ENERGY AND CO2 EMISSION EVALUATION OF CONCRETE WASTE

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ABSTRACT

A significant amount of solid wastes produced every year from construction and demolition activities, and had caused significant pollution to the environment and risen public concern. Therefore, the minimization of construction wastes has become a critical issue in construction industry Concrete is the most commonly used construction material in the world, and after water is the second most consumed product on the planet. The huge popularity of concrete also carries environmental costs, the most harmful of which is the high energy consumption and CO2 release during the production. This paper investigates the amount of energy used and CO2 emission generated during the production of concrete. Furthermore to estimate the total impact of both indicators based on concrete wasted generated on site. Data were obtained through questionnaire survey and interview within the building construction projects in U.T.M. These impact assessment were followed the life cycle assessment (LCA) methodology. The results show that the production of the raw material and the transports of the concrete are the main contributor to the total environmental load . The highest impact value was generated during the production of cement at upstream level .the amount of energy used and CO2 emission by cement production was about 70 percent of the total embodied energy and 95% of the carbon dioxide emissions of concrete production and Within the transportation operations, the transportation of concrete is the largest contributor equal to 25% to 28% the production of concrete and on the other hand 12% to 14% for CO2 emission.

ABSTRAK

Jumlah sisa pepejal daripada kerja pembinaan bangunan menyebabkan pencemaran alam sekitar dan meningkatkan keprihatinan masyarakat awam akan perkara ini. Oleh yang demikian, pengurangan akan sisa tersebut menjadi isu yang kritikal dalam industri pembinaan. Konkrit merupakan bahan yang digunakan dalam kerja pembinaan. Penggunaannya yang berlebihan menyebabkan kesan kepada persekitaran iaitu pembebasan gas CO2 semasa proses penghasilannya. Kajian ini menyiasat tenaga yang digunakan dan pembebasan gas CO2 semasa menghasilkan konkrit. Kajian ini juga menganggar kesan bagi kedua-dua perkara tersebut. Data diperolehi dengan dapatan soal selidik dan temu bual yang dilakukan di sekitar projek pembinaan di UTM. Seterusnya penilaian kitar tenaga (LCA), di jalankan dan keputusan mendapati penghasilan bahan mentah dan pengangkutan konkrit merupakan penyumbang utama kepada beban persekitaran. Kesan tertinggi diperolehi semasa penghasilan simen pada peringkat akhir. Jumlah tenaga yang digunakan dan pembebasan gas CO2 oleh penghasilan simen ialah 70 peratus daripada jumlah sebenar tenaga yang digunakan dan 95 % pembebasan gas karbon dioksida. Dalam tempoh operasi penghantaran, iannya merupakan penyumbang terbesar iaitu 25% ke 28 % bagi penghasilan konkrit dan 12 % ke 14 % bagi pembebasan gas CO2.

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INTRODUCTION

1.1 Introductions

The construction industry plays a vital role in meeting the needs of its society and enhancing its quality of life. The industry remains as a major economic sector, thus the pollution generated from construction activities continuously presents a major challenge to implement environmental management in practice. The investigations demonstrated that construction business is a large contributor to waste generation.

Environmental and human health impacts of materials are a hidden cost of our built environment. Impacts during manufacture, transport, installation, use, and disposal of construction materials can be significant, yet often invisible. A broad and complex web of environmental and human health impacts occurs for each of the materials and products used in any built landscape, a web that extends far beyond any project site. Construction materials and products can be manufactured hundreds, even thousands, of miles from a project site, affecting ecosystems at the extraction and manufacturing

locations, but unseen from the project location. Likewise, extraction of raw materials for these products can occur far from the point of manufacture, affecting that local environment. Transportation throughout all phases consumes fuel and contributes pollutants to the atmosphere. Disposal of manufacturing waste and used construction materials will affect still another environment. These impacts are “invisible” because they are likely remote from the site under construction and the designer’s locale.

Parallel to rapid economic growth and urbanization in Asia, environmental impacts from construction and demolition (C&D) waste are increasingly becoming a major issue in urban waste management. C&D waste management in developing countries in the Asian region is relatively undeveloped and emerging. Environmental issues such as increase in volume and type of waste, resource depletion, shortage of landfill and illegal dumping, among others are evident in the region. Furthermore, the Asian countries have limited or no available data on C&D waste and the management aspects, particularly with regards to their C&D waste generation and composition; practices and policy, key actors and stakeholders’ participation. (Asian Institute of Technology,2008)

1.2 Background of the study

Concrete is the most commonly used construction material in the world, and after water is the second most consumed product on the planet. Each year worldwide the concrete industry uses 1.6 billion tons of cement, 10 billion tons of rock and sand, and 1 billion tons of water. Every ton of cement produced requires 1.5 tons of limestone and fossil fuel energy inputs (Mehta 2002). The huge popularity of concrete also carries environmental costs, the most harmful of which is the high energy consumption and

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CO2 release during the production of Portland cement. While the resources for aggregate and cement are considered abundant, they are limited in some areas, and more importantly, mining and extraction of the raw materials results in habitat destruction, and air and water pollution. (Mehta 1998).

Several measures can be taken to minimize the environmental and human health impacts of concrete and some can result in improved performance and durability of the concrete as well. Perhaps the most important strategy is to minimize the use of Portland cement by substituting industrial by-products (e.g., fly ash, ground granulated blast furnace slag, or silica fume) or other cementitious materials for a portion of the mix. Recycled materials substituted for both coarse and fine natural aggregates will minimize use of nonrenewable materials and the environmental impacts of their excavation. (Mehta 2002)

1.3 Problem statement

In Malaysia, the construction industry generates a lot of construction waste which cause significant impacts on the environment and increasing public concern(Begum et al., 2005). Thus, the minimization of construction waste has become a pressing issue. The source of construction waste at the project site includes materials such as soil and sand, brick and blocks, concrete and aggregate, wood, metal products, roofing materials, plastic materials and packaging of products. Concrete and aggregate is the largest component with 65.8% of total waste generation (Begum et al., 2005). CO2 production has been directly linked to climate change and global warming and governments have set specific targets to reduce national emissions. Production and demolition of concrete in sites are of direct importance both in terms of the contribution

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to CO2 and energy. Environmental and human health impacts of materials are a hidden cost of our built environment. Impacts during manufacture, transport, installation, use, and disposal of construction materials can be significant, yet often invisible

1.4 Aim and Objectives

The aim of this research is estimate the impact of concrete waste in construction sites in term of energy consumption and CO2 emission:

i. To estimate the amount of energy used and CO2 emission for production of concrete in addition with transportation to the site.

ii. To determine the amount of concrete waste in construction sites.

iii. To estimate the total energy and CO2 emission based on the different weight of concrete waste on site.

iv. To evaluate the disposal option of concrete waste.

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1.5 Scope of the Study

The scope of this study is as the following:

i. Areas of study were within the building construction in U.T.M

ii. The impact indicator used in the study were limited to the energy usage and CO2 emission only. The evaluation of total impact will be based on the percentage of concrete wastage on sites.

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References

Asian Development Bank, Institute for Global Environmental Strategies and United Nations Environment Programme. (2006). Synthesis Report of 3R South Asia Expert Workshop Katmandu, Nepal.

Asian Development Bank and the Clean Air Initiative for Asian Cities (CAI-Asia) Center. (2006).Country Synthesis Report on Urban Air Quality Management: Vietnam. ADB: Philippines.

Burström P. G., 2001, *Byggnadsmaterial* Uppbyggnad, tillverkning och egenskaper, Chapter 12, Studentlitteratur, Lund

Begum, R., Siwar C., Pereira J., and Jaafar A. H. (2006). A benefit–cost analysis on the economic feasibility of construction waste minimisation: The case of Malaysia. *Resources, Conservation and Recycling*, Elsevier Science Ltd. Volume 48, Issue 1, pp. 86-98.

Björklund T. & Tillman A-M., 1997, *LCA of Building Frame Structures* Environmental Impact over the Life Cycle of Wooden and Concrete Frames, Technical Environmental Planning Report 1997:2 Chalmers University of Technology, Uppsala

Chung, J.K.O. (2000), Monitoring of solid waste in Hong Kong 1998, Environment Protection Department, Hong Kong Government.

EFCA, *Environmental Declaration Superplasticizing Admixtures*, 2002, European Federation of Concrete Admixture Associations, URL: http://www.admixtures.org.uk/downloads/xIS%Environmental%Declaration%20Supeplasticizer.

`

EIA 2001. *Annual Energy Review*: 2000, U. S. Department of Energy, EIA. August 2001.

EPA 1998. Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste, U.S. Environmental Protection Agency, Office of Solid Waste.

Franklin Associates. US EPA (1998). Characterization of Building-related Construction and Demolition debris in the United States. Retrieved date: March 13, 2007. Website: http://www.epa.gov/epaoswer/hazwaste/sqg/c&d-rpt.pdf.

Franklin Associates. US EPA (1998). Characterization of Building-related Construction and Demolition debris in the United States. Retrieved date: March 13, 2007. Website: http://www.epa.gov/epaoswer/hazwaste/sqg/c&d-rpt.pdf.

Gadja, John 2001. "Absorption of Atmospheric Carbon Dioxide by Portland Cement Concrete," Portland Cement Association, Skokie, Illinois, PCA R & D Serial No. 2255a

Gavilan, R.M. and Bernold, L.E. (1994), Source Evaluation of Solid Waste in Building Construction, *Journal of Construction Engineering and* Management 120*, 536-552.*

Graham, P. (2003). Building Ecology: First Principles for a Sustainable built Environment. UK:Blackwell Science Ltd.

Guthrie, P., Woolveridge, A.C. and Patel, V.S. (1999), *Waste minimization in construction: site guide*, London: Construction Industry Research and Information Association.

Humphreys, K., and M. Mahasenan. 2002, March. *Substudy 8:Climate Change—oward a Sustainable Cement Industry.* An Independent Study Commissioned by the World Business Council for Sustainable Development (WBCSD)

`

Jeannette Sjunnesson,2005 Life Cycle Assessment of Concrete, Master thesis

Johansson S-E., 1994, *Cement* in Betonghandbok Material, Ed ited by Ljungkrantz, Möller & Petersons, AB Svensk byggtjänst, Solna

Kulatanga, U., Amaratunga, D., Haigh, R. and Rameezden, R. (2006). Attitudes and perceptions of construction workforce on construction waste in Sri Lanka. *Management of Environmental Quality: An International Journal*. Emerald Group Publishing Ltd., United Kingdom. Vol. 17, No. 1, pp. 57-72.

Lau,H.H. et al.(2008). Composition and Characteristics of Construction Waste Generated by Residential Housing Project,*Internayional journal of environmental research.*

Li et. al (2004). Recycling concrete—an overview of development and challenges. DEMEX Consulting Engineers A/S, Denmark. Fourth International RILEM Conference on the Use of recycled Materials in Buildings and Structures, Barcelona, Spain

Lippiat, B. (2000). *BEES 1.0. Building for Environmental and Economic Sustainability.* NISTIR 6144. U.S. Department of Commerce.

Medgar, L. M., M. A. Nisbet, and M. G. Van Geem. 2006. "Life Cycle Inventory of Portland Cement Manufacture." PCA R&D Serial No. 2095b, prepared for the Portland Cement Association (PCA), Skokie, Illinois

Medgar, L. M., M. A. Nisbet, and M. G. Van Geem. 2007. "Life Cycle Inventory of Portland Cement Concrete." PCA R&D Serial No. 3011, prepared for the Portland Cement Association (PCA), Skokie, Illinois.

Mehta, P. K. 1998. The role of fly ash in sustainable development. *Concrete, Fly Ash and the Environment Proceedings,* December 8, 1998. pp. 13–25.

`

Mehta, P. K. 2002. “Greening of the Concrete Industry for Sustainable Development,” *Concrete International,* Vol. 24, No. 7, July 2002, pp. 23–28.

Mills, T.M., Showalter, E. and Jarman, D. (1999), A cost-effective waste management plan, Cost Engineering, 35-43

NTM – Nätverket för Transporter och Miljön, [2005-05-13]
www.ntm.a.se

Ofori, G., Briffett, C., Gang, G. and Ranasinghe, M. (2000). Impact of ISO 14000 on construction enterprises in Singapore. *Construction Management and Economics.* 18, pp. 935–947

Pappu, A., Saxena, M. and Asolekar, S. (2006). Solid wastes generation in India and their recycling potential in building materials. Building and Environment, Volume 42, Issue 6, pp. 2311-2320.

PCA, *U.S. and Canadian Labor-Energy Input Survey 2003*, Portland cement association, Skokie, Illinois, USA, 2005, 46 pages.

Poon, C.S., Yu, T.W. and Ng, L.H. (2001a), A Guide for Managing and Minimizing Building and Demolition Waste, The Hong Kong Polytechnic University.

Poon, C.S., Yu, A; Wong, S. and Cheung, E. (2004). Management of construction waste in public housing projects in Hong Kong. *Construction Management and Economics*. UK: Taylor and Francis Ltd. 22:7, pp. 675 – 689.

Portland Cement Association (PCA). “Concrete Thinking for a Sustainable World.” Skokie, IL: Portland Cement Association. http://www.cement.org/concretethinking/ (accessed April 14, 2006).

`

Rogoff, M. J. and Williams, J. F. (1994), Approaches to implementing solid waste recycling facilities, Noyes, Park Ridge, NJ.

Rydh C. J., Lindahl M. & Tingström J., 2002, *Livscykelanalys –en metod för miljöbedömning av produkter och tjänster*, Studentlitteratur, Lund

Stripple H., 2001, *Life Cycle Assessment of Road –A Pilot Study for Inventory Analysis*, p.48, 2nd revised Edition, IVL-report B1210E, March 2001, Gothenburg, Sweden URL: http://www.ivl.se/rapporter/pdf/B1210E.pdf

Skoyles, E.R. and Skoyles, J.R. (1987), *Waste prevention on site*, London: Mitchell.

Shen, L. Y., Tam, W. Y. Vivian, Chan, C. W. Steven and Kong, S. Y. Joseph (2002), "An examination on the waste Management practice in the local construction site", Hong Kong Surveyor 13(1), 39-48.

Snook, K., Turner, A. and Ridout, R. (1995), *Recycling waste from the construction site*, England: Chartered Institute of Building.

Tam, V. and Tam, C. (2005). A review on the viable technology for construction waste recycling. *Resources, Conservation and Recycling.* Elsevier Science Ltd. UK.

U.S. Geological Survey (USGS). 2007. "Cement." In *2005 Minerals Yearbook.* Washington, DC: USGS.

USGS 2000. "Recycled Aggregates—Profitable Resource Conservation." USGS Fact Sheet FS–181–99

Vold M. & Rønning A., 1995, *LCA of Cement and Concrete –Main report* OR 32.95 Stiftelsen Østfoldforskning, Fredriksstad, Norway

`

U.S. EPA 2002a. Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks, U.S. Environmental Protection Agency, June 2002. EPA530-R-02-006.

Wilburn and Goonan 1998, “Aggregates from natural and recycled “U.S. Geological Survey

`