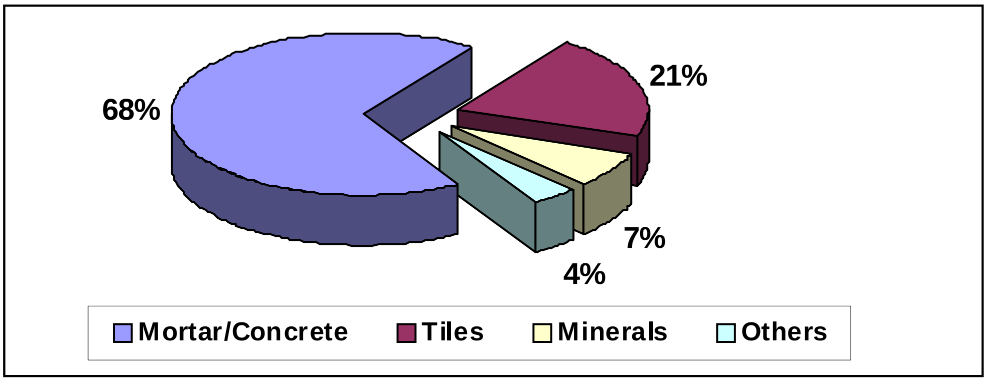


FIGURE 1 - Composition (% in weigth) of CDR in the City of Lençóis Paulista

Figure 2 shows the composition of CDR in the City of São Paulo. According to data from the Waste Workers Association of São Paulo (ATESP), in 2000, nearly 330 thousand tons of CDR was collected per month and 80% of this volume was deposited at clandestine sites.

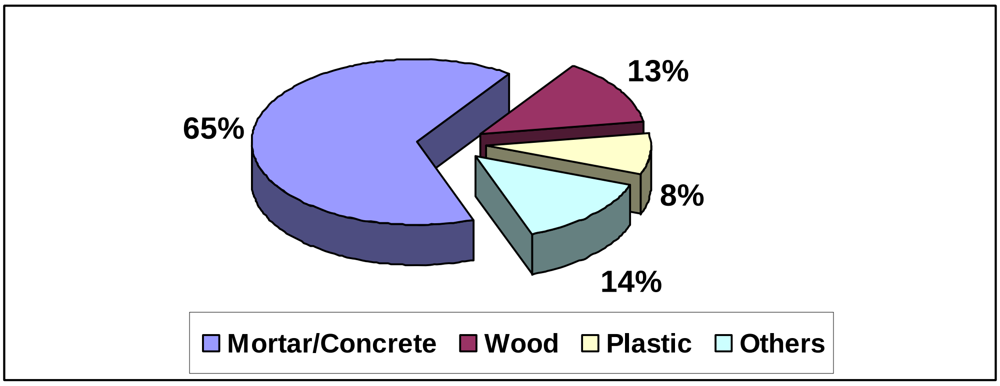


FIGURE 2 - Composition ( % in weight) of CDR in the City of São Paulo (Levy, 2007)

**5. CDR recycling process**

Civil construction is one of the oldest activities we have knowledge of and since the beginning of humanity it has been carried out in an artisanal manner, generating a large amount of mineral waste as a byproduct. Levy (2007) underscores that this fact already aroused the attention of builders back in the days of the Roman Empire, from when we have the first records of reusing civil construction mineral residue to produce new works.

The author also says the first significant application of recycled residue was only recorded after the Second World War, in the reconstruction of European cities. Their buildings had been completely demolished and the resulting debris was recycled for the production of aggregates aimed at meeting the demand at that time.

The document that resulted from ECO 92 in Rio de Janeiro, AGENDA 21, brought up a topic called "sustainable construction". This initiative rethought the entire production chain, beginning with the extraction of raw materials, and took into account the production processes, based on the reduction of pollution, energy and water savings and the reduction of natural resource consumption. Given the growing demand for inputs from the civil construction sector, new ways to obtain raw materials were developed to supply that need. One way to mitigate this problem is recycling CDR, generating the recycled aggregate.

The recycling process normally obeys the steps shown in Figure 3.

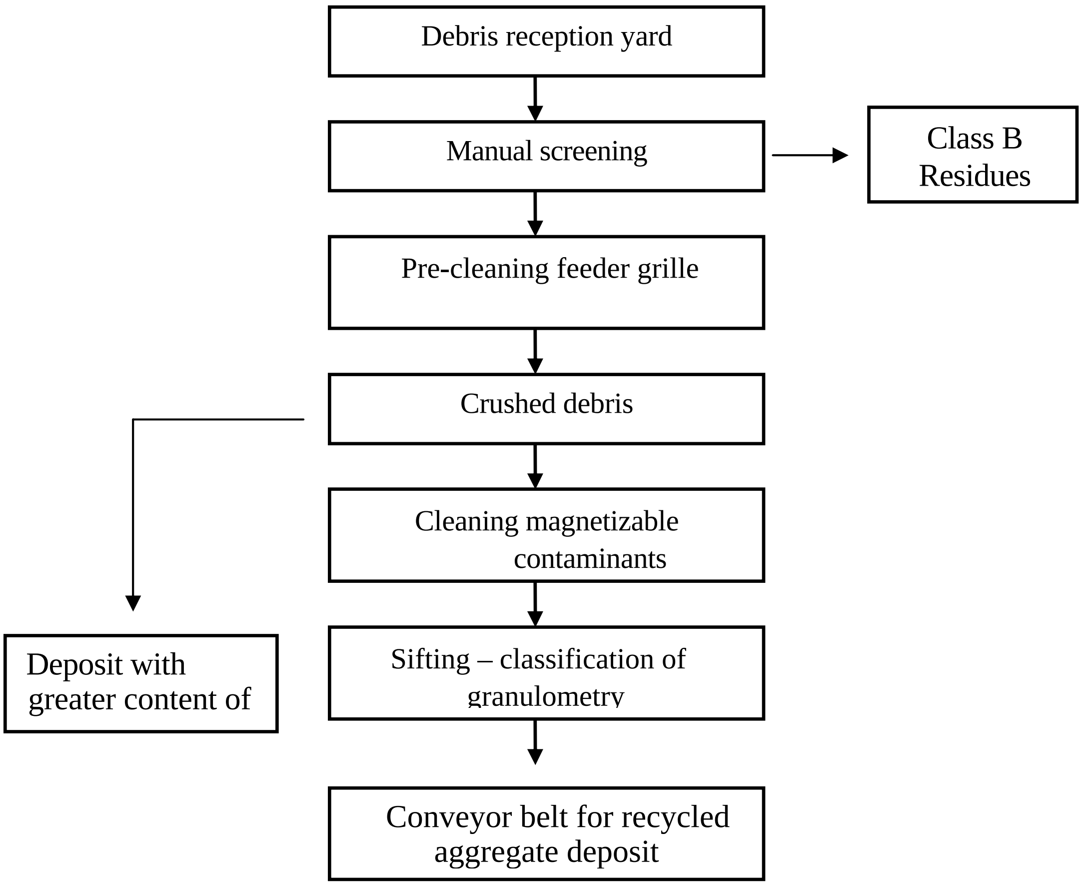


Figure 3 – CDR recycling process flowchart

Recycled aggregate is the granular material from processing construction residue that has technical characteristics for application in buildings, infrastructure, landfills or other engineering works. (CONAMA, 2002).

Debris can be recycled to generate aggregates for civil construction with a quality comparable to natural aggregates. In the United States, this has been done for more than thirty years in the production of artificial aggregates to make a base and sub-base for pavement. (ESPINOSA & TENÒRIO, 2007).

In countries like Holland, 70% of the CDR is recycled and in Germany 30%. Copenhagen, in Demark, recycles nearly 25% of demolition debris because the country has a scarcity of granulated material and there is a 10% surcharge for consuming natural aggregates, favoring recycling by the mining companies.

According to Lanzellotti et. al. (2004), the reuse of aggregates through debris recycling is one of the simplest forms of reuse. In Brazil, debris recycling is recent and there are few plants in existence for this process.

When opting for investing in a CDR Recycling Plant it is necessary to make use of a detailed statistical study of residue generated at the site for dimensioning the unit. It is then necessary to take into account production costs like labor, machinery and maintenance. At present, there are plants with production capacity starting at 20 tons/hour, with a minimum initial investment of R$ 400,000.00 (MAQBRIT, 2008).

In general, the equipment used for recycling construction residue comes from the mining sector and it is adapted or simply used in recycling. This activity requires a differentiated quality control system due to CDR variability and contamination and it is necessary to manually separate contaminants and to have complementary equipment, like magnetic separators (JADOVISKI, 2005).

A statistical study is necessary so the unit does not operate with idle capacity, jeopardizing the financial return on the investment. In Brazil, these investments are most often observed when carried out by municipal authorities. There are few production units and those that stand out are in the cities of Ribeirão Preto, São Paulo, Piracicaba, Belo Horizonte, Vinhedo (Jodovski, 2005) and São José do Rio Preto.

## 6. Production of new materials

### 6.1 Recycled aggregate

Debris recycling plants produce recycled aggregates of all granulometric fractions used to make pavements and pre-molded elements, in the elaboration of concrete without structural purposes and as partial replacement of natural aggregates.

Chart 1 shows the byproducts from recycling civil construction ceramic residue.

| Product | Characteristics | Main uses |
|---|---|---|
| Sand | Max D < 4.8 mm<br>From blocks of demolished concrete | Mortar, bricklaying<br>Sub-floors<br>Sealing blocks |
| Sleet | Max D < 6.3 mm<br>From blocks of demolished concrete | Concrete artifacts<br>Interlocking floors and guides<br>Sealing blocks |
| Crushed rock 1 or 2 | Max D < 39 mm<br>From blocks of demolished concrete | Concrete without structural functions<br>Drainage works |
| Crushed rock | Max D < 63.0 mm<br>From civil construction residues | Sub-base and base for pavements highways<br>Regularization of unpaved roads |
| Coarse rock | Max D < 150.0 mm<br>From civil construction residues | Soil replacement<br>Landscaping<br>Drainage |

Chart 1 – Recycled aggregate and granulometry (Levy, 2007)

### 6.2 – Concrete blocks for sealing

In Brazil, we find some cases of works made with concrete blocks manufactured from construction residue. One example is the Torre Almirante building constructed in 2003-2004 in Rio de Janeiro. With the demolition of an old skeleton of a nine-story building, nearly 5,000 m³ of debris was produced, transformed into 600,000 14x14x39 cm blocks and used to build 600 popular homes (LEVY, 2007 apud CAMPANILI, 2005).

**6.3 – Cement artifacts**

Another possibility for construction and demolition residue use is in infrastructure works like the construction of rain water gallery pipes, curbs, hexagonal pavement tiles, stakes and ornaments for squares and leisure areas.

The City Hall of São José do Rio Preto maintains a cement artifacts factory at its Debris Recycling Plant where recycled aggregates from the Plant are used. After the production of the artifacts, they are used in city works, serving the diverse secretaries such as Works, Environment and Education, generating savings in the purchase of aggregates.

**6.4 Soil-cement**

The reuse of construction and demolition residues to obtain soil-cement emerged as a result of realizing that sandy soils are most indicated. According to Alcântara & Segantini, (2007), the technical feasibility of residues after crushing resembles thick sand.

In studies carried out at UNESP in Ilha Solteira, SP, the incorporation of concrete residues to make soil-cement bricks was observed to provide substantial improvements in resistance and absorption properties with results that were superior to those stipulated in Brazilian technical norms. The use of concrete residues to make the bricks plays an important role in society, because it enables a low-cost technical option for producing new civil construction materials, totally inserted in the context of sustainable development (SOUZA, 2006).

## 6.5 Mortar

According to Levy (2007), in the 1990s, replacement of tiny natural aggregates with recycled aggregates was common in the production of mortar for laying bricks and even mortar for cladding, falling into disuse over the years. Miranda (2000) says the biggest problem in using CDR in mortar is the quantity of fine material, exceeding 30%. This high content of fine material demands more water to maintain mortar consistency, favoring the appearance of cracks and fissures. Levy underscores that if used in mortar at proportions of 1:3:8 (cement, recycled material, sand) for indoor jobs and 1:1.5:6 for outdoor cladding, the appearance of fissure is minimized.

## 6.6 Pavement

The use of recycled aggregates in the form of a base or sub-base for asphalt has the simplest characteristics for reusing recycled residues when applied as crushed rock. This process uses less technology, resulting in lower costs, and it also uses all the components of residue mineral fractions without the need for prior separation and in large quantities. There is also energy savings since the residue can be applied in works to be paved with greater granulometry without any need for further crushing.

Jadoviski 2004, apud Carneiro 2001 state the recycled aggregates are materials that can be used to reinforce pavement subgrades, sub-bases and bases since they have low granulometric percentages of clay and silt. The author also underscores that due to permeability, it can be used in pavement draining layers or sites with high water tables.

The City of São José do Rio Preto uses recycled crushed rock with lower granulometry to construct walkways for pedestrians.

Another option for reusing demolition residue is the recycling of asphalt pavements used in new pavements. In this case, the old pavement to be recycled is cut and then crushed in equipment that prepares the material for a new asphalt mix. At the job site both new asphalt and aggregates are added to the mobile equipment. The recommendation for this type of application is for the recycled material to be used as an intermediate asphalt base for a new thin rolling base (PETROBRÁS S.A., 2008). For any pavement made with recycled asphalt it is necessary for carry out a physical-chemical analysis of the aged asphalt binder to determine the new asphalt content to be added to the mix.

The reuse of recycled asphalt generates a savings in the acquisition of natural aggregates because machining is done at the job site reducing transportation costs for aggregates and asphalt mass.

### 6.7 Recycling of wood

Wood residue from construction and demolition can also be transformed and reused in new materials for civil construction. According to Levy, 2007, in the City of São Paulo, only one recycler is able to produce 240,000 $m^3$/month. The wood that arrives at the recycler undergoes a process where it is transformed into three sizes of chips. The smallest chip has a granulometric dimension of up to 4.8 mm and is used to produce MDF. MDF is a board made from the agglutination of wood fibers with synthetic resins and the joint action of temperature and pressure. The larger chips are sold for use as biomass and converted into energy in direct combustion in kilns and boilers.

### 6.8 Plastic wood compound

This is comprised of wood particles (sawdust and remains) with polystyrene (PS) and Polyethylene terephthalate (PET). The boards are made in proportions of 0%, 25% or 50% plastics and 100%, 75% or 50% eucalyptus grandis wood particles. Besides being ecologically correct, the plastic wood offers greater resistance when compared to common wood and it also waives the application of varnish and sealant needed with conventional wood.

## 7. Technical norms in the production of recycled aggregates

Brazil is one of the few countries that have the approval of specific technical norms for the use of recycled aggregates.

Between 2003 and 2004, through studies conducted by the Technical Committee for the Environment of the Brazilian Institute of Concrete (CT-MAB IBRACON) and the Study Group on Recycled Aggregates at SINDUSCON-SP, a text was elaborated that gave origin to the technical norms approved by the Brazilian Association of Technical Norms (ABNT) with regard to the recycling operation and the use of aggregates, shown in Chart 2:

| Norms | Reference | Procedures |
|---|---|---|
| NBR 15112/04 | Civil construction residues and voluminous residues | Overflow and screening areas Guidelines for design, implementation and operation |
| NBR 15113/04 | Solid residues from civil construction and inert residues | Landfills, guidelines for design implementation and operation |
| NBR 15114/04 | Solid residues from civil construction | Recycling areas, landfills and Guidelines for design, implementation and operation |
| NBR 15115/04 | Recycled aggregates and solid residues from civil construction | Pavement layers |
| NBR 15116/04 | Recycled aggregates of solid residues from civil construction | Used in pavement and preparation of concrete without structural functions |

Chart 2 – Standardization in the production of recycled aggregates (Levy, 2007).

As a result of the norms in force, private initiative must improve the quality of recycled aggregates, permitting their large-scale commercialization. These norms do not consider the use of recycled materials in structural concrete. However, Levy (2007) points out that in Holland the replacement of 20% of natural aggregates with recycled aggregates does not alter the physical and mechanical properties of concrete.

## 8. Conclusion

The recycling of CDR is a way to mitigate the problem of civil construction production chain residues because recycled CDR materials can be used to produce new materials to be employed in small and mid-sized jobs or in large constructions in the private or public sector.

With recycling, it is possible to obtain new aggregates like sand, stone and gravel with technical quality similar to natural aggregates. The same can then be used as raw materials for producing concrete artifacts like rain water gallery pipes, curbs, hexagonal concrete tiles, benches and construction blocks for homes. Deteriorated asphalt residue can also be used to produce a new asphalt mix in intermediate layers of pavements. Another form of reuse is observed in the production of MDF boards by employing shredded wood residues.

CDR recycling is an environmentally correct solution for the final disposal of debris that when discarded incorrectly entail in the proliferation of vectors that brings the threat of disease to the population. It also mitigates the issue of natural resource extraction by the civil construction industry which demands a large volume of resources and energy and is highly pollutant. It therefore permits the activity’s sustainable growth.

It is necessary to invest in research to improve the quality of recycled aggregates so they can receive commercial acceptance and generate growth in the recycling activity.

The results observed fully meet the objectives established by CONAMA’s resolution 307 related to CDR management, making the processes technically feasible and generating environmental, social and even economic benefits.

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