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Design for Deconstruction: Emergy Approach to Evaluate Deconstruction Effectiveness

Tese de Doutoramento
Arquitectura / Projecto e Tecnologias da Construção

Trabalho efectuado sob a orientação do
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Dezembro de 2009

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Título tese:

Design for Deconstruction: Emergy Approach to Evaluate Deconstruction Effectiveness

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Ano de conclusão: 2009

Designação do Mestrado ou do Ramo de Conhecimento do Doutoramento:

Arquitectura / Projecto e Tecnologias de Construção

É AUTORIZADA A REPRODUÇÃO INTEGRAL DESTA TESE/TRABALHO APENAS PARA EFEITOS DE INVESTIGAÇÃO, MEDIANTE DECLARAÇÃO ESCRITA DO INTERESSADO, QUE A TAL SE COMPROMETE;

Universidade do Minho, 28 / 12 / 2009

Assinatura: ____

APOIO FINANCEIRO

Ciência.Inovação 2010

Programa Operacional Ciência e Inovação 2010
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

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ABSTRACT

Recovery of materials is a crucial concern to avoid depletion of natural resources nowadays. Industrial Ecology recognised the role of industrial activities in order to minimise waste flows and to maximise materials and components recovery, by means of reuse and recycling. Construction industries, however, is slowly becoming aware of building materials recovery and at present new approaches are seriously examined such as Design for Disassembly/Deconstruction (DfD).

Furthermore, in order to evaluate the building deconstruction several approaches can be employed. In this research work the Emergy approach (spelled with an "M") is considered to be a more effective tool for such evaluations. This approach looks beyond the technosphere and takes into account the role of our planet as the sole source of materials and the largest recycler of material´s life cycle.

Principles and practices of Design for Disassembly from car and electronics industries are examined and their applications provide avenues of development for construction industry.

Using principles of DfD and Emergy theory, a model to measure the environmental net benefit of building materials recovery at the design stage is proposed. The model estimates the Deconstruction Effectiveness index (DE) of a building and enables designer to compare the alternative options, selecting the optimum solution.

By introducing the idea of 'effectiveness', rather than 'efficiency', the model describes the balance between the resources that are consumed in a building or building element, and the amount of non-extracted resources due to their reuse or recycling.

The model analyses the building design and estimates an index that expresses the quantitative environmental net benefit of building materials recovery. This index considers the materials that are saved by materials recovery and the input of materials during the Lifespan of a building or building element. Thus, it may be used also as a reference for improvement of the solution at the design stage with regards to the feasible end-of-life scenarios that maximise materials recovery.

The proposed model is composed by the following steps: (1) analysis of technological building configuration, (2) accounting for the flows within the building system, (3) estimating the DE index, and (4) solution improvement. The DE index varies between 0 and 1, for buildings with no recovered materials (DE=0) and buildings that are reused totally (DE=1).

For the assessment of the model, three different internal walls (brick masonry, plasterboard, and wood frame), and three different construction systems (concrete, steel, and wood) were used.

Results obtained indicated that DE varies between 0.25 and 0.59 for different wall systems evaluated, while, for different building systems varies between 0.30 and 0.51. The better result is due to plasterboard disassemblability properties and high Emergy per mass of materials used, which benefits this option due to the raw materials that are saved. Results obtained from the application of DE index to buildings are also influenced by the disassemblability of the construction systems, the Emergy per mass of the materials, and the feasible end-of-life scenarios.

The application of Deconstruction Effectiveness to these case studies highlights the model's sensitivity to the disassembly properties of buildings, materials durability, end-of-life scenarios, and the environmental value of materials for which the recovered materials are a substitute.

Application of the DE index to building design meets the DfD principles, enhances the quality of the recovered building materials and the environmental value of those materials in which nature made the greatest investments, i.e. non-renewable resources, provided by longer natural cycles and higher energy flows.

Concepção para a Desconstrução:
Abordagem Emergética à Avaliação da Efectividade da Desconstrução

RESUMO

Actualmente, a recuperação dos materiais é uma preocupação crucial para evitar a exaustão dos recursos naturais. A Ecologia Industrial reconhece o papel das actividades industriais na minimização dos fluxos de resíduos e na maximização da recuperação de materiais e componentes, por meios de reutilização ou de reciclagem. Nas actividades da construção, no entanto, começa-se lentamente a tomar consciência da necessidade da recuperação dos materiais de construção e, no presente, novas abordagens são estudadas e apresentadas, como a Concepção para a Desconstrução.

No entanto, de modo a avaliar a desconstrução de edifícios, um conjunto de diferentes abordagens pode ser empregue. Neste estudo a teoria da Emergia (escrita com "M") é considerada como sendo uma ferramenta mais efectiva para tais avaliações. A abordagem da Emergia está para além da tecnosfera e tem em conta o papel do nosso planeta como sendo a única fonte de materiais e o maior sistema de reciclagem no ciclo de vida dos materiais.

Princípios e práticas da Concepção para a Desconstrução nas indústrias de produção de automóveis e produtos electrónicos, bem como a sua aplicação, fornecem igualmente linhas de orientação para a indústria da construção.

Através da aplicação dos princípios da concepção para a desconstrução e da teoria da Emergia, é proposto um modelo para estimar o benefício da recuperação dos materiais de construção. O modelo estima o índice de Efectividade da Desconstrução (ED) de um edifício e permite que o projectista compare soluções alternativas, escolhendo a solução optimizada.

Através da ideia de "efectividade", em vez de "eficiência", o modelo descreve assim o equilíbrio entre os recursos que são consumidos num edifício ou elemento do edifício, e a quantidade de recursos que não são extraídos devidos à sua reutilização ou reciclagem.

O modelo analisa a concepção do edifício e estima um índice que expressa quantitativamente o benefício ambiental da recuperação dos materiais de construção. O índice considera os recursos que são poupados pela recuperação de materiais e o fluxo de materiais durante o tempo de vida de um edifício ou elemento da construção. Assim, o modelo poderá ser também uma referência para a melhoria das soluções durante a fase de concepção, tendo em conta os cenários de fim de vida mais viáveis para a maximização da recuperação dos materiais.

O modelo proposto é composto pelos seguintes passos: (1) análise da configuração tecnológica do edifício, (2) estimativa dos fluxos que atravessam o sistema do edifício, (3) cálculo do índice ED e (4) melhoria da solução. O índice ED varia entre 0 e 1, sendo ED=0 para edifícios sem possibilidade de recuperação de materiais e sendo ED=1 para edifícios cujos materiais serão totalmente reutilizados.

Para a avaliação do modelo, foram utilizados três tipos de paredes interiores (alvenaria de tijolo, gesso cartonado, e madeira) e três tipos de sistemas de construção (betão armado, aço e madeira).

Os resultados obtidos indicam que ED varia entre 0.25 e 0.59 para os diferentes tipos de paredes interiores avaliadas e que ED varia entre 0.30 e 0.51 para os diferentes tipos de sistemas construtivos. O melhor resultado obtido pela parede de gesso cartonado reflecte as suas propriedades de desmontagem e os elevados valores de Emergia por massa dos materiais empregues, o que beneficia esta opção em comparação com os recursos que são salvos. Os resultados obtidos da aplicação do índice ED aos edifícios são igualmente influenciados pela facilidade de desconstrução dos sistemas, a Emergia por massa dos materiais e a viabilidade dos cenários de fim de vida.

A aplicação da Efectividade da Desconstrução aos casos de estudo evidencia a sensibilidade do modelo às propriedades de desconstrução dos edifícios, durabilidade dos materiais, cenários de fim de vida e, inclusive, ao valor ambiental dos recursos para os quais os materiais recuperados são substitutos.

A aplicação do índice ED à concepção dos edifícios observa os princípios da Concepção para a Desconstrução e o valor ambiental dos materiais nos quais a natureza fez os maiores “investimentos”, i.e. recursos não renováveis, providos por longos ciclos naturais e grandes fluxos de energia.

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LIST OF ACRONYMUS

BIM	Building Information Modelling
BRE	Buidling Research Establishment
BREEAM	BRE Environmental Assessment Method
CC	Closed Connection
C&DW	Construction and Demolition Waste
CIB	Conseil International du Bâtiment / International Council for Building
CSA	Calcium Sulfoaluminate
DE	Deconstruction Effectiveness index
DfA	Design for Assembly
DfD	Design for Disassembly / Design for Deconstruction
DfE	Design for Environment
ECM	Environmental Conscious Manufacturing
ELS	End-of-Life Scenario
EOTA	European Organisation for Technical Approvals
EPR	Extended Producer Responsibility
EPS	Expanded Polystyrene
EU	European Union
FSL	Forecast Service Life
HDPE	High-Density Polyethylene
IISBE	International Institute for Sustainable Building and Environment
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LDPE	Low-Density Polyethylene
LEED	Leadership in Energy and Environmental Design
LLDPE	Linear Low-Density Polyethylene
LPG	Liquefied Petroleum Gas
MDF	Medium Density Fibreboard
NGO	Non-Governmental Organisation
OC	Open Connection
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturers
OSB	Oriented Strandboard
PA	Polyamide
PC	Polycarbonate
PE	Polyethylene
PET	Polyethylene Terephthalate
PMMA	Polymethylmethacrylate
PP	Polypropylene

PRD	Product Recovery and Disposal
PS	Polystyrene
PUR	Polyurethane
PVC	Polyvinyl Chloride
RAP	Reclaimed Asphalt Pavements
RBR	Recyle Benefit Ratio
RE	Recovery Effectiveness
RER	Recyle Efficiency Ratio
RR	Recovery Rate
UL	Useful Life
WB	Waferboard
WPC	Wood-Plastic Composites
XPS	Extruded Polystyrene

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