ENVIRONMENTAL PERFORMANCE AND LEAN CONSTRUCTION CONCEPTS: CAN WE TALK ABOUT A 'CLEAN CONSTRUCTION'?

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ABSTRACT

This paper tries to answer this question: in the same way that lean production concepts give support to lean construction ones, can we talk about a 'clean construction', supported by environmental performance and lean construction concepts?

The goal should be to better meet environment demands, while respecting the production purposes.

This paper shows that the answer is affirmative. More than that, it shows that we can improve the performance of the production management process, including environmental aspects. This new approach could lead to a so-called 'clean construction'.

This article shows the state of the art in this matter, describing some of the solutions found in academic researches and some on-site experiences concerning environmental aspects in building construction.

The main objective is to identify the major environmental approaches that could lead to a 'clean construction', respecting production goals, so that the building sector could contribute to a more sustainable development.

KEY WORDS

Sustainable development, environmental performance, lean construction, clean production, clean construction.

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INTRODUCTION

The increasing global apprehension with the maintenance and improvement of the environment, as well as the protection of human health, has become an important aspect to be considered by construction companies.

Contractors support an increase on regulatory demands and on financing programs' restrictions, both concerning the environment. So, they must start performing prior analyses to measure the impact that their products and activities may have on the environment, trying to find solutions to minimize them.

Based on papers defining 'clean production' and 'lean construction' philosophies, this article proposes a set of 'clean construction' values, in order to better meet environment demands while respecting the production goals coming from 'lean' concepts.

A literature review allows us to describe the basic theory and also a brief state of the art of the environmental practices on building organizations and of the academic researches and other movements that could lead building construction to improve its environmental performance.

Even if the 'lean production' concepts are more related to the firms themselves, to the 'micro' level, they could be extended to the 'meso' or medium and to the 'macro' ones, concerning relationship between firms in an industry, and relating to the environment, in the economic sense, where the actors of this industry operate.

In addition, it is significant to mention that this article intends to cover the environmental aspects of the sustainable development, although it considers that the social and economic ones are also reached while the stakeholders' requirements are respected.

ENVIRONMENTAL PERFORMANCE IMPROVEMENT TENDENCIES ON BUILDING CONSTRUCTION

This item reveals the significance of environmental performance on the building process and also on the building itself as a product. It presents the scale and width of their environmental impacts, showing the important role of building companies, not only on the sites where the production takes place, but also taking part in all the activities involved on a building's life-cycle from planning and design to occupation, maintenance and demolition. And also, buildings must be seen not only as a product, but as a service rendered to customers (delivering, operation, maintenance, rehabilitation, demolition, etc.). This paper deals with at most two of these aspects: construction and conception.

ENVIRONMENTAL ASPECTS

According to the United States Green Building Council (2002), a project with a good environmental performance is characterized by having its environmental and users negative impacts minimized or even eliminated. The Council evaluates the buildings' environmental performance under five aspects: sustainable planning of the building area; energy and water efficiency; use of renewable energy; conservation of resources and materials; and indoor air quality.

Every project is an opportunity to improve the building's environmental performance on sites, during its use and afterwards, when demolition or rehabilitation becomes necessary (Doerr, 2002).

The program "Brown is Green" from Brown University[3] emphasizes the importance of choosing materials that will result in a good environmental performance – for example, the non-toxic, the renewable, and the ones that contain recycled components are preferable.

Also relevant is that the environmental challenge is complex and includes how materials are obtained, what the best way is to achieve their maximum, and also the elimination of any possibility of waste of materials.

Emphasizing the construction process, many authors consider that the major negative environmental impacts of civil construction activities may be caused by: residual generation (solids in large quantities; particles spread in the air; waters served thrown in public ways and sewer networks; dissolution of sulfate of plaster; toxic residues; inadequate residual discharge; discharge of renewable sources; loss and waste of construction materials, and also of energy and water; emissions of noise and vibration; consumption of a large amount of manufactured and natural products; interference on the hydraulic and drain systems; removal of the vegetation).

Among these aspects, the one that has been highlighted as particularly important is the large amount of solid residues that have been generated and disposed on the urban environment, during construction but also throughout maintenance and demolition.

There are many authors that relate the solid residues generated on sites to the loss and waste of materials that occurs during construction processes. In Brazil, Andrade *et al.* (2001) consider that the waste generated on building sites represents approximately 5 percent of the finished building, considering the building mass to be 1,000 kg/m^2.

Pinto (1999) lists the environmental consequences of the incorrect disposal of construction and demolition residues on the Brazilian urban environment. The author considers from soil pollution to fuel burning related to the transportation of residues to landfills, which is caused by an increase in journeys as a consequence of the growth of cities.

Analyzing a share of construction residues, and concerning its heterogeneity, almost the whole of the materials that compose it have a great aggregate value and good mechanical properties, being a potential source of materials (Brito Filho, 1999 and Pinto, 1999). Agopyan *et al.* (1998) also believe that the building construction would be able to absorb almost the whole of the residues that are produced by it. Moreover, Pinto (1999) considers that a special kind of management would be necessary that was able collect and recycle the residues that come from construction activities.

Besides the pollution caused by solid residues, it is also important to mention that during a building's life-cycle we also find: (a) air pollution caused by particulate emissions in the construction and demolition phases, and by CO_2 and CFC emissions caused by the possibility of fire, equipment and other utensil perforations during use, maintenance or demolition phases; (b) noise detected during construction, maintenance or demolition phases, which affects directly the neighborhood; (c) indoor air pollution, detected during building use and caused by air conditioning, by pollutants emitted by materials, soil, and also by the activities related to regular use and also related to equipment operation and cleaning products (e.g. emission of volatile organic compounds, pathological microorganisms, dust, particulates and fibers, radon, and others).

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[3] Providence, Rhode Island. Available at: <www.brown.edu/Departments/Brown_Is_Green/greenarch> Access on: April 2002.

STATE OF THE ART ON ENVIRONMENTAL PRACTICES IN BUILDING ORGANIZATIONS

In most countries, the regulations do not require formal and comprehensive environmental management structures. Up to now the contractors do not pay attention to the influence of their activities on the environment, although there are some regulations applied on heavy construction and on buildings that will be built on natural resource areas - situations where the environmental impacts are quite evident. In these cases, environmental impact analyses and periodic environmental reports are usually required. But, in general, little has been done to minimize the environmental impacts of civil construction activities.

In Brazil, contractors say that the initiative for environmental approaches starts with an environmental awareness and go through to the anticipation for the new requirements that they expect to impact their practices as a market differential.

There are exceptions. Some organizations have started to be environmental-friendly. A good example is the construction company Skanska[4], which took the environmental approach strategically by introducing certified environmental management systems according to ISO 14001. However, as mentioned by Wenblad (2001), this company agrees that to be a leader on environmental issues they have to do more than meet the ISO specification requirements, but that this international standard is a good framework to develop their social responsibility.

One of the tools that Skanska has developed is a project database, which is available internally on their Intranet. It was created because they consider the design phase to be critical to the environment, and also responsible for the technical solutions specifications that will be felt during all the service life of the buildings. They also developed a database of chemical products in Sweden in order to control their use and disposal.

It is possible to list some other on-site experiences concerning environmental practices in building companies. It has been noted that these organizations usually already have some kind of management system and start up these environmental practices by integrating them to the existent ones. That includes, for example: procedures to identify the impact of the project on the environment during the execution phase, and also during all of the building's life-cycle, which includes service life, maintenance and demolition (this practice is conducted for each individual project and performed by that project's specified technical team); periodic reports that illustrate the environmental aspects and solutions implemented on the sites; a routine to measure the significant environmental aspects on plants; having a list of residues and their respective classification according to the presence of contaminants; implementing methods for disposal of residues, including screening of residues; adoption of principles on selecting the sources that will be bought; suppliers' evaluations and sites' feedback on environmental issues; training to minimize water and energy waste; monitoring vehicle gas emissions during delivery of products; adoption of some facilities to minimize particulate emissions, like sprinkling the outdoor storage of materials or sprinkling the dry soil; doing noise measurements and establishing time schedules through agreements with the neighborhood; having a means of communication with the community and the neighborhood.

[4] Skanska is among the world's five largest construction companies, with construction-related activities and project development operation in some 60 countries. It is a Swedish organization.

ACADEMIC RESEARCHES AND OTHER MOVEMENTS

There are solutions that may be used by construction organizations to minimize their relevant environmental impacts. Some studies support this statement. According to Angulo (2000), the current researches concerning the sustainable development of building construction foster: i) minimization of waste; ii) improvement on the quality of products; iii) recycling of residues by re-using construction residues and other industrial residues that could also be applied on construction; iv) sustainable development focused on project designs; v) increase of the durability of components. The recycling and waste reduction matters deserve to be mentioned as the most relevant ones.

There are important research centers and other institutional and private actions that must be a reference to contractors in order to act truly to the environmental issue. They show that there is already a tendency for external pressures:

- Technical committee of RILEM (*Réunion Internationale des Laboratoires d'Essais et de Recherches sur les Matériaux et les Construction*) called RILEM 121 – DRG;
- ISCOWA (The International Society for the Environment and Technical Implications of Construction with Alternative Materials), which promotes the WASCON conferences 'Environmental aspects of construction with waste materials', the outcome of which is edited by Elsevier;
- Group TG-16 Sustainable Construction of CIB (International Council for Building Research Studies and Documentation);
- Researches and actions being developed by some European organs like *CSTB (Centre Scientifique et Technique du Bâtiment)* , *PUCA (Plan Urbanisme Construction et Architecture)*, *ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie)*, *Association HQE - Haute Qualité Environnementale* and *FFB (Fédération Française du Bâtiment),* in France, or the Delft University of Technology, the Rutgers University, and also the TNO (*Nederlands Instituut voor Toegepaste Geowetenschappen*), in the Netherlands;
- Charter for the Environment – requirement elaborated in 2000 by FIEC, an entity representative of the building sector in 14 countries in the European Union;
- Austin Green Building Program – architectural program developed in Texas, USA, which has been encouraging similar programs in other states;
- Resource Conservation and Recovery Act (RCRA) established by the EPA[5], which includes rules applied to environmental management practices;
- In Brazil, the institutions concerned about environmental issues on building construction are: i) PCC/EPUSP – Civil Construction Engineering Department, Polytechnic School, USP[6]; ii) NORIE-UFRGS researches in *Edificações e Comunidades Sustentáveis*; iii) CT-206 *Comitê para o Meio ambiente* of IBRACON[7]; iv) group of residues of the *Associação Nacional de Tecnologia*

[5] US Environmental Protection Agency.
[6] Available at: <www.reciclagem.pcc.usp.br>.
[7] *Instituto Brasileiro do Concreto.*

do Ambiente Construído (ANTAC); v) NPC-UFSC, UFSM, and CIENTEC-RS, among other.

Environmental assessment for buildings already exists, like EcoHomes, from British Research Establishment, and LEED – Leadership in Energy and Environmental Design, from UG Green Building Council. In France, *CSTB*, *Association HQE* and *ADEME* are developing a methodology to assess the environmental performance of buildings.

Also, there are other movements such as eco-building, sustainable building, eco-design, eco-architecture, green building and environmental building. According to Furtado (2002), they are an international language to express the initiatives that aim to improve the relationship between environment and building construction in all of its stages from planning and designing through to demolition. This article emphasizes the 'clean production' concepts that are the basis of the environmental guidelines proposed here and that are dealt with in the next item.

'CLEAN PRODUCTION' CONCEPT

The principles of the 'clean production' appeared in the 80's as a proposal from the international environment organization Greenpeace, in their campaign for "a deeper change on the industrial behavior".

According to Greenpeace's report "*O que é produção limpa?*" (Greenpeace, 1997), the major goal of 'clean production' is to meet the product demand while being sustainable, efficiently using renewable and non-toxic materials and energy, and preserving biodiversity at the same time.

The 'clean production' involves juridical, political and social components represented by the vision of the global production system and the application of their four fundamental principles: precaution, prevention, integration and democratic control. In detail and according to Greenpeace (1997) and Furtado (2002) these four principles are:

- PRECAUTION – do not use materials and neither generate outputs that could cause environmental damages (that is already a legal requirement in Europe);
- PREVENTION – propose the replacement of pollution control with prevention of residues and their environmental impacts. That includes: i) elimination or reduction of potentially pollutant emissions; ii) creation of guidelines to reorient product design; iii) reorientation of customer demand; iv) stimulation of changes on patterns of use or material consumption;
- INTEGRATION – application of both principles — precaution and prevention — on all production system flows and at the product life-cycle assessment[8];
- DEMOCRATIC CONTROL – involve workers, consumers and communities, and observe the right of public access to information about product and process risks to human health and to the environment.

The Greenpeace (1997) also establishes some criteria for 'clean production' systems and their derived products. They are:

[8] The life-cycle assessment includes the product design, the material selection and production, the product manufacture itself, distribution and marketing, service life, and the social management of materials until the end of its life.

- The production systems must be i) non-toxic; ii) energy-efficient; iii) renewable materials must be adopted, always recycled and extracted in harmony with the ecosystem and its original community, or made from non-renewable materials but recyclable in a non-toxic way and without great energy expenditure;
- The products must be i) durable and reusable; ii) easy to deconstruct, fix and reconstruct; iii) minimal and regularly packed for distribution; iv) made of reusable, recycled or recyclable materials.

HOW WILL CONTRACTORS MEET ENVIRONMENT DEMANDS WHILE RESPECTING 'LEAN CONSTRUCTION' CONCEPTS?

LEAN CONSTRUCTION

Koskela (1992) introduced some concepts and established some principles for the function of production in construction. These concepts and principles perceive construction as a net of cycling production flows that have conversion and non-conversion activities, as well as activities that add value and activities that do not add value to the final product or byproduct.

It means that, in addition to transformation, there are waiting, inspection and moving stages, and the production management equates to minimizing the share of non-transformation stages of the production flow.

In Koskela (2000) another principle was added to these, the value generation concept. This new conceptualization views production as a means for the fulfillment of the customer's needs, where "the production management equates to translating these needs accurately into a design solution and then producing products that conform to the specified design".

Concluding, the general approach within 'lean construction' is to make the construction process leaner by reducing non-value-generating activities considering also the customer's needs.

Koskela (2000) summarized several principles that enable the reduction of the share of non-value-adding activities conducted, as follows: increase output value through systematic consideration of customer requirements; reduce variability; reduce cycle times; simplify by minimizing the number of steps, parts and linkages; increase output flexibility; increase process transparency; build continuous improvement into the process; balance flow improvement with conversion improvement; benchmark.

HOW TO BE CLEAN AND LEAN

Huovila; Koskela (1998) have already pointed out the two major contributions of lean construction to sustainable development: adding value to the customer and eliminating waste, mainly related to materials.

Being 'clean' requires a focus on the environmental aspects of organization activities, but it should not stop the production process from improving. The 'lean' concept, that tries to reduce or eliminate non-value-adding activities must be integrated into these new approaches brought by global sustainable development issues, mainly environmental ones.

To achieve both, contractors should consider the value added by each new procedure or by changes in the behavior implemented on the organization under the new 'clean' concepts. The next paragraphs exemplify some aspects that should be considered.

Environment-concerned organizations are committed to investigating the environmental aspects and impacts of each individual project. They must plan its performance during all of the project's life-cycle and before the project starts, at the same time as the decisions regarding the production system are taken.

The 'lean' requires the increase of the product output value through systematic consideration of customer requirements. These requirements should be amplified in order to achieve all of the organization's stakeholders, which include the community and consequently the environment where it is immersed. In this case, being 'lean' also meets the environmental requirements.

The 'clean production' principle named 'democratic control', which enables public access to contractors' information, only adds value if the contractors know how to get a real feedback from them. It is also essential to identify the key stakeholders with whom an ongoing dialogue can be established. Considering that, and according to Skanska, dialogue means two-way communication (not only inform but listen), and it is usually too late to start the dialogue when the problems have already materialized. Again, the 'lean' and the 'clean' complement each other.

The procedures implemented to measure and control the environmental aspects of each site's activity must not interfere with the production process by creating new ways of wasting time or money. Contractors must consider only the environmental aspects that are really meaningful and the ones with which they could interfere efficiently; maybe spending a little extra time, but compensating that by adding value to the final result.

In order to be 'lean' and 'clean' on the material selection, it must be considered that the recycled products must already be well-known as to their application technology and performance, just like the renewable or other new experimented materials. And also, the materials adopted must not generate more residues than the traditional ones. Concluding, before the adoption of a 'green' alternative a balance must be reached, considering those aspects above and also their storage and transportation requirements.

However, the most significant way the 'clean' concepts could bring value to the 'lean construction' ones, relates to the waste issue. According to Lee *et al. (19*99) the "waste categories are: defects; over-production; unnecessary processing; unnecessary people moves; unnecessary movement of material; waiting; inventories; designing something that does not meet client's needs."

Analyzing this question under an environmental concern, it is easy to see that these non-value-generating activities also increase the environmental impacts. For example: the unnecessary people moves increase the risk of accidents and the loss of material; unnecessary material movement increases energy consumption and could also generate residues; the over-production could be related to the incorporated material on buildings and, also the increase of the final amount of demolition residues. Conclusion: minimizing these non-value-generating activities minimizes the environmental impacts; they both go together.

Still considering the waste matter as any activity that does not generate value, it is important to mention that one source of waste may be not properly recognized in the absence of appropriate tools for measurement and evaluation. The 'clean production'

concept appears as an additional tool for the 'lean construction', although the 'lean' principles already consider some ways to control the generation of waste.

Some 'lean construction' implementation approaches that contribute to reducing waste are i) the reduction of variability through standardized measurement, finding and eliminating problems; ii) the cycle time reduction through the minimization of distances and changes in the order of the process, that also minimize wastage. They show once more that 'lean' and 'clean' propositions for minimizing waste could be achieved by integrating both concepts.

The implementation of 'clean' principles requires time for learning and training, but this time spent must not be considered wasted – it will later add value to the global process. And some extra time will also have to be spent on environmental inspections, and again this time will be worthwhile, since it is much easier to prevent or correct a potential impact during the design stage than during the building execution or end use.

GUIDING PRINCIPLES FOR 'CLEAN CONSTRUCTION'

Re-visiting the previously discussed drawbacks of 'clean production' and the above considerations on how to be 'clean' and 'lean', this item describes some guiding principles for 'clean construction'.

MATERIALS AND COMPONENTS

The selective process of materials and components that will be used and applied during the construction process, including the ones that remain as part of the final product, must be analyzed under its toxicity during the manipulation, application and installation. The residues generated by those activities must also be toxicologically verified.

It is also very important that these materials and components have been selected based on an assessment of the building's life-cycle as a whole, involving: i) the presence of contaminants (no toxicity); ii) durability; iii) quality; iv) application methods; v) constructability; vi) deconstruction aspects; vii) easy maintenance and reuse; viii) safe final disposal.

The materials and components that come from renewable resources, which may be recycled or the ones that are already recycled, are preferable.

Contractors should also evaluate their suppliers and get site feedback in order to improve the relationship between them. They should be encouraged to adopt environmental practices too.

Another 'clean' principle guideline that contractors should follow involves situations when their projects may damage any area, or impact the local community. In these cases the project should be accompanied by recuperation projects.

TECHNOLOGY AND EQUIPMENT

The technologies adopted must act on reducing the pollution, above all the presence of pollution during the building's life-cycle as mentioned some items above. Especially on site, it means to provide devices to reduce the emission of solids residues, particles spread in the air and noise.

The technology must also be used in benefit of an efficient application of materials e.g. i) reusing goods; ii) installing facilities like local recycling equipment, water collection service or local treatment station, or other residual treatment concerns.

Additional advice is that planners should also pay attention to energy and water consumption efficiency of the selected equipment that will be used during construction and the ones that will be permanently installed in the building.

CONTROLS

Many controls should be implemented on construction sites. The procedures adopted to control environmental aspects must start on the planning stage and should influence the selection of technology, sources and also the transforming processes.

The source management should pay attention to the consumption level of materials, fuels and energy during production processes. They should also better control the storage and manageability in order to prevent losses.

The management of non-value-adding activities must be fitted into 'lean' principles and must include a control of water, materials, time and costs. A good waste management depends on the transparency and good knowledge of the production processes and cycles. There must also be a residue management especially to take care of the solid residues. Contractors should replace the simple transportation and disposal of construction residuals on local landfills with their reduction on resources. That means that treatment should be applied to the very process that has generated them.

For a good knowledge and control of residue generation, its volume must be quantified and its origin investigated. Contractors should list their residues and classify them according to the presence of contaminants and recyclability, so that it will be possible to collect these residues selectively and use an adequate form of disposal for each type. It is also important to act in dialogue with the companies in charge of collection.

Another way to reduce residual generation is to reduce waiting time, storage and movements, and these non-value-generating activities found on site flow should be always under control, as mentioned before.

There is another kind of control that could be implemented by environment-concerned contractors; it is the control of the social aspects of construction activities. This must be done by providing the community and neighborhood with access to the project information. There must be a means of communication; one example could be the determination of the building schedule based on the needs of the neighborhood, like the establishment of regular periods of noise emissions.

DESIGN

For this purpose the design phase is fundamentally important because it is responsible for defining the sources and the constructive technology that will be implemented on each specific site. Another important role of design is to define the layout conceptualization, which is held responsible for most of the non-value-added activities on sites throughout flows, and also to simplify the building geometry in order to save utilities and materials.

There are innumerable benefits provided by the sustainability-focused design concerning environmental building performance. They will be felt when designers adopt a preventive positioning during their design decisions. There are some characteristics probably present in sustainable designs: i) interior space optimization; ii) increase of natural lighting, conditioning and heating, in order to be energy-efficient; iii) optimization of usage of materials; iv) efficiency on water consumption and low maintenance; v) a design that enables good home recycling practices; vi) concern about the building’s

durability; vii) provision of water recycling; viii) structure adaptable to other future uses and the selection of materials and components that could be reused or recycled in the future; ix) use of recommendable practices to minimize the radon entrance on building, preventing potential risks to human health, and also other toxic materials. (Mother Earth News Online, 2000[9]).

Concerning exclusively the 'lean construction', Lam *et al. (20*01) paper exposes some ways to follow those principles through design specifications.

OTHER CLEAN PRINCIPLES

There are other guidelines to be adopted by contractors in order to achieve the 'clean construction', as described below.

In order to be 'clean producers', contractors must be committed, but not only the top management, since it is vital to get the middle management on board (Wenblad, 2001). Training programs and information for the education of employees are important tools to disseminate environmental concern throughout all the sectors of a company.

It is also necessary to measure the environmental performance achieved in order to maintain its continuous improvement. Writing periodic reports is a good way to take control of performance.

Another good framework for 'clean construction' is to follow the ISO 14004 standard requirements and have an environmental management system implemented. The formulation of objectives and action programs, implementation of actions, internal follow-up (measurements, internal environmental audits, management reviews), suggested by the international standard, are excellent guidelines and principles to achieve a 'clean construction'. However, while the ISO specification is an important element to focus the attention of the organization on these issues, it is not enough to enable a company to become an environmental leader in its business sector.

CONCLUSIONS

Because sustainable development and attitudes aimed at minimizing environmental impacts and maximizing environmental performance are now a tendency and soon will become an exigency of stakeholders, organizations should anticipate them.

The significance of environmental aspects varies over the life-cycle of a project, from land use planning to construction, service life and demolition. And this matter could not come separate from the 'lean construction' concepts, since they add value to each other when correctly combined.

One of the main conclusions of this study is that some 'lean construction' concepts and methods that have been used for production planning and control can be easily extended to environmental planning. And also, that we can improve the performance of the production management process by including these environmental aspects.

This paper identifies that the residue management is the main point to be controlled and improved by contractors on the site environment, that is why the word 'clean' fits well to this issue. So, we hope that building organizations recognize their stuff being in surplus and the techniques available in order to achieve rationality on non-renewable sources and application of renewable ones.

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[9] Available at < www.motherearthnews.com/building >. Access on: September 2000.

The authors hope to stimulate further discussion to make sustainable development possible in the construction industry, mainly concerning environmental performance subjects. Since there is not enough knowledge on how to implement this practice, this gap has recently encouraged the ongoing research project being developed by these authors entitled "Study of the applicability of environmental management system on contractors".

So, environmental issues should become a natural element of the way organizations do business.

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REFERENCES

Agopyan, V. et al. (1998). *Alternativas para a redução do desperdício de materiais nos canteiros de obras: relatório final.* Escola Politécnica da Universidade de São Paulo (EPUSP), Departamento de Engenharia Civil. São Paulo. 5v.

Andrade, Artemária C.; Souza, Ubiraci E. L.; Paliari, José C.; Agopyan, Vahan. (2001). *Estimativa da quantidade de entulho produzido em obras de construção de edifícios. In*: IV Seminário Desenvolvimento Sustentável e a reciclagem na construção civil. IBRACON / CT-206. São Paulo.

Angulo, Sérgio C. (2000). *Variabilidade de agregados graúdos de resíduos de construção e demolição reciclados.* EPUSP. Dissertação de mestrado.

Brito Filho, J. A. (1999). *Cidades versus entulhos. In*: II Seminário Desenvolvimento Sustentável e a Reciclagem na Construção Civil. IBRACON / CT-206. São Paulo.

Doerr Architecture (2002). *Definition of Sustainability and the Impacts of Building*. Colorado, EUA. Available at: <doerr.org/html/GreenChecklistResidential.doc>. Access on April 2002.

Furtado, João S. (2002). *Atitude ambiental responsável na construção civil: Ecobuilding & Produção limpa*. Available at: <www.vanzolini.org.br>. Access on March 2002.

Greenpeace Report (1997). *O que é a produção limpa?* Available at: <www.greenpeace.org.br>. Access on November 2001.

Huovila, Pekka; Koskela, Lauri (1998). *Contribution of the Principles of Lean Construction to Meet the Challenges of Sustainable Development*. *In*: Proceedings IGLC-6 - Sixth Annual Conference of the International Group for Lean Construction. August 1998, Guarujá, Brazil.

Koskela, Lauri (1992). *Application of the new production philosophy to construction.* Technical Report 72, CIFE, Stanford University, Ca, September.75pp.

Koskela, Lauri (2000). *An exploration towards a production theory and its application to construction.* Espoo 2000. Technical Research Centre of Finland, VTT Publications 408. 296p.

Lam, Patrick T.; Kumaraswamy, Mohan; Ng, S. Thomas (2001). *The Multiple Roles of Specifications in Lean Construction. In*: Proceedings IGLC-9 - Ninety Annual Conference

of the International Group for Lean Construction. August 2001, National University of Singapore, Singapore.

Lee, S.; Diekmann, J. E.; Songer, A.D.; Brown, H. (1999). *Identifying waste: Applications of construction process analysis. In*: Proceedings IGLC-7 - Seventh Annual Conference of the International Group for Lean Construction. July 1999, University of California, Berkeley, USA.

Pinto, Tarcísio de P. (1999). *Metodologia para a gestão diferenciada de resíduos sólidos da construção urbana.* EPUSP. Tese de Doutorado. São Paulo. 189p.

United States Green Building Council (2002). *An Introduction to the US Green Building Council and the LEED™ Green Building Rating System*. Washington, DC. March, 2002. Available at: <www.usgbc.org/USGBCCintroSLIDES.ppt>. Access on April 2002.

Wenblad, Axel (2001). *Sustainability in the Construction Business – a case study.* Corporate Environmental Strategy, vol 8. No.2. Elsevier. p.157-164.