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ENERGY CONTENT AND CARBON EMISSION AUDIT OF BUILDING MATERIALS

by

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A thesis submitted to University of Moratuwa

for the Degree of Master of Philosophy

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SUMMARY

The main thesis examined in this research is that "the embedded energy of construction is much more significant than the operational energy for buildings in a tropical country such as Sri Lanka".

All building elements (e.g. brickwall), materials (e.g. bricks) and "primitive" raw materials (e.g. clay) are placed in an aggregation-decomposition hierarchy. The process analysis carried out here basically captures most of the energy inputs associated with levels 1 and 2 in the IFIAS (1974) scheme, and accounts for around 90% of the embedded energy in a product. These calculations are based on Tonnes of Oil Equivalent (TOE). The data required to estimate these embedded energies were collected from building materials manufacturers.

A computerised database was implemented using a relational database management system. This can be used to represent and calculate the embedded energies and carbon coefficients of building materials and elements that are hierarchically arranged. It can also handle multiple sources of data and perform calculations to give the average, maximum and minimum embedded energies, which are also classified according to fuel type and process stage. Though the analysis was done assuming that the final building is located in the City of Colombo, these database values can be used, with some caution, for buildings even outside the Colombo City or District.

The embedded energy requirements were also calculated on the basis of the lowest quality energy (bio-equivalent energy), in addition to the more conventional basis of TOE. According to energy quality calculations carried out (based on efficiency considerations), 1 GJ of energy from electricity is equivalent to 5 GJ of biomass energy, 1 GJ of fossil fuel energy is equivalent to 1.8 GJ of biomass energy and 1 GJ of electrical energy is equivalent to 2.78 GJ of fossil fuel energy.

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It is seen that the price per unit of biomass energy based on the actual prices of products is around one third of the actual price per unit of biomass energy. For fossil fuel and electricity on the other hand, the actual prices of products are much higher than the actual prices of the energy sources used for their production.

In order to minimise adverse energy effects and to give a beneficial effect to halting global warming, policy measures to promote timber products are desirable. It is also seen that though materials which use timber fuels (e.g. bricks and tiles) consume more energy, the use of timber fuels is more competitive when compared on a bio-equivalent unit basis. Furthermore, with respect to carbon emissions, wood fuels are considered to be self-sustaining. The use of timber, whether as a construction material or a fuel, will require properly planned re-forestation strategies.

The energy contribution from walls for a typical two storey house is from 10 - 44%; for a single storey house it is from 29 - 49%. The contribution from roofs for the two storey house is from 4 - 7%, whereas it is 8 - 16% for the single storey house. The contribution from windows is 0.6 - 3% for the single storey house and 0.2 - 4.5% for the two storey house. The contribution from the floor slab for the two storey house is 6 - 7%. The above ranges are a result of the difference of the between the use of low and high energy materials.

The ratio between total embedded energy and annual operational energy for the buildings selected lies between 14 to 35 for the houses while for an office building with air-conditioning loading it is 5. Though air conditioning has a large contribution towards the annual operational energy of a building, the total number of air conditioned buildings are small for a developing country such as Sri Lanka. Nevertheless, the results of the analysis show that the focus of energy efficient designs for buildings with air conditioning has to be on the operational energy. On the other hand, for houses, which are largely not air conditioned, the way to promote efficiency is by reducing the embedded energy through the appropriate choice of building materials. This is borne out not only by the high ratio of construction to operational energy ratio obtained, but also by the fact that the ratios for

houses with low energy materials is almost half those for the houses with high energy materials.

Key Words : Embedded Energy, Process Analysis, Building Materials, Carbon Emissions, Energy Database

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DECLARATION

This thesis is a report of research carried out in the Department of Civil Engineering, University of Moratuwa, between July 1998 and March 2000. Except where references are made to other work, the contents of this thesis are original and have been carried out by the undersigned. The work has not been submitted in part or whole to any other university. This thesis contains 199 pages.

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