



Joel Vieira Baptista Júnior

**Uma Proposta Para Logística de Reciclagem dos
Resíduos da Construção Civil na Cidade do Rio de Janeiro**

Dissertação de Mestrado

Dissertação apresentada ao Programa de Pós-Graduação em Engenharia Urbana e Ambiental da PUC-Rio como requisito parcial para obtenção do título de Mestre em Engenharia Urbana e Ambiental (opção Profissional).

Orientador: Prof. Celso Romanel

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Prof. Celso Romanel

Presidente / Orientador

Departamento de Engenharia Civil – PUC-Rio

Prof^a. Michéle Dal Toé Casagrande

Departamento de Engenharia Civil – PUC-Rio

Prof. Rodrigo Rinaldi de Matos

PUC-Rio

Prof. José Eugenio Leal

Coordenador Setorial de Pós-Graduação
do Centro Técnico Científico - PUC-Rio

Rio de Janeiro, 28 de setembro de 2011.

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Joel Vieira Baptista Júnior

Graduou-se em Engenharia Civil pela Universidade Gama Filho do Rio de Janeiro em 1982. Pós – Graduado em Engenharia Urbana e Ambiental (Mestrado Profissional) pela Pontifícia Universidade Católica do Rio de Janeiro em 2011. Principais áreas de interesse: planejamento em engenharia civil, engenharia urbana e ambiental.

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Resumo

Baptista Júnior, Joel Vieira; Romanel, Celso (Orientador) **Uma Proposta para Logística de Reciclagem dos Resíduos de Construção Civil da Cidade do Rio de Janeiro.** Rio de Janeiro, 2011, 125p. Dissertação de Mestrado - Departamento de Engenharia Civil, Pontifícia Universidade Católica do Rio de Janeiro.

Existem milhares de técnicas e metodologias construtivas sustentáveis, e para o tratamento e reaproveitamento do resíduo da construção civil nos centros urbanos. Esse trabalho procura ordenar, de forma sintetizada, esses procedimentos para redução da geração e reaproveitamento do resíduo da construção civil no Rio de Janeiro, apresentando sugestões para as fases de idealização, projeto e execução do empreendimento e uma logística reversa para a reinserção do resíduo à cadeia produtiva. A pesquisa sugere no capítulo dois a utilização da ferramenta de Avaliação do Ciclo de Vida (ACV) na fase de idealização dos empreendimentos para uma visão ampla do impacto ambiental durante a execução da obra e na utilização do empreendimento até o descarte final, mostrando que a manutenção na fase de utilização representa mais de oitenta por cento do custo de toda a sua vida útil. O capítulo três apresenta uma análise do resíduo, sua composição, as classificações de acordo com o CONAMA e NBR 10.004, e seu potencial de impacto nas regiões urbanas, as principais fontes geradoras, um resumo das principais leis e resoluções brasileiras que regulamenta a sua gestão. Trás ainda uma comparação entre tipos de desconstruções com apresentação de um exemplo de uma demolição certificada no centro do Rio de Janeiro. O capítulo quatro apresenta um panorama geral da gestão dos resíduos da construção civil nas grandes cidades, evidenciando no Rio de Janeiro a existência de dois tipos distintos de geradores de resíduos na construção civil, o gerador das obras com canteiros instalados, licenciados, que segue as normas e exigências técnicas para seletividade do resíduo e os geradores das pequenas obras e reformas, responsável pela contribuição acima de 50% do total de resíduo gerado e pela quase totalidade da poluição. O capítulo cinco trabalha sobre a formula: (**Sustentabilidade = Projetos eficientes + Reaproveitamento dos detritos**). Projetos eficientes, obras com baixa geração de resíduos e erradicação dos desperdícios é o caminho para a sustentabilidade no setor. Apresenta métodos construtivos para esse objetivo e sustenta que a segregação do resíduo na fonte é pré condição para um processo eficiente de reciclagem. Apresenta o Social como o principal legado da logística para reciclagem dos resíduos nas grandes cidades nos países em desenvolvimento. O capítulo seis propõe um caminho para a logística de reciclagem do resíduo da construção civil no Rio de Janeiro, transformando o processo linear em um processo circular para a indústria da construção civil. O fim do despejo de resíduo da construção civil in natura é uma meta a ser continuamente perseguida por toda a sociedade no compromisso com as gerações futuras. Esse trabalho apresenta sugestões para esse fim.

Palavras - chave

Resíduos da Construção; Reciclagem de Resíduos da Construção; Gestão de Resíduos da Construção; Política para Resíduos da Construção.

Abstract

Baptista Júnior Joel Vieira. Romanel, Celso (Advisor). **A Proposal for Recycling Waste Logistics Construction of the City of Rio de Janeiro.** Rio de Janeiro, 2011. 125p. MSc Dissertation – Departamento de Engenharia Civil, Pontifícia Universidade Católica do Rio de Janeiro.

The historical importance of the construction industry in the constant improvement of society's quality of life is undeniable. A major source of employment, it accounts for twenty percent of all U.S. economic activity, and in Brazil, in 2008, it represented 8.9 percent of the GDP; in 2000 it consumed 210 million tons of natural aggregates. These figures express the sector's strategic need justifying investments in research for its sustainability, which is currently less than 1% from the U.S. government and 6% in Europe. There are thousands of sustainable building techniques and methodologies, as well as those for the treatment and reuse of construction waste in urban centers. This article aims to organize, in a summarized way, these procedures to reduce generation and treat construction waste in Rio de Janeiro, making suggestions for sustainable processes in the idealization, design and implementation phases of a new development and the reverse logistics for treating waste and reintegrating it into the production chain. In chapter two the study suggests the use of the Life Cycle Assessment (ACV) tool during new developments' idealization phases for a broad overview of the environmental impact of their execution, during the use of the developments until their final disposal. Research shows that maintenance costs in a development's utilization phase represent more than eighty percent of its entire life span. The ACV study qualifies knowledge of sizing, materials specifications and construction techniques, as well as routines for use of developments. It adjusts its viability guiding developments toward sustainable principles, for example, low power consumption settings, minimizing the use of natural resources, parameters for diversity of materials being used, the impact of the use of assembly and/or mounting adhesives that hinder selective disassembly for reuse, and the importance of planning deconstruction ahead of time in order to reuse materials; these factors are crucial in the quest for sustainability in the sector. Chapter three brings an analysis of this waste, its impact potential in urban areas, major generating sources, and a summary of the main Brazilian laws and resolutions regulating its management. By listing the main sources generating waste and scrap in construction, attention is drawn to the selective deconstructions of yesteryear that reused materials. Made viable by the construction techniques used at that time in these buildings that allowed the selective removal of material. Also in chapter three, an example of a current certified demolition in downtown Rio de Janeiro is presented. Finally, it shows the general composition of waste and its classifications according to CONAMA (the National Environment Council) and NBR (Brazilian Technical Standards Association) #10,004. Chapter four provides an overview of construction waste management in large cities, in Rio de Janeiro it is evident that two distinct types of waste generators exist in constructions: the first is the generator in construction works with installed and licensed construction sites, which follow the standards and technical requirements for waste selection

from generation to transportation under joint liability during the whole process until the final destination, in accordance with CONAMA's resolutions; these generators are monitored throughout the process. Yet the second, the generator in small construction works and renovation without installed construction sites, they do not comply with waste management standards and requirements, they use the same bucket to carry all classes of mixed waste, with no responsibility for the segregation and final disposal. Most often these wastes are dumped in illegal transshipment areas, mostly in protected areas. This widespread practice under the pretext of lack of segregation space in the civil work is endorsed by the lack of an urban policy to empower and require waste segregation at source and its reprocessing. The segment of small generators is responsible for contributing over 50% of waste generated in the city, and for almost all of the total pollution generated by construction waste, due to their crude mixtures that cannot be recycled and untreated transshipments into nature. Thus this study focuses on studying a suggestion for waste segregation logistics and recycling for this second group of generators. Chapter five dissects the formula: (Sustainability = Effective projects + Waste reutilization). Efficient projects, civil works with low waste generation and waste elimination is the way toward sustainability in the sector. In some regions of Brazil, the loss reaches 33% as opposed to the world average of 10%. Several factors rooted in the country's culture of raw material abundance are mentioned. There is still a lack of sustainable efficiency concern in national projects, of doing more using fewer natural resources, using construction methods to lower the impact on the use and disposal of materials in the process. Some examples of methods that can be used for this purpose are listed below:

- **Foundations with removable stakes and metal structures** – allow stakes to be reused several times. The same apparatus used for crimping the stake is used to remove it. Ideal for small construction works like structural reinforcement, temporary buildings, etc.
- **Hybrid Construction System using timber** – wood is a carbon fixation material in adulthood, and is renewable, biodegradable and reusable. It replaces materials with high energy and natural resource production costs and its energy cost is 21 times smaller than cement production, as shown below in the table comparing steel, concrete and timber.

PRODUCTION	Concrete	Steel	Timber
Energy in MJ/m ³	1920	234000	600

Source: Miotto, 2008

Glued laminated wood beams are a very attractive option, which allow the use of low-density timber of lower quality than hardwoods, which should be saved as structural pieces.

The use of timber in construction, when done conscientiously, generates less debris due to reuse of the same material in different sizes in distinct stages of construction; aside from small amounts of waste being disposed it also leads to homogeneous waste. Unfortunately a large part of timber demand in construction

in Brazil is for temporary use, creating even more heterogeneous waste mixed with concrete and masonry.

- **Ventilated Facades**

External coating is fixed in profiles located 5-8 cm from the building providing a second skin. This method creates an air cushion with upward flow caused by the temperature difference between outside and inside air providing a series of advantages to the building throughout its lifetime.

- 1) Thermal and acoustic isolation
- 2) Energy savings in air conditioning temperatures
- 3) Prevention of moisture on the façade
- 4) Weather protection
- 5) Completely reusable after deconstruction

- **Waste Reutilization**

In chapter five it becomes evident that waste segregation at the source is a prerequisite for any efficient recycling process. The large amount of waste generation imposes an urgent need for recycling; the United States of America produce about 136 million tons of waste annually and recycle 25% of the total, while in the Netherlands 90% of the volume of waste is recycled.

There are countless environmental, economic and social benefits for recycling waste and the replacement and subsequent reduction of consumption of natural aggregates. In Brazil, 210 million tons of gravel were consumed in 2009; aside from the ecological impact of harnessing gravel deposits, the reduction of waste disposal areas is one of the environmental and economic benefits of recycling demonstrated in this chapter. But the main benefit of waste recycling logistics in large cities in developing countries is social, using the collectors' skilled labor, who currently earn their sustenance working in subhuman conditions rummaging through trash. The social reintegration of these people living below the poverty line is the great legacy of this logistic.

The main measures necessary for implementing construction waste management are the following:

- Requiring that a study of the reutilization and final disposal of demolition waste be part of existing projects' designs;
- Require separation of waste per category at the origin;
- Create waste collection stations at strategic locations near concentrations of small generators;
- Establish an efficient waste collection and recycled material replacement infrastructure;
- Develop ways to encourage the use of recycled material to create a consumer market with permanent support from vendors and all those involved;
- Educate the population toward a sustainable culture.

"The same management style that large construction works implement when recycling construction waste needs to be implemented in small construction works."

Class A construction waste processing in treatment centers aims to replace gravel and sand with reused material in construction elements that have no

structural function. Production at recycling plants is similar to mining activities in the stages of reduction and belt transport, which determine the movement of materials marking out the operations scripts for the Reception - Selection - Operation - Storage - Shipping phases.

The main products recycled from construction residue are: concrete powder, pebbles, gravel #s 1, 2, 3 and 4, bank gravel, stones, #4 gravel. Studies have shown that the use of recycled aggregate concrete, whose mixture is equal to or greater than 1:7, have the same results in compression and curing tests as concrete using natural aggregate.

Below is a comparative analysis with the natural aggregate consumption volume used for 1:7 concrete in the construction industry in São Paulo; we can see that the volume of recycled aggregate in the region could be fully absolved, as shown below:

Major Gravel Consumption Segments

SEGMENT	PARTICIPATION (%)	Recycled potential	
		Segment	In total
Concrete	32	0%	0%
Construction	24	10%	2%
Prefabricated	14	80%	11%
Reseller	10	15%	2%
Asphalt plant	9	9%	1%
Public agency	7	50%	4%
Others	4	50%	2%
Source: ANEPAC		Total	21%

Gravel Production in the Greater São Paulo Area, 2009

YEAR	PRODUCTION (t)		
2005	25,753,933.00		
2006	26,975,988.00		
2007	29,764,948.00	Estimated recycled demand (t)	
2008	35,158,412.00		
2009	37,619,501.00	21%	8,054,335.16

Comparison between waste generation and demand in São Paulo - 2009

annual waste production (t)	recyclable index	recycled aggregate (t)	recycled gravel demand (t)
6,292,600.00	63%	3,964,338.00	8,054,335.16

We see above that there is a strong market for recycled aggregate usage, ensuring economic viability for mineral waste recycling. In Rio de Janeiro, recycled aggregate appears as an item within the City Hall's SCO (Construction Works and Engineering Services Costs) Index, used to prepare municipal public works budgets.

Class B residues (Paper, Cardboard, Glass, Metal, Plastic, Timber) are not a problem for recycling, they can be easily reinserted into the production chain and have an enormous number of interested companies.

Class C and D residues, when segregated at source, are collected by authorized companies to be chemically reprocessed into a blend for use as raw material in other industries or for final disposal.

Chapter six proposes a path for construction waste recycling logistics in Rio de Janeiro.

Most of the construction works with sites are designed to segregate waste and process those that are Class A on-site for reuse or forward it to treatment plants, where they are well-accepted due to their segregation quality, resulting in a clean and homogenized mixture. However, waste generated by small construction works without sites is transported in buckets without segregation, creating a crude mixture which is not accepted by private waste recycling stations, so they are transshipped into landfills without subsequent processing, often inappropriately, causing great environmental impact due to pollutant mixtures they represent.

We must transform this **linear** industrial segment process into a **circular** process, implementing a reverse logistics in order to reuse waste and reintegrate recycled material into the production chain, as illustrated in the chart shown below:

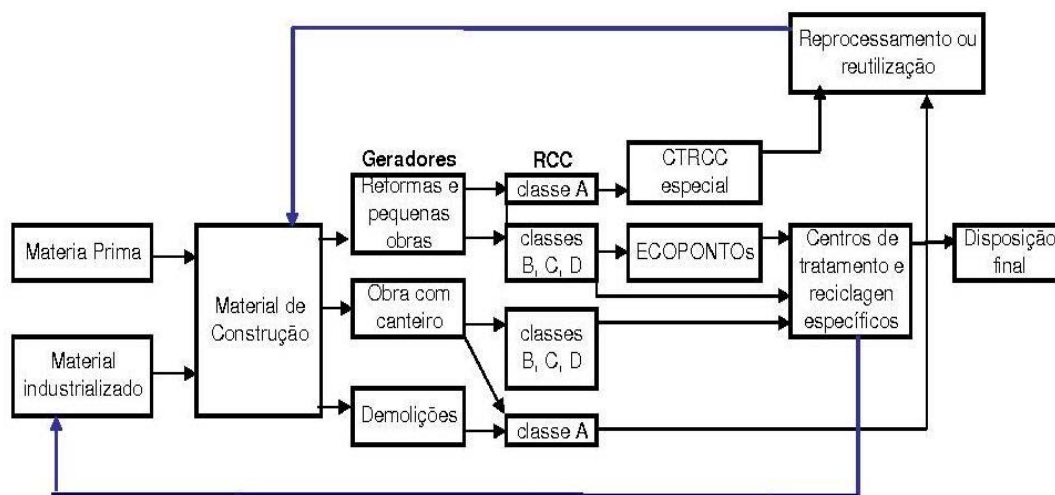


Image:

Matéria Prima	Raw Material
Material Industrializado	Industrialized Material
Material de Construção	Construction Material
Geradores	Generators
Reformas e pequenas obras	Small construction works
Obra com canteiro	Construction with construction site
Demolições	Demolitions
RCC	RCC (Construction Waste)
classe A	Class A
classes B, C, D	Classes B, C, D
CTRCC especial	Special CTRCC (RCC Treatment Station)
ECOPONTOS	ECOPOINTS
Reprocessamento ou reutilização	Reprocessing or reuse
Centros de tratamento e reciclagem específicos	Specific recycling and treatment stations
Disposição final	Final disposal

Implementation of construction waste recycling logistics in a city is a daily task for all of its inhabitants; a communication campaign about its social and environmental importance is required in order to build awareness and mobilization, and an oversight and feasibility infrastructure needs to be provided by the public sector. Without these prerequisites, it will not be maintainable. Society's awareness of this logistic's social and environmental value, using labor from underprivileged sectors for reintegration into society, reducing the exploration of deposits and disposal of waste into natural environments, is essential for this sustainable policy to solidify.

The implementation of this new logistics does not change the “actors” currently participating; rather, it is the methodology and objectives that will be changed to a new organization and criteria, into their respective new roles:

- **Public Power**
 - Legal regulation and oversight
 - Implementation of operational and physical infrastructure
 - Encourage consumer market for recycled products
- **Generators**
 - Notify of waste generation
 - Segregate to transport
 - Transport small quantities free of charge to an Eco Point
- **Waste collection companies**
 - Transport only legalized buckets
 - Transport waste to a CTRCC
 - Pay differentiated prices for transshipment
- **Collectors associations**
 - Perform recycling work
 - Selection and provision of labor
- **Waste treatment stations**
 - Reception and treatment of waste
 - Sale of recycled material
- **Existing Landfill**
 - Licensed to receive as final destination
- **Universities**
 - Surveys in CTRCCs
 - Academic course on waste management
- **Class Councils: CREAS (Engineering and Architecture Regional Council), IAB (Brazil Architects Institute), etc...**

Mobilize and communicate relevance to professionals.

The operation of the new logistics is based on waste segregation at the source.

The generator has the option to take small amounts of materials to the closest point of capture (Eco Point) or hire a collection company, depositing segregated waste into buckets separated by class. The waste collection points, here called ECO points, will receive materials from generators and store them in containers or their equivalent to be transported by Comlurb (the municipal urban sanitation company) to treatment stations.

Treatment stations whose function is to select and treat waste for re-insertion into the industrial process should be installed at strategic points in the city, plant locations should take into account availability, processing type, production volume and transportation cost for recycled product sale at competitive prices. The objectives of treatment plants are formalization of the sector's labor, reuse of waste in order to replace natural resources, and prevention of environmental degradation at disposal sites.

A careful study of neighborhood impact is critical to installation and operation success within the city's urban network, these impacts must be addressed with effective measures, some listed in this paper, for a perfect harmony with the population.

The choice of equipment, which can be fixed or semi-mobile, depends on the amount of RCC to recycle, the dimensions of the blocks present in the RCC, and the grain size required in the final recycled aggregate according to its use (SALVADOR, 1999).

Very often old equipment is used, coming from mining plants, the main ones are:

- **Jaw crushers**
- **Impact crushers**
- **Hammer mills**

There is a great variety of techniques mentioned in this paper that can be used to improve the recycled aggregate quality and reduce the fine and light (or porous) organic material proportions.

This logistics' major demand for financial investment will be in the implementation phase that should be left to the public sector and private initiative, but as previously mentioned, the value and demand for natural aggregate reassure the financial return for recycled aggregate use.

Despite the difficulty in ascertaining the current cost of the city's construction waste collecting logistics we can do comparison by tasks. Currently "impure" waste collection uses trucks and/or private bucket companies at points around the city. The proposed new logistics will continue with the same cost standard for the generator who pays the collection to private companies, or use Comlurb free collection, the gratuity is maintained when delivered to the nearest Eco point for amounts not exceeding 1 m³ per day.

Private collector companies will continue to pay for transshipment as they currently do. Buckets in the recycling centers will pay different prices according to the impurity degree in the residue segregation.

Waste transport from ECO points to the recycling stations should be done by Comlurb, which in turn will not collect free of charge in homes as it does today, exempting the standard, pre-packed, point to point transported payment.

Plant operation will be the responsibility from the collectors' cooperatives who already work in the industry.

To stimulate demand for recycled aggregates the public sector, SOEs, should encourage State working contractors to use recycled aggregate in poor traits (1:7 concrete or higher) through the public tenders, this procedure does not change final product quality, as seen in previous chapter.

Conclusion

Elimination of “in nature” (untreated) civil construction waste dumping is a goal to be continuously pursued by all of society as a commitment to future generations. The path suggested here is to make use of preventive actions in design and implementation phases to reduce its generation and waste, and planning ahead for material recycling after deconstruction.

The recycling of almost all the waste in the city of Rio de Janeiro depends on the implementation of a logistics plan for the segregated collection of small works generators and waste treatment for reinsertion into the production chain. These are actions that follow the criteria for segregation, transportation and transshipment procedures under the new waste management law.

Keywords

Construction Waste; Construction Waste Recycling; Construction Waste Management; Construction Waste Policy.

Sumário

1. Introdução	19
1.1. Considerações Gerais	19
1.2. Objetivo	23
1.3. Organização da dissertação	24
2. O impacto ambiental de um empreendimento	26
2.1. Conceito geral do estudo do Ciclo de Vida	26
2.1.2. As etapas do estudo do ciclo de vida	26
2.2. Estudo do ciclo de vida aplicado a construção civil	29
3. Resíduo da construção e demolição (RCD)	33
3.1. Análise das fontes geradora de resíduos da construção civil	35
3.2. Principais fatores de desperdício	36
3.3. Demolições	39
3.3.1. Demolição planejada em canteiro de grande obra	40
3.4. Entulho	45
4. Uma visão macro do RCC em três centros urbanos	50
4.1. Rio de Janeiro	50
4.2. Belo Horizonte	55
4.3. São Paulo	58
4.4. Fortaleza, Ceará	59
5. Sustentabilidade – Projetos + Reaproveitamento dos detritos	61
5.1. Projetos eficientes = menor geração de resíduos	61
5.2. Fundações com estacas removíveis e estruturas metálicas	62
5.3. Sistema Construtivo Híbrido utilizando madeira	63
5.4. Fachadas Ventiladas	68
5.5. Reaproveitamentos do resíduo da construção civil	71
5.5.1. Benefícios da reciclagem do entulho	72
5.5.1.1. Ambientais	72
5.5.1.2. Econômicos	73
5.5.1.3. Social	74
5.5.1.4. Principais Fatores necessários a essa política	74
5.5.2. Reciclagem do resíduo da construção civil (RCC)	75
5.5.2.1. Resíduo tipo Classe A - Resíduo Mineral	76
5.5.2.1.1. Os principais usos aos produtos reciclados	78
5.5.2.1.2. As etapas do processo de reciclagem do entulho	79
5.5.2.2. Resíduo Classe B	80
5.5.2.2.1. Papel Papelão	80
5.5.2.2.2. Vidro	81
5.5.2.2.2.3. Metais	81
5.5.2.2.4. Plásticos	82
5.5.2.2.5. Madeiras	82
5.5.2.3. Resíduos Classe C e D	82

6. Projeto Logístico para o entulho no Rio de Janeiro	84
6.1. Participantes	85
6.1.1. Poder Público	85
6.1.2. Geradores	86
6.1.3. Empresas de coleta de entulho	87
6.1.4. Associações de catadores	87
6.1.5. Centros de tratamentos de resíduos especiais	87
6.1.6. Aterros existentes	88
6.1.7. Universidades	88
6.1.8. Conselhos de classe CREAs, IAB, etc.	88
6.1.9. Sociedade em geral	89
6.2. Como funciona?	89
6.3. ECO Pontos	89
6.4. Centro de tratamento dos resíduos da construção civil especial – CTRCC	91
6.5. Ponderação Financeira para nova logística	96
7. Conclusões	98
Referências bibliográficas	100
ANEXO 1 - Nova Lei nº 12.305/10 sancionada em 02 de Agosto de 2010	103
ANEXO 2 - RESOLUÇÃO CONAMA Nº 307, DE 5 DE JULHO DE 2002	118
ANEXO 3 - RELAÇÃO DE LOCAIS RECEPTORES PARA RECICLAGEM NO RIO DE JANEIRO	122
ANEXO 4 - FORMULÁRIO DE AUTORIZAÇÃO PARA TRANSPORTE DE RESÍDUOS DOS CANTEIROS	127

Lista de figuras

Figura 1.1 – Distribuição da geração de resíduos sólidos por várias atividades industriais (ISWA/UNEP, 2005). Publicação Janeiro 2005 – ISWA/UNEP	21
Figura 2.1 – Ciclo de vida de uma edificação - (TAVARES e LAMBERTS, 2005).	29
Figura 2.2 – Ciclo de vida de um produto - (TAVARES e LAMBERTS, 2005).	30
Figura 3.1 – Composição de geradores de entulho ¹¹	40
Figura 3.2 – Retirada da alvenaria para preparação da implosão (Arcoenge)	41
Figura 3.3 – Colocação dos explosivos nos pilares (Arcoenge)	41
Figura 3.4 – Marteletores demolindo elementos estruturais remanescentes da implosão (Arcoenge)	42
Figura 3.5 – Equipamento pulverizando a estrutura para separação da ferragem (Arcoenge)	42
Figura 3.6 – Material segregado por etapas no canteiro de obras.	43
Figura 3.7 – Equipamento para britagem do entulho.	43
Figura 3.8 – Detalhe da esteira da britadeira.	44
Figura 3.9 – Entulho granulado pronto para reutilização.	44
Figura 3.10 – Agregado reciclado aguardando utilização.	45
Figura 3.11 – Composição média dos resíduos depositados no aterro de Itatinga – São Paulo	48
Figura 4.1 – Caçamba estacionada no Leblon, em 23 de março de 2011, com entulho de reforma.	51
Figura 4.2 – Ponto de recebimento de material reciclável (Comlurb)	55
Figura 4.3 – Quantidade total de resíduos retirados dos eco pontos (Secretaria Municipal de Serviços Públicos de São Paulo)	58
Figura 5.1 – Teste de cravação de estaca removível em Londres – Inglaterra.	62
Figura 5.2 – Prédio residencial de apartamentos em madeira em Murray Grove, Londres.	66
Figura 5.3 - Canteiro de obra na construção de edificações em madeira.	67
Figura 5.4 – Fachada ventilada do hotel Surgut – Rússia.	68

Figura 5.5 – Fachada ventilada de prédio comercial em Zoetermeer – Holanda.	69
Figura 5.6 – Ilustração de funcionamento da fachada ventilada	69
Figura 5.7 – Esquema da sequência de montagem dos painéis de uma fachada ventilada.	70
Figura 5.8 – Pavimentação utilizando agregado reciclado (Depto Engenharia de Transporte da USP).	77
Figura 5.9 - Resíduo granulado estocado no canteiro da Arcoenge – obra moinho	77
Figura 5.10 – Resíduos de materiais classe C e D aguardando transporte (Arcoenge)	83
Figura 6.1 – Produção em ciclo linear	84
Figura 6.2 – Produção com ciclo circular	84
Figura 6.3 – Organograma macro de um CTRCC (centro de tratamento de resíduo da construção civil)	95

Lista de tabelas

Tabela 2.1 – Exemplo para Cálculo do Fator de Impacto Ambiental (Hermmann, 2007)	28
Tabela 2.2 – Cálculo do Fator de Impacto Ambiental na Fabricação de Cerâmica (Soares et al., 2002)	30
Tabela 3.1 – Impactos dos Resíduos de Construção e Demolição no Ambiente Urbano (Sinduscon-SP, 2005)	33
Tabela 3.2 – Coleta de RCD da Região Sudeste	36
Tabela 3.3 – Perdas na construção por tipo material	37
Tabela 3.4 – Taxas de Desperdício de Materiais (Espineli, 2005)	38
Tabela 3.5 – Classificação dos resíduos sólidos, segundo a Norma Brasileira Regulamentar (NBR) 10004/04.	46
Tabela 3.6 – Quantidade de fração mineral no entulho	47
Tabela 3.7 – Composição, em porcentagens, do RCD por cidade	48
Tabela 5.1 – Energia de Produção	64
Tabela 5.2 – Comparação de impacto madeira vs aço	65
Tabela 5.3 – Comparação impacto madeira vs concreto	65
Tabela 5.4 – Energia consumida em cada fase do ciclo de vida da construção de madeira vs aço vs concreto	66
Tabela 5.5 – Impacto no meio ambiente e consumo de recursos naturais entre madeira x aço x concreto	67
Tabela 5.6 – Consumo de madeira serrada amazônica pela construção civil, no estado de São Paulo, em 2001.	68
Tabela 5.7 - Produção de Brita na Grande São Paulo	73
Tabela 5.8 - Utilização de brita por segmento	74
Tabela 5.9 - Resistencia à compressão 28dias (%)	78
Tab. 5.10 - Resistencia à compressão 60dias (Mpa)	78
Tabela 5.11 – Composição SCO	80
Tabela 6.1 – Características do britador de mandíbulas	91
Tabela 6.2 – Características do britador de impacto	92
Tabela 6.3 – Características do moinho de martelos	92