THE DEVELOPMENT OF ECO-EFFICIENT PRODUCTS AND PROCESSES IN THE BRAZILIAN CIVIL CONSTRUCTION INDUSTRY

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Abstract

The development of constructive products and processes that reduce environmental impact and lower costs has become a differentiating factor for Brazilian construction companies. The increase in competition, rapidly changing technology, reduced product lifecycles and greater knowledge and expectancy from consumers require companies to operate swiftly and with high levels of productivity and quality. This is dependent upon the efficiency and effectiveness of the company in these processes. Therefore, environmental methodologies are being created to allow the implementation of these strategies, and Cleaner Production is becoming increasingly successful in small, medium and large construction companies. This research is compiled using several cases in which Cleaner Production has been applied on the construction site of Brazilian construction companies, with the aim of analysing the benefits offered by this methodology for the development of eco-efficient products and processes, or in other words, for improving environmental and economic performance.

Keywords: development of products and processes; eco-efficiency; civil construction.

1 Introduction

Civil construction is a sector that does not traditionally display large changes in the construction process. Over time, new legal demands and the competitive nature of the sector have come to represent important factors that must be taken into consideration when changing the practices implemented. Concern with material wastage, costs and the environment become important within management models for construction companies that aim to survive in the long-term.

The concept of Sustainable Development is motivated by a new reality: the scarcity of natural resources and the difference between social classes. Civil construction activities are directly related to this new reality, and subsequently there is a need to minimise and control the environment impact, and also to adopt suitable working conditions on the construction site.

For companies to remain competitive in the marketplace, it is important to work towards sustainable development. Consequently the evolution of environmental awareness is being incorporated within company management. The reasons justifying this statement are the search for quality of life, sources of financing technological innovations, competitiveness, globalisation, an increasingly aware consumer market, new laws, and primarily environmental accidents that represent benchmarks for changes in strategic business guidelines and in operational procedures.

The reasons mentioned above reveal that unprecedented advances have been made in the evolution of business competitiveness. End-of-tube technology does not meet the needs of a society in search of sustainable development. Oliveira Filho (2001) describes how end-of-tube technology solutions do not solve the problem of environment loss caused by a production system. These technologies alleviate the effects of production systems, but without tackling the causes that produce these effects. On the other

hand, P+L technology proposes changes in production processes with the aim of reducing or eliminating all kinds of waste and pollution.

2 Literary Review

2.1 Sustainability in Civil Construction

A UNEP study (2010) states that sustainability in the construction sector is not only a challenge faced at local level, but also on a global level, because several obstacles need to be overcome in accordance with the following statistics:

- 1,8 billion people will suffer from water shortages by 2025, mainly in Asia and Africa,
- 1,6 billion have no access to electrical energy,
- Every year 2 million people die prematurely due to air pollution,
- 1 billion people currently reside in slums without water or sanitation,
- Millions of people face the threat of flooding related to climate change.

According to Furtado (2005), civil construction is one of the areas of greatest influence in socioeconomic activities, yet it plays a significant role in terms of environmental deterioration. According to the author, an analysis of data gathered in the United States, considered applicable to civil construction in other industrialised countries, reveals the following statistics: it uses 30% of raw materials, 42% of energy consumption, 25% of water consumption and 16% of land consumption. The sector contributes 40% of atmospheric emissions, 20% of liquid waste, 25% solid waste and 13% of other releases. These numbers demonstrate the importance of the issue and the need to search for action aimed at reducing the environmental impact of civil construction.

Florim & Quelhas (2005) state that the inadequate installation and operation of housing projects (poorly conceived projects, lack of consideration for physical requirements, insufficient socioeconomic analysis, absence of mitigation measures, among other factors) have resulted in situations of environmental degradation in the intervention site, causing damage to the housing and creating environmental impacts that exceed the boundaries of the project. This leads to a reduction in the quality of life for the population, and awareness of how serious the situation is only increases when, with no other options remaining, we see the inefficiency of the preventative actions (PINTO, 1999).

Accelerated urbanisation and the rapid densification of medium and large cities has caused several problems for the destination of a great volume of waste generated by construction, restoration and demolition of buildings and urban infrastructure activities, and this requires public administrators to adopt more efficient solutions for the management of these residues.

Productive inefficiency leads to environmental and economic waste, and this directly affects the competitiveness of organisations and the quality of life of the human population. For the civil construction sector especially, a new reality emerges. This is the search for survival in an increasingly competitive and demanding market, where the reduction of costs through greater efficiency in the production process represents an important differential in the market and in terms of waste reduction.

In Brazil, the current policies for environmental protection in the civil construction sector focus on the management of solid waste from works, based on the CONAMA Resolution 307/2002 (MMA, 2002), which consists of the correct separation, measurement, storage and destination on behalf of the party responsible for producing the waste, establishing the polluter pays principle. Nevertheless, meeting this Resolution is not a rapid process, and is one that requires costly technology. This is one of the reasons that underline the importance of implementing Cleaner Production methodology.

2.2 Cleaner Production

With the aim of reducing environmental impact and the consumption of natural resources, UNIDO (The United Nations Industrial Development Organization) and UNEP (The United Nations Environmental

Programme) created a program for spreading information about P+L policies around the world. In Brazil, in 1995, the National Centre for Clean Technologies (CNTL) was founded, based within the Federation of Industries for Rio Grande do Sul – FIERGS. In 1999, the Brazilian Network of Cleaner Production was formed, and has since expanded across 20 States, involving institutions such as the government, banks, industry and universities. This network aims to promote sustainable development in Brazilian companies, spreading the concept of Eco-efficiency and Cleaner Production methodology.

According to the CNTL, "Cleaner Production is the application of an integrated technical, economic and environmental strategy in production processes, with the aim of increasing efficiency in the use of raw materials, water and energy through the non-creation, minimising or recycling of residues and emissions leading to environmental benefits, and gains in terms of occupational and economic health" (CNTL, 2004).

Therefore, Cleaner Production does not represent a solution for an isolated problem, but is instead a lucrative tool for establishing a multidisciplinary and integrated concept. Some of the reasons leading to the implementation of Cleaner Production methodologies are detailed below:

- reduce production costs,
- improve process efficiency and product quality, thereby contributing towards industrial innovation and competitiveness;
- reduce risks to workers and the community;
- improve the company image;

According to the CNTL (2004), the implementation of Cleaner Production techniques allows solutions to be found that contribute towards a definitive solution for environmental problems, because the main focus of this methodology is based on identifying ways of not generating residues.

For Nascimento (2008), Cleaner Production is, above all, an economic action, because it is based on the fact that any residue from any productive system can only come from raw materials or production materials used in the process. Previously all residues were raw materials and were purchased and paid for as such.

Meanwhile, the CNTL (2004) believes that Cleaner Production is not only an environmental and economic issue, but also a social issue, as it states that the reduction of waste generation in the production process often helps to solve problems related to the occupational health and safety of the workers.

Developing Cleaner Production minimises these risks, because it identifies less toxic raw materials and production materials, thereby helping to improve the quality of conditions in the workplace.

In civil construction, constructive processes can be subjected to the implementation of cleaner production methodology. From a starting point of environmental diagnosis, of balancing public opinion, identifying opportunities and studying economic viability, the project staff is in a position to offer eco-efficient solutions for construction products and processes.

3 Prioritisation Criteria for Cleaner Production in the Civil Construction Industry

The CNTL (2004) proposes 3 levels of application for Cleaner Production that should be used as criteria for the prioritisation of the opportunities for Cleaner Production identified after the diagnosis of the construction process.

Level 1 – Reduction at the source

The prioritisation of opportunities that aim to solve the problem at the source is recommended. These include changes both in the production process and in the product itself.

a.1) Changes in the production process

This is defined as the careful use of raw materials and taking care when carrying out processes, including organisational changes, with the aim of standardising procedures and defining the new parameters and indicators. In most cases, these measures are the most economically interesting and are the easiest to implement.

The prioritization of opportunities for Cleaner Production must first include an analysis of operational practices and look for housekeeping solutions, also known as good Cleaner Production practices. Funds provided for good operational practices can facilitate new investment in the company, including new technology.

Table 1 presents some good Cleaner Production practices (process changes, housekeeping) and examples of their application in the field of civil construction.

Table 1: Opportunities for Process Modifications and their application in civil construction

Cleaner Production Opportunities	Examples of Application in Civil Construction
Change in the proportioning and concentration of products	Use material depending on the specifications of the supplier
Maximise the use of the production process capacity	Define indicators of ceramic residues
Reorganise cleaning and maintenance intervals	Keep the construction site well organised
Eliminate losses due to evaporation and leakage	Create an inspection program in the hydraulic network
Improve logistics for purchasing, stocking and distributing raw material, production materials and products	Define the construction site lay out, focused on reducing waste and environmental impact
Create manuals for good practices operations and training for staff involved in the Cleaner Production program.	Incorporate Cleaner Production opportunities in the execution procedures for work activities, for example, in the layout definition in Ceramic Tiling activities
Change in the material flow, small Layout adjustments	Define layout for walls to avoid damaging bricks needlessly in the mitres.
Improve information system	Implement computational tools with the aim of integrating departments: Works, planning and finance.
Standardisation of operations and procedures	Mapping processes, identifying inflows (raw material, energy and water) and outflows (residues, waste and emissions)
Substitute raw materials and suppliers	Identify eco-efficient production materials: water-based paintings, bricks with definitive finishing

a.2) Product changes

After the simplest opportunities have been exhausted, product changes must be identified (Table 2). These can improve environmental performance in activities involving production, use and availability of the product.

Table 2: Opportunities for Process Modifications and their application in civil construction

Cleaner Production Opportunities	Examples of Application in Civil Construction
Substitute the product / Change the product design	Define the squared metres in the workplace depending on the dimensions of the tiling and layout
Increase longevity	Define specification plans taking into consideration the increased longevity of the raw materials used in activities and products. For example: types of ceramic, roof structures
Use recyclable materials	Use ground debris for street pavements and fills for access roads
Make product return possible	Compare the use of industrialised cement with cement mixed on the construction site
Substitute product items	Identify alternatives for the internal reuse of cement and lime packaging
Change product dimensions to make better use of raw materials	Better planning in order to minimise the excessive waste of wood when mounting and dismounting

a.3) Technological changes

Changes vary from simple implementation opportunities to more complex opportunities that involve reducing activity execution times, reducing energy and water consumption and reducing the use of raw materials (Table 3).

Table 3: Opportunities for Process Modifications and their application in civil construction

Cleaner Production Opportunities	Examples of Application in Civil Construction
Technologies that segregate residues and waste	Identify technologies for separating residues and waste that are unsuitable for reuse
Change process parameters	Identify sources of funding for investing in technological innovation for the construction process
Completely substitute the technology	Identify viable technologies for using solar energy and wind power

Cleaner Production opportunities need to be analysed with the aim of lowering costs and achieving greater environmental benefits. Technological changes include:

Level 2 – Internal recycling

The residues that cannot be avoided by taking preventative measures (reduction at the source) must be reintegrated into the production process (Table 4).

Table 4: Opportunities for Internal Recycling and their application in Civil Construction

Cleaner Production Opportunities	Examples of Application in Civil Construction
Use the raw materials or products again for the same purpose	Reuse wood for roofing structures
Utilise the used the raw materials or products for a different purpose	Reuse of the wood in roofing structures for shoring flagstones
Reutilise the additional use of a material for a lesser purpose than its original use	Reuse pieces of ceramics (cuts) for creating mosaics
Recover intermediary compounds from the process or from residues in the process stages	Reuse cement

Level 3 – External recycling

The opportunities for Cleaner Production related to external recycling must be adopted as a last resort, because it is not possible to guarantee suitable waste management this way. In other words, the residue generating company transfers the environmental problem.

In most cases, it is more lucrative to end the product cycles within the same company, but if this is not possible then companies must resort to external recycling (Table 5).

Table 5: Opportunities for External Recycling and their application in Civil Construction

Cleaner Production Opportunities	Examples of Application in Civil Construction
External recycling of residues	Identify clients to purchase paint packaging

After identifying Cleaner Production opportunities, we recommend drawing up a Continuity Plan, which is one of the differences of this methodology. It is essential to perform an economic viability study for each Cleaner Production opportunity identified, so that the project staff (phase of project development) defines the actions that will be implemented in the short, medium and long term, in line with the criteria listed in Table 6 related to investment and the environmental benefits.

Table 6: Prioritisation Criteria for Cleaner Production Opportunities

Actions	Cleaner Production Concept	Investment
Short Term	Prevention, reducing residue generation at the source	Zero or low
Medium Term	Internal recycling, reuse	Medium
Long Term	External recycling	High

Based on the Continuity Plan, Cleaner Production implementation becomes an attractive proposal for micro and small companies, because this plan shows that the businessman will achieve economic and environmental gains with a low level of investment.

4 Case Studies

4.1 Description of Case Studies

The CNTL, in 2007, launched the guide "Cleaner Production in Buildings", which aims to introduce companies and professionals from the field of civil construction to some of the measures implemented by companies that have already adopted this practice, helping them in the Cleaner Production implementation process. Six case studies available in this guide are described as follows:

- Case Study 1: Minimise wood wastage in the structure phase – mounting and dismounting of flagstones

Description: This study aims to reduce the amount of plywood plates required for the assembly and dismantling of pavement flagstones.

First of all the parameters were measured for a regular flagstone; then measured for another flagstone made in accordance with an engineering work project focused on optimizing the use of plates.

Indicators: Wood and plywood consumption for form production; wood and plywood residue generation for total generation of wood and plywood residues; Cost of wood and plywood for production form; Cost with residues for form production.

Results:

Economic benefit: R$15.760,00 for the whole project (two towers with 14 floors each).

Environment benefit: Reduction in wood consumption and of 20 plywood plates per flagstone, or 720 plates for the whole project, totalling 1.344 m2 plywood plates.

Additional benefit: Initial creation of a culture of seeking to not generate residues and continual improvement in processes.

Case Study 2: Minimise the waste of bricks in the brickwork stage

Description: this study seeks to accompany the course of the bricks on the construction site, until they are positioned in the brickwork stage, seeking to minimise the amount of residue. This study has a target of 4% of loss value, because the company considers this to be a satisfactory value.

Indicators: Consumption of bricks for area worked; Residue generation for area worked; Cost of material for area worked; Cost of residue generation for production area.

Results:

Economic benefit: R$ 2.097,02 in relation to the amount of raw material acquired.

Environmental benefit: At least 27 m3 of brick residue created and that previously had to be transported away and disposed of. Furthermore, a reduction of 9.900 units in brick consumption, that also do not need transporting and storing.

Occupational health and safety benefit: Reduction of all possible problems that might arise from the handling of these bricks, for example: the chance that these bricks might break and harm workers; the creation of dust; ergonomic damage created during transportation, etc.

- Case Study 3: Layout benefits when applying tiles and ceramics

Description: This study seeks to measure the importance of layout before placing ceramics and tiles in bathrooms. Firstly, the regulation application of tiles and ceramics in the company was measured. Then the layout was performed and the measurements were taken again.

Indicators: Tile residue generation for tiled area; Tile consumption for tiled area; Costs of tile residue for tiled area.

Results:

Economic benefit: 10% reduction in the cost value for tiling.

Environmental benefit: Reduction of 6% in the amount of tiles used. Reduction of 47% of the amount of residue generated.

- Case Study 4: Assess the cost of client changes in relation to the original project

Description: The company has a feature of personalising units in line with the will of its clients.

The objective of this study is to quantify and assess the adaptations requested by clients, looking for solutions to the problem, minimising the amount of residue created and/or finding value to add to the unit selling price.

Indicators: Residue generation for area built; Total raw material consumption for area built; Total cost for area built; Labour costs for area built.

Results:

Economic benefit: Reduction of 127% of the expected brickwork value.

Environmental benefit: Reduction in solid residue generation in 5 m3 of rubble, which reduces the amount of residue transported and stored internally.

- Case Study 5: Comparison between industrial and conventional cement

Description: In the works performed by the company, cement is made conventionally, in other words, mixed on the construction site. The cement mixer in placed at the level the cement will be applied and the raw material is taken to the mixer. Then the cement mix is applied to the brickwork.

This study aims to compare the advantages and disadvantages of the conventional process and the industrialised process.

Indicators: Total consumption of materials for cement production; Cement consumption for applied area; Packaging residue generation for cement production; Total cost of tiling for applied area.

Results:

Economic benefit: Economic disadvantage of R$ 2.442,27 in relation to industrialised cement, taking into consideration the raw material and labour costs. However, it is possible to reduce costs, using a lesser plaster thickness on the wall, and increasing productivity.

Environmental benefit: Industrial cement consumes approximately at least 15.504 kg less sand than cement mixed on the construction site. Consequently, the generation of industrialised cement cardboard packaging residue is approximately 2.5 times greater than cement mixed on the construction site.

- Case Study 6: The Optimization of the Production Process for Ceramic Floors aiming to minimise the residues generated

Description: The company estimates a loss pattern (when purchasing raw materials) in the process of laying ceramic floors and/or noble stones, but does not directly measure the stones during the production phase. There is no productivity control by the contractor in charge in terms of material consumption or waste.

The optimization of the global conditions in the production process, from the receipt, storage and transport of materials phases to the control execution stage can create subsidies for a lower consumption of raw materials and for managing residues produced. Additionally, the conditions of quality of the contractors involved can be assessed.

Indicators: Total consumption of porcelain tiles for the floor area; Total consumption of cement paste for the floor area.

Results:

Economic benefit: Economy of approximately R$ 4.000,00 for the services performed on the work.

Environmental benefit: Reduction of approximately 37 m2 of the porcelain tile floor through the streamlined purchase of the necessary materials for the execution of porcelain tile floors and the separation of packaging for recycling/resale.

The environmental and economic benefits displayed are those that were recorded, but there are other benefits that can be attained through the use of Cleaner Production. According to Goron et al, (2009), in all work projects there are gains related mainly to cultural issues. The people involved genuinely begin to acknowledge that measuring is possible.That managing residue is possible. That having cleaner construction is possible. But, most importantly, the realization that adapting to the environment can generate profit instead of creating extra expenses.

5 Conclusion

Cleaner Production in civil construction is an extremely satisfactory method given the traits of the sector, and provides benefits on several levels, some already mentioned and others identified from the critical analysis of the research, namely:

- large number of activities that allow the reduction of the environmental impact;
- large number of suppliers that allow improvements in environmental development along the production chain, when opportunities related to eco-efficient materials are implemented;
- large areas constructed that allow rainwater to be recycled;
- large consumption of energy that encourages the search for efficient energy;
- wide range of diversity in architectural projects, that allows the use of natural light and ventilation;
- large volume of residues that encourages the economic development of the community in the project field, beginning with the sale of recyclable residues, setting up a policy of social responsibility;
- large range of equipment that helps to reduce noise and dust emissions, preventing problems with the surrounding area during works, improving the image of the constructor;
- large number of materials with toxic components that means worker health and safety risks can be reduced or eliminated;
- wide range of activities that place the worker at risk, thus allowing the number of accidents to be reduced;
- large number of contactors that allow product quality to be improved;
- fairly unskilled labour force, thus allowing changes in worker behaviour, creating professionals who are more concerned with the environment and the cost of carrying out activities.

Success in the application of this methodology is conditioned by constant training of the labour force and the search for behavioural changes, because activities in the construction sites are temporary, and the outputs of the constructive process (residues, waste and emissions) persist in the long run. The Continuity Plan allows the permanent implementation of Cleaner Production across the diverse activities on the construction site, without damaging the constructor, and this allows the formation of a workforce that is better prepared for the demands of the new market. With the knowledge acquired from participation in a Cleaner Production project, employees become more responsible citizens, as well as fulfilling their potential in terms of professional growth and development.

This means that it is not enough to simply invest in machines and equipment when changing processes and products. It is also necessary to invest in managerial techniques, in planning and in training, taking into consideration that the employees themselves create better procedures, technological innovations and make companies more responsible and more competitive.

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