RECYCLING PLANT AND RESEARCH CENTER OF CONSTRUCTION AND DEMOLITION WASTE IN THE METROPOLITAN AREA OF VITÓRIA (ESPÍRITO SANTO, BRAZIL)

REMBISKI, Fabrícia D. Architect. Master's Student in Civil Engineering (PPGEC) at Federal University of Espírito Santo, CAPES Scholarship. Montevidel St. 254, Araçás. Vila Velha-ES. 29103-025. Brazil. Phone +55 27 3339-0116.E-mail: frembiski@gmail.com

ALVAREZ, Cristina E. Architect.Professor Doctor in Architecture and Urbanism. Pos-Graduation Program in Architecture at Federal University of Espírito Santo. Av. Fernando Ferrari, 514. Cemuni I. Goiabeiras. Vitória-ES. 29075-910. Brazil. Phone: +55 27 4009-2581. E-mail: engel@npd.ufes.br

BISSOLI, Márcia. Architect.MSc in Civil Construction at Federal University of Espírito Santo. Profª Zilda Andrade St., 165. Ed. Alamanda. Ap. 303. Bairro de Lourdes. Vitória-ES. 29.042-751. Brazil. Phone: +55 27 9941.1476. E-mail: marciabissoli@gmail.com

ABSTRACT

This article presents the design essay of a Recycling and Research Center for Construction and Demolition Waste planned for the Greater Vitória Metropolitan Area (GVMA) and developed during the study that resulted in the research paper required for obtaining the Architecture and Urbanism degree at the Federal University of Espírito Santo (Vitória, Brazil). For conceptual, technical and methodological basis, semi-structured interviews and field work were carried out in the cities of São Paulo (SP), São Bernardo do Campo (SP), Guarulhos (SP) and Belo Horizonte (MG), the ones representing the national scenario of construction and demolition waste (CDW) management. The cities of Cariacica, Vila Velha, Vitória and Serra, in the state of Espírito Santo, served as samples of the local scenario. International literature review on similar cases showed recycling plants with sustainable characteristics, which also provided basis for developing this architectural design. The design essay mainly aims at reusing CDW, which is intended for meeting the demands deriving from the expansion of urban nucleus in GVMA. In order to achieve these goals, systematized guidelines were adopted and grouped according to the following themes: i) Building; ii) Conservation and protection of natural resources; iii) Sustainable surroundings; iv) Thermal, acoustic and lighting comfort; and v) Social, environmental and economical issues. It was verified that there is a national demand for recycling plants to mitigate environmental and economical problems caused by the irregular deposition of these wastes.

Keywords**:** construction and demolition wastes, recycling, design essay, sustainability, project guidelines.

1. INTRODUCTION

The Civil Construction Industry (CCI) is responsible for a large part of the solid waste generated in Brazilian cities because of peculiarities of their productive technologies, and especially because of construction material wastage that takes place in distinct stages of the construction of buildings. Frequently, this waste is called rubbish, which is formed by different materials such as ceramic waste, soil, concrete, mortar, plastic, cardboard, metal and so on.

In order for the CCI to cooperate with sustainable development in Brazil, material wastage rate should be reduced in building sites, decreasing consequently, residue generation. The use of recycled CDW as building materials in sites is inevitable and undelayable because of the waste generation reduction and the impact this waste has on nature (GRIGOLI, 2000).

An increasing number of residential, commercial, industrial and infra-structural constructions has been verified in the GVMA. These constructions do not display sustainable CDW management. We should highlight that there are segregated areas for irregular depositions distributed throughout the urban area, which affect not only the quality of life of the population, but also the environment and urban landscape.

Therefore, this study mainly aims at developing a design essay for a CDW recycling plant to suit the Brazilian social and economical scenario. The study was carried out through qualitative approach about the production of CDW in some cities of the GVMA, and it is theoretically based on sustainable concepts supported by the international production technology. This project also provides space for reinserting recyclable products and involving neighboring communities through educational and income-generating activities, which take place through professional qualification.

2. THEORETICAL REFERENCE

The problems related to CDW affect several cities in Espírito Santo and in Brazil. However, it is believed that there is a relation between several factors that, together, contribute to increasing waste generation, such as culture, local development, recycling techniques and CDW properties.

These problems also affect developed countries because of their dynamical economy and the fast urban development through construction, restoration and demolition of buildings, which result in significant amounts of CDW. Recycling is a reality in countries such as The United States, Japan, France, England, Holland and Germany, which have reached good results through the implantation of environmental policies, government and private investments and installation of recycling plants.

In Brazil, the Conama resolution 307 was the first approved document to clearly define the participation and responsibilities of the actors involved in the process of disposing CDW (Brazil, 2002). According to this resolution, cities are responsible for elaborating the Construction Waste Integrated Management Plan, which also includes specific areas for disposing these wastes: stations for voluntary delivery for small waste generators; transfer stations, recycling plants and CDW landfills for large waste generators.

The CDW recycling plant adds value to materials that would be deposited in irregular areas. The Brazilian experience with these large devices is recent, but has been expanded into several cities, sometimes as a result of CDW management plans and, other times, as mere disorganized acquisition of recycling equipment.

During this study, the international literature showed examples of recycling plants with high technological investment in the United Kingdom and Spain. Both presenting characteristics considered sustainable because the process is carried out using equipment with dust and noise control. The technology used also decreases workers' effort, increasing productivity and decreasing the risk of occupational lesions. Figures 1 to 3 below show examples of international recycling plant facilities in the United States.

Figure 01 - Production Line of the recycling plant.
Source: CANDD...(2005).

Figure 02 - CDW Storage station.
Source: CANDD...(2005).

Figure 03 - External view of place to recyclable material
Source: CANDD...(2005).

3. METHODOLOGY

This study is characterized as both descriptive and applied, because it aims at investigating and proposing solutions to community problems. It investigates the CDW problem in different Brazilian states, proactively interacting with the actors involved in the theme, such as city urban managers, recycling plant managers and researchers.

In order to support the theoretical and design bases, the following research methods were adopted: national and international bibliographical research; documental and field work in the cities of the case study; photographic survey and semi-structured interview with Urban Services and Cleaning managers.

The field work was carried out in two stages and took place in the states of Espírito Santo, Minas Gerais and São Paulo. The first stage aimed at estimating the CDW generation, its final destination and the impact caused by its irregular deposition in the cities chosen for this study: Cariacica, Vila Velha, Vitória and Serra, which located in the state of Espírito Santo (Figures 4 and 5) and presented high CDW generation levels.

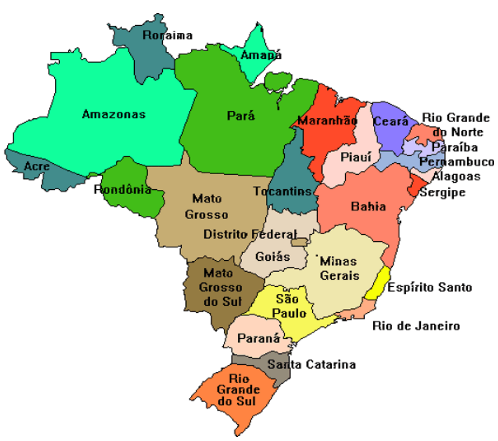


Figure 04 – Location of the state of Espírito Santo in relation to Brazil.

Figure 05 - Location of the city of Vitória in relation to the state of Espírito Santo.

The second stage comprises the field work in the recycling plants and the areas for delivery and CDW transfer station, where the management models of Belo Horizonte, São Paulo and Guarulhos were compared.
In the bibliographical research, the equipment used in the recycling plants was analyzed considering the technical descriptions provided by the manufacturers. This allowed understanding the crushing process and putting together information about suppliers and available models in the market. The employment of qualitative and quantitative approach enabled the identification of the positive and negative points in the Brazilian cities under study. This also led to tracing sustainable project guidelines that allowed breaking up with the current models of recycling plants.

3.1 Delimitation of the study area

The study area is located by an important highway (Rodovia do Contorno) in the city of Cariacica, which shows significant need of legislation and CDW management in general. The design essay is located at private sanitary landfill that receives CDW from some cities in Espírito Santo. Because of its privileged geographical position, developing the project in this place would minimize transportation costs and the emission of pollutant gases in the atmosphere (Figure 6).

Figure 06 – Location of Study Area in relation to GVMA. Source: LOCATION...(2006).

According to the environmental impact study zoning, the area highlighted in Figure 07 is reserved for building a CDW landfill, and also to serve as destination and treatment of dimension stone processing waste. In this area, vegetation is typically low, including some average-sized young bushes, which are spread over the area.

Figure 07 – Localization of the project area
Source: Google Earth 4.0 (version), 2007.

4. PRESENTION AND DISCUSSION OF RESULTS

4.1 Urban recycling equipment in Brazil

Figures 8 to 10 show some of the urban recycling equipment visited during the study, which do not comply with the project guidelines established by the Conama resolution 307 (Brazil, 2002).

Figure 8 - Recicling Plant in São Bernardo do Campo, São Paulo.

Figure 9 - Recicling Plant in Estoril (Belo Horizonte, Minas Gerais).

Figure 10 - Recicling Plant in Pampulha (Belo Horizonte, Minas Gerais).

4.2 CDW management in Greater Vitória Metropolitan Area

The problem of irregular deposition of urban solid waste has worsened in the past years in GVMA. Each day, new illegal deposition points appear and new areas of environmental interest are landfilled, mainly with CDW. This area fits the national context, characterized by urban disorder caused by city growth combined with poor planning of infrastructure networks. This fact is worsened because of lack of CDW urban recycling equipment.

The interviews have shown that the diseases caused by the proliferation of insects and other animals, traffic impediment in streets and sidewalks, and deposition of urban solid waste in the same place are the main problems generated by irregular deposition of CDW.

4.3 Project Guidelines

The specific guidelines were listed based on theoretical data and field work, through observation and knowledge about similar cases. In the list presented in Table 01, we can highlight important points related to constructive systems and disposition of space and activities, which guided the design essay development. These guidelines were divided into 5 theme groups: 1) Building; 2) Conservation and protection of natural resources; 3) Sustainable surroundings; 4)Thermal, acoustic and lighting comfort; and 5) Social and economical issues.

Table 01: Syntesis of project guidelines. (REMBISKI,2007)

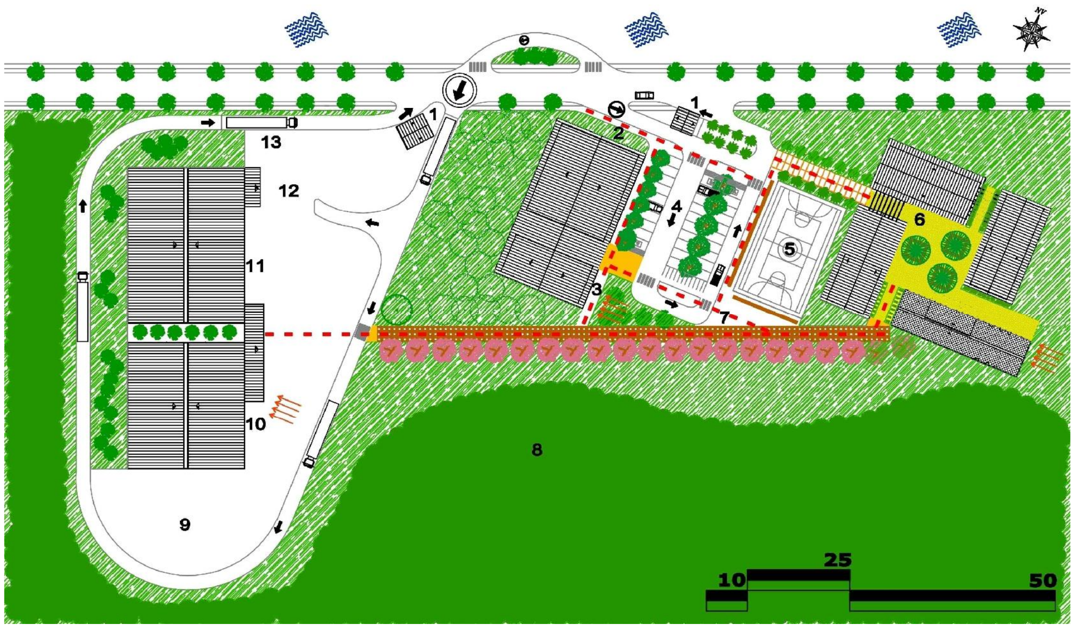
Theme groups	Project guidelines sustainable
Building	⇒ To project buildings in the N-S direction in order to favor the capture of the predominant winds (northeast wind); ⇒ To ensure free movement for the physically challenged by providing ramps and bridges connecting two or more buildings; ⇒ To use generous eaves, wide openings and high ceilings; and ⇒ To enable future enlargement (BISSOLI, 2007).
Conservation and protection of natural resources	⇒ To suggest fabric typology in compliance with the sustainable construction principles; ⇒ To treat grey water in the building itself for later reuse in toilet flushes; ⇒ To reuse rain water in less noble purposes, through collectors close to the building or passageways; ⇒ To specify low-consumption light bulbs (fluorescent type) and make sure they are placed adequately to avoid dimming and shadowing (BISSOLI, 2007); ⇒ To use faucets with sensors and aerators; and to provide the place with selective garbage bins (BISSOLI, 2007).
Sustainable surroundings	⇒ To propose large wooded and grassy areas to prevent erosion and ensure a more pleasant microclimate; ⇒ To promote tree planting in common areas, especially close to facades receiving afternoon sunlight (BISSOLI, 2007); and ⇒ To ensure maximum permeability of the ground.
Thermal, acoustic and lighting comfort	⇒ To use certified eucalyptus and reforested wood in frames and frameworks because they are recyclable and renewable materials found in many part of Espírito Santo; ⇒ To use double-pitched roof with non-vitrified ceramic tiles; ⇒ To provide adequate and correctly positioned openings and/or openings protected from sunlight, favoring daylight illumination inside environments (BISSOLI, 2007).
Socio-economical issues	⇒ To project buildings from axes calculated according to the dimension of materials used, thus decreasing waste of building materials; ⇒ To promote income generating activities such as food production, embroidering, and handicraft cooperatives (BISSOLI, 2007); and ⇒ To employ soil-cement bricks made of clay from the digging of part of the area.

The Recycling Center project was developed from project determining factors (environmental and technical) concerning elaboration; implantation; and operation of recycling, screening and transfer station areas, in compliance with the CONAMA resolution 307, NBR 15.112:2004 and NBR 15.114:2004. Nevertheless, understanding the operational system characteristics became a determining factor in accomplishing the design essay. This comprises the production line, storage, flow of people, vehicles and raw-material; infra-structure; the integration among the several buildings; and so on.

4.4 Flow and sectorization

Because of the characteristics of material, vehicles and people flow in the recycling plant, land sectorization studies were carried out aiming at an adequate implantation based on the existing flow in order to avoid possible crossing and/or accidents between employees and cargo vehicles.

Organizing the main kinds of flow, together with terrain climate conditions, was fundamental to trace sustainable project guidelines, especially those related to thermal and acoustic comfort. It is important to highlight that the green barrier, composed of trees with dense top, located between the Dining Hall/Locker-Room block and the warehouse, is intended for mitigating the noise produced by the flow of vehicles and equipment operation (Figure 11).



LEGEND
1-Main entrance (left= cargo vehicles; right=employees,visitors) 2-Dining Hall 3-Locker-room 4-Parking
5- Sports Court 6-Study and Research Center 7-Footbridge 8- Reforested area 9- Storage RA
10- Screening and Recycling warehouse 11- Storage warehouse 12- Maneuver Patio 13- Industrial scales

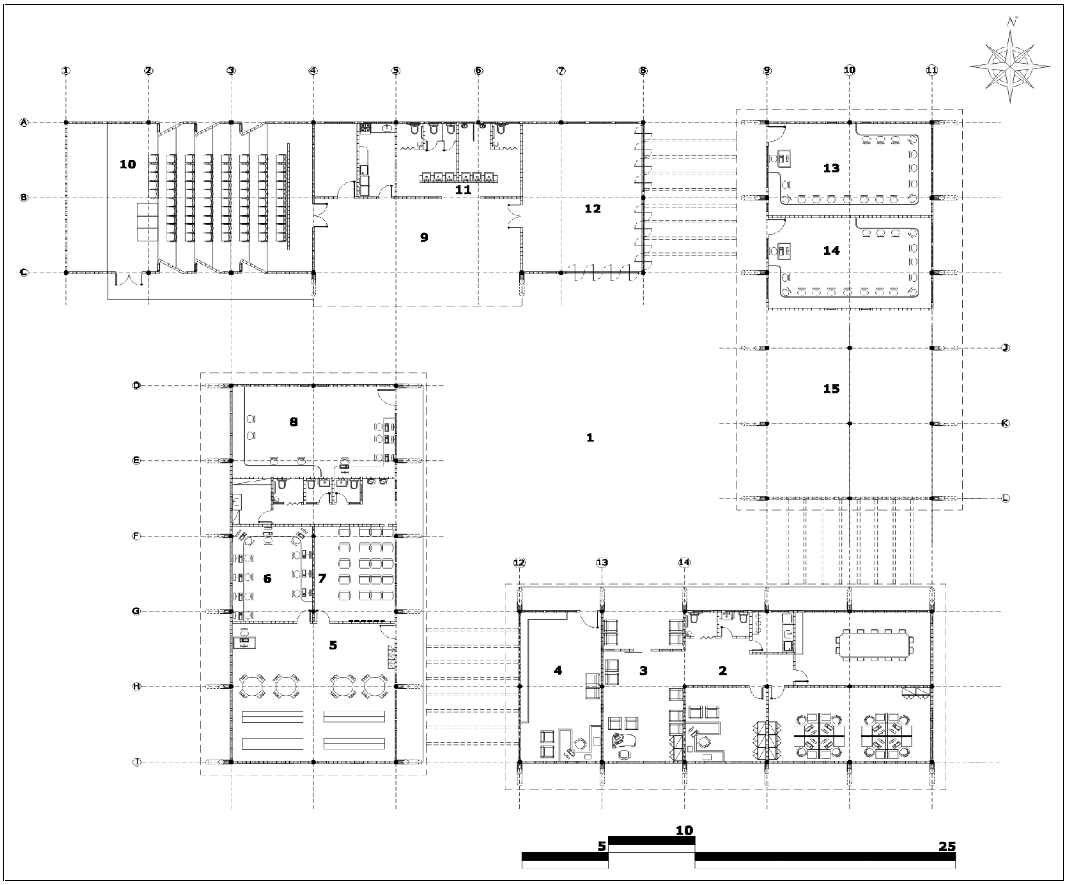
Favorable Sunlight **Predominant winds** **Flow of people**

Figure 11: Implantation of Recycling Center. Source:REMBISKI (2007).

The Recycling Center was projected in distinct parts: Study and Research Center (*SRC);* Dining hall/Locker-room; and Recycling Plant, made of 3 warehouses (storage, screening and recycling). There are also supporting areas to facilitate activities, such as a guardhouse for visitors and employees, water tower, substation,parking and sports court.

4.5 The Design Essay

The SRC is intended for receiving visitors and employees who arrive through the social guardhouse/gate, passing through a square with benches and trees - a meeting point for all users. It is divided into 4 blocks: Management, Research, Cultural and Workshop blocks (Figure 12). From the theater foyer one will be able to see the square and the complex, where wide eaves that shade the inner environment can also be seen (Figure 13). The outside paving is made of semi-permeable material: interlocking concrete blocks and Megadrain, which are considered environmentally friendly for contributing to terrain permeability (Figures 14).



LEGEND

1- Square 2-Administration 3-Reception 4- Show Room 5-Study and documentation room
7-Training room 8-Tests Lab 9-Foyer 10- Auditorium 11-Bathrooms
12-Recycling Museum 13- Handicraft atelier 14- Recycled products atelier 15-Covered Patio

Figure 12- Study and Research Center. Source:REMBISKI (2007).

Figure 13 – From foyer of the theater an ample vision of the square and the SRC. Source:REMBISKI (2007).

Figure 14 – View of the parking and square, from footbridge. Source:REMBISKI (2007).

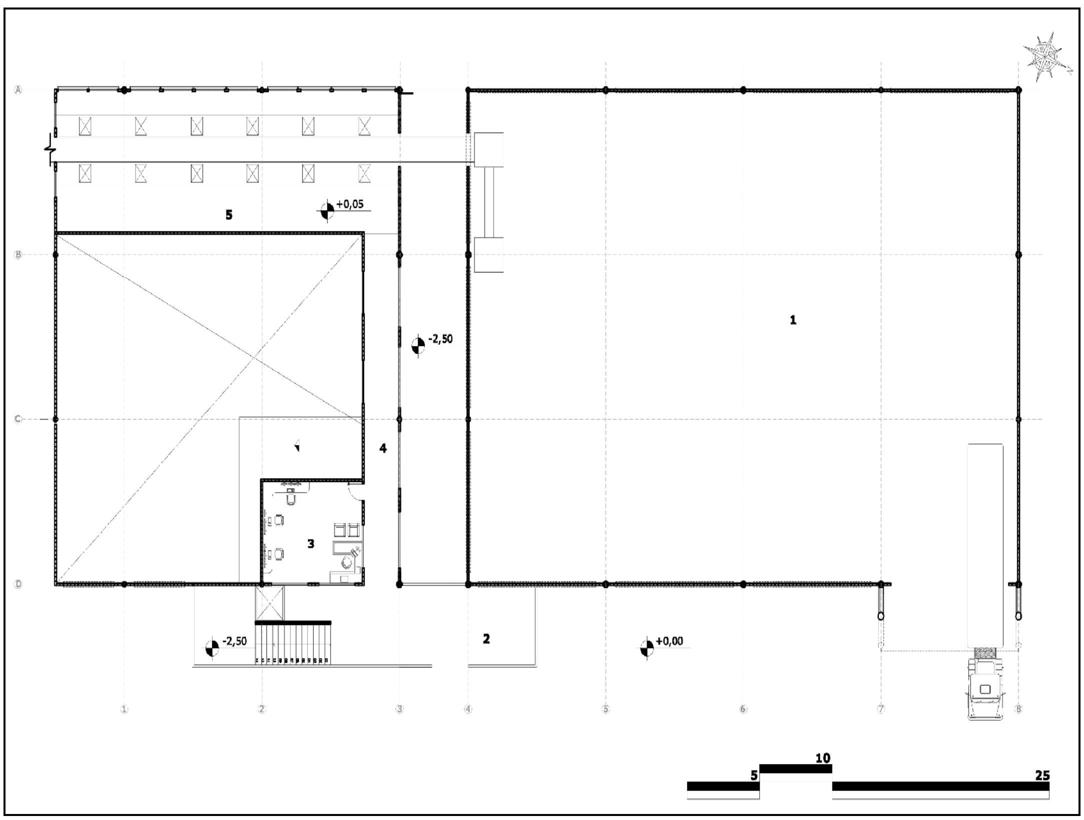
In Figures 15 and 16, we can see the integration between the several parts of the Recycling Unit, which favor permeability through areas with grass and other kinds of vegetation.

Figure 15 – Aerial view of recycling center. Source:REMBISKI (2007).

Figure 16 – Warehouse to storage, selection and CDW recycling. Source:REMBISKI (2007).

The recycling warehouse is considered the heart of the unit, since all the others are designed based on the needs and activities developed in this warehouse. It provides space for the free and simultaneous access of employees and visitors through the footbridge of the upper floor. It was designed to operate 24/7, relying on approximately 80 employees.

Only Class II B waste (inert – construction waste, soil from digging, among others) are recycled, whereas Class II A (non-inert: paper, scrap, steel, cardboard, plastic, aluminum, among others) should be submitted to a selective collection process and future commercialization. The contaminated waste is forwarded to its final destination in an industrial landfill near downtown (Figure 17).



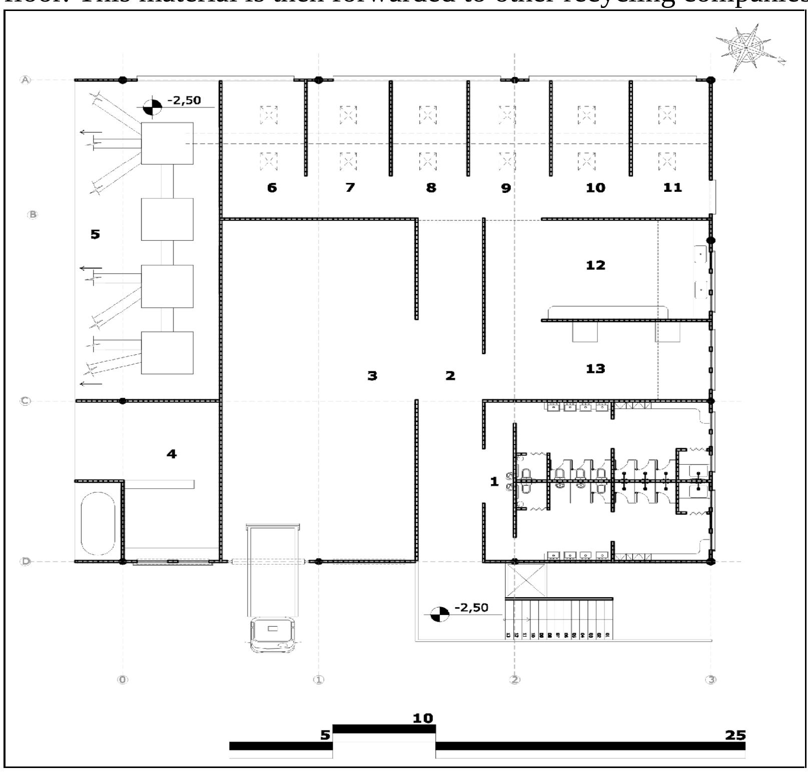
LEGEND

1- Warehouse Storage 2-Footbridge 3-Operational Control Center 4-Corridor 5-Select and screening warehouse

Figure 17- Warehouse to storage and CDW selection- Ground floor. Source:REMBISKI (2007).

This way, it is estimated that the factories within the unit produce recycled aggregates of different grading, type A (concrete) and type B (mixed: concrete + ceramics) and consequently, concrete articles such as sealing blocks, precast elements, among others, which are sent to the CCI. In the storage warehouse, the waste is transported to the vibrating feeder using a backhoe loader, where it is distributed onto the conveyor belt. The storage warehouse has independent access ways for employees and cargo vehicles, which also includes a truck yard (Figure 17).

Twelve recyclable material collection units are located on the upper floor of the screening warehouse, where materials such as steel, glass, copper, wood, plastic, paper/cardboard, organic waste, among others, are separated and cast through pipes. Meanwhile, the cleaning, pressing and storage of the material takes place in the lower floor. This material is then forwarded to other recycling companies (Figure 18).



LEGEND

1-Loocker-rooms 2-Corridor 3-Recyclable Material Storage 4-Maintenance 5-Recycling Warehouse 6-Others 7-Organic Waste 8-Hood 9-Cardboard 10-Metal 11-Plastic 12- Cleaning waste 13-Hydraulic press to waste

Figure 18 – Warehouse to selection and CDW recycling - Basement floor. Source:REMBISKI (2007).

The materials that are not separated by the screening division follow through conveyor belt to the recycling warehouse. Then, they go through vibrating sieves and crushers that perform the material recycling and separation. Next, the materials follow through conveyor belts, again, to the storage yard. The area has a wide vehicle yard for maneuvering and driving, intended for facilitating traffic. It is planned so that loading and unloading activities do not disrupt the flow of vehicles throughout the unit.

Another characteristic of the unit is the generous openings, which allow cross ventilation and provide more thermal comfort to users. The openings height contributes to relieving hot air masses and at the same time to preventing the dust generated by inside activities from spreading out to the surrounding area.

The implantation costs of a recycling unit are high, but the investment and estimated to return within three to five years. Due to these facts, the option for inter-municipal joint-ventures to implant the urban recycling equipment, as well as Public-Private Partnerships, are an interesting alternative to consolidate the undertaking.
The free areas were planned so that users could have a different perception concerning the waste recycling activity. In order to do so, urban furniture, such as concrete and wood benches and vegetation, was employed. This provides pleasant places to protect users from noise and air pollution and to emphasize the environmental approach in the unit.
The supporting areas collaborate on the proper operation of the recycling plant, especially on its safety and maintenance. They were created based on the analyses of other industrial plants, focusing on the electric power and water supply needs, as well as on the safety of the unit.

5. CONCLUSION

In order for the present GVMA scenario concerning CDW to be reverted, the implantation of a city management model, or even a metropolitan model, is essential. This can be done through inter-municipal joint-ventures that reach small waste generators by means of environmental and economical educational campaigns.
Although some actions such as the construction of CDW screening and recycling units have taken place to develop the CDW recycling production chain in Brazil, most cities in this country are still a long way from an effective solution concerning waste management. Therefore, in order for actions and programs to be effectively accomplished, environmental awareness and socio-environmental practice are required from all the actors involved in this process. The list of guidelines presented here is an important tool that may be the basis for initiatives similar to this one.
Even though waste recycling is a feasible alternative, the result can hardly be fully achieved at first; it should be the fruit of gradual improvements that include, among other initiatives, the implantation of CDW landfills for proper destination of that portion of waste whose recycling cannot be immediately performed. Thus, a partnership between public and private institutions, waste generators and education institutions is imperative for the success of recycling programs.
The graduation research paper is a contribution to developing CDW management in its aspects of research and extension to the community. In order to carry this research on, we suggest further technical, economical and market feasibility studies to consolidate the research together with financing alternatives such as inter-municipal joint-ventures or public-private partnerships.
The search for a sustainable architecture and a sustainable world demands a long and daily struggle based on citizens' respect for the environment, for the preservation of the existing natural resources, and for the other, which may be translated into the practice of a unique concept – sustainability.

6. REFERENCES

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 15.112/04 Civil Construction waste and voluminous waste -** Selection and Transfer station areas – Guidelines for project, implantation and operation.Rio de Janeiro: 2004. (in Portuguese)

______. **NBR 15.114/04 – Solid Civil Construction waste – Recycling areas -** Guidelines for project, implantation and operation**.** Rio de Janeiro: 2004. (in Portuguese)

BISSOLI, M. **Sustainability recommendations for a social housing project**: a boarding to the Residential Set Barreiros, Vitória (ES). Thesis (MSc). Federal University of Espírito Santo, Vitória, 2007. 231 p. (in Portuguese)

BRAZIL. **CONAMA Resolution 307**, 5 July of 2002. Define guidelines, criteria and procedures for the management of construction and demolition waste. Brasília, 2002. Available from: <http://www.mma.gov.br/port/conama/res/res02/ res30702. .html>. Accessed: 11 oct. 2005. (in Portuguese)

CANDD Waste Center. Available from: < http://www.rockteceurope.com/opencontent/default.asp?itemid=99&section=WASTE>. Accessed: 29 nov. 2005.

GRICOLI, A.S. Construction waste used as building material at the site it was generated. *In:* Procedings of Seminary sustainable development and the recycling in the building construction, 3, 2000. São Paulo: IBRACON, 2000. (in Portuguese)

LOCATION of study area. Available from: <http://www. googleearth.com>.Accessed: 02 nov.2006.

REMBISKI, F.D. **Architecture and Sustainability**: Construction Civil wastes recycling. 2007. Monograph. Architeture and Urbanism Department, Federal University of Espírito Santo, Vitória, 2007. 157p. (in Portuguese)