Key Engineering Materials *Online: 2014-02-27*
ISSN: 1662-9795, Vol. 599, pp 315-318
doi:10.4028/www.scientific.net/KEM.599.315

Life Cycle Assessment of External Thermal Insulation Composite System Based on Rock Wool Board

LI Zhu[1, a], GONG Xianzheng[1,b*], WANG Zhihong[1, c], LIU Yu[1, d],

[1]College of Materials Science and Engineering, Beijing University of Technology, 100 pingleyuan, Chaoyang district, Beijing, 100124, China

[a]tsclizhu@163.com, [b]gongxianzheng@bjut.edu.cn, [c]wangzhihong@bjut.edu.cn, [d]liuyu@bjut.edu.cn

Keywords: rock wall; external thermal insulation system; life cycle assessment

Abstract. Although external wall thermal insulation layer protects the major structure effectively and is capable of the prolonging of the service life of the structure, building thermal insulation material production brings environmental impact in some degree. In this research, quantitative analysis and evaluation of resources consumption and pollutant emission caused by materials on external wall were carried out based on Life Cycle Assessment (LCA). The results show that, environmental load brought by rock wool board production has a decisive influence on the total environmental load of the external thermal insulation system production.

Introduction

With the gradual improvement in energy conservation requirements, external thermal insulation has become a major form of energy-saving thermal insulation of walls [1]. At present, the composite system based on thermal insulation board is extensively adopted. In recent years rock wool attracted much people's attention because of its non-inflammable performance.

The way thermal insulation layer located at the outside of the structure layer of walls can reduce the energy consumption of building in its operating stage, meanwhile the production of thermal insulation material add the energy consumption of building material production. As one of the several environmental management techniques, life cycle assessment (LCA) addresses the environmental aspects and potential environmental impacts (e.g. consumption of resources and environmental consequences of releases) throughout a product's life cycle [2]. Here, a cradle-to-gate life cycle study was conducted by using data for materials of external thermal insulation composite systems (ETICS) based on rock wool board to calculate the environmental impact based on LCA theory.

Goal and scope definition

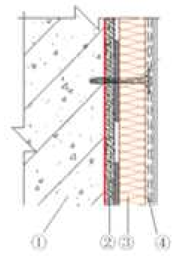
The main purpose of this research is to investigate the environmental impacts of ETICS materials production and determine how much all kinds of materials contribute to environmental performance. This article sets 1 m^2 of ETICS based on rock wool board as the functional unit. The basic structure of (ETICS) based on rock wool board were listed in Table 1.

Considering the feasibility of this study, the system boundary of life cycle assessment for product is simplified as follows:

(1)Raw material acquisition, transportation and manufacturing processes are taken into account, and shared devices such as manufacturing facilities and vehicles, infrastructure construction (factory building), are not included in this scope.

Table 1 Basic structure of ETICS

①substrate wall	②bonding layer	③thermal insulation layer	④rendering coat		
200mm Reinforced Concrete Wall	bonding mortar	rock wool board	rending mortar	Glass fiber mesh	anchors
Mass of material	8kg	17.5kg	8kg	0.2kg	0.2kg



(2) Specific production process of energy is not considered, and its environmental emission of production process is added to relevant process according to its consumption.

(3) Though noise, raised dust, sewerage and garbage emitted in the course of construction have some influence on environment, these pollutions are not calculated in this study. Since it is unavailable to obtain the date, and environmental load is relative small.

Life cycle inventory analysis

Data of resource and energy input is referenced from published dissertation and literature. The electric power used in production processes is mainly supplied by a national power grid. The emission factors of power plants were obtained from the data based on the situation of China, and the inventory comes from Di[3].The inventory of other energy production is obtained from achievements of Yuan[4]. Part of the transport distance data is obtained from the survey, other's was assumed to be 182 km (the average transportation distance of road transportation for goods in 2011). The environmental inventory of transportation is cited from achievements of Ma [5].

Environmental emissions involved in the case are CO_2, CO, CH_4, SO_2, NO_X, NMVOC, particulates and COD. Data on liquid emissions except COD are unavailable because they are beyond the control of producers, and the impact of liquid waste will not be taken into consideration. Bulk solid waste mainly consists of rejected product which may become toxic at low levels to human beings and environment, environmental impact of bulk waste could be ignored.

(1) Rock wool board is the main body of ETICS. Raw material is basalt, and slag is used as auxiliary material. Energy consumed is coke, diesel and electric power. The inventory of main resources and energy consumption per ton: 485kg coke, 55kg diesel oil, 365kWh electric power.

(2) Polymer modified mortars added re-dispersible powder is often used in bonding mortar and rendering coat mortar. Dry-mixed mortar is composed of binding material (cement), mineral admixtures (ground calcium carbonate), fine aggregate (sand), cellulose ester and re-dispersible powder. The production of dry-mixed mortar in factory can be divided into three steps: the pre-treatment of raw materials, batching and mechanical mixture. Energy consumption in this process is 12kg coal and 4.7kWh electric power per ton.

(3) Alkali-resistant glass fiber mesh is used as reinforcing material of mortar for tensile strength, flexural strength and impact strength. It is reported that both energy resource consumed and greenhouse gases emitted in process of continue glass fiber products mainly focus on the stage of glass melting. However, the downstream process of products used by end users had a fairly limited role. Thus inventory of glass fiber mesh is instead of inventory of glass produced by Direct-melting Process.

(4) It is necessary to use mechanical fixings to ensure the system's reliability. Generally, anchor in ETICS is composed of two parts, expansion element with plate anchor and screw. Expansion element is made of plastic such as polyamide, polyethylene and polypropylene, recycled materials can't be used. The material quality of screw is stainless steel. Its environmental burden

inventory refers to achievements of Zhou [6]. While plastic accounts for a very little share of anchor compared to steel, environmental load caused by expansion element was ignored.

The life cycle inventory results for external thermal insulation composite system based on rock wool board (ETICS) were illustrated in Table 2.

Table 2 Life cycle emissions inventory of ETICS

item	unit	rock wool	bonding mortar	rendering coat mortar	glass fiber mesh	anchors	total
CO_2	[kg]	3.92E+01	2.65E+00	2.18E+00	1.29E-01	3.48E-01	4.45E+01
SO_2	[kg]	6.35E-02	8.23E-03	7.11E-03	1.05E-03	5.31E-04	8.04E-02
NOx	[kg]	1.24E-01	1.01E-01	1.11E-01	2.36E-03	1.24E-04	3.38E-01
CO	[kg]	7.98E-02	7.72E-02	8.54E-02	1.85E-04	2.95E-05	2.43E-01
CH_4	[kg]	1.54E-02	6.17E-03	5.31E-03			2.68E-02
NMVOC	[kg]	4.93E-03	1.38E-02	1.49E-02			3.36E-02
PM	[kg]	1.26E+00	1.53E-01	1.53E-01	9.58E-04	8.16E-04	1.57E+00
COD	[kg]	6.07E-04	3.11E-05	3.10E-05			6.69E-04

Life cycle impact assessment

The life cycle assessment approach, developed by the Institute of Environmental Sciences (CML) of Leiden University, was used in this study. The impact assessment method consists of characterization, and normalization [7,8]. Given the scope of this case study and relevant LCI, the environmental impact categories considered were as follows: depletion of abiotic resources (ADP), global warming (GWP), acidification (AP), human toxicity (HT), photochemical (POCP), and eutrification (EP). The normalization results were listed in Table 3.

Table 3 Environmental impact indicators for rock wool board and EPS board

item	rock wool	bonding mortar	rendering coat mortar	glass fiber mesh	anchors	total
ADP	1.26E-14	2.34E-13	2.61E-13	9.11E-16	1.71E-15	5.10E-13
GWP	1.03E-12	7.19E-14	5.93E-14	3.35E-15	1.13E-14	1.17E-12
AP	8.89E-12	2.65E-13	2.84E-13	9.05E-15	2.58E-15	9.45E-12
POCP	2.40E-13	2.69E-13	2.90E-13	2.67E-15	8.17E-16	8.02E-13
HT	2.36E-14	4.97E-15	5.21E-15	7.47E-17	2.19E-17	3.39E-14
NP	1.24E-13	1.02E-13	1.12E-13	2.38E-15	1.57E-16	3.41E-13

Results and discussion

AP is the most serious environmental impact, then GWP, HT follow behind, and rock wool board contributes 94%, 87%, 70% respectively. The reason is that there is more fossil fuel used in the rock wool production, which lead to the large amount of CO_2 emission, while CO_2 is the major gas to cause greenhouse effect in materials production. The gases that contribute to acidification were mainly SO_2 and NO_X. These two kinds of gas emission also owe to fossil fuel combustion.

Almost all of ADP comes from dry-mixed mortar process, approximately 97%. This result owing to there is much industrial slag used as raw material in the process of rock wool board, and consequently, natural resource is saved in some degree. Cement and natural sand is prime component of mortar. Natural sand is a kind of non-renewable resources. Cement manufacturing is a process that vast resources be consumed, meanwhile numerous noxious gas emitted to environment. Then relevant environmental impact was raised accordingly. In addition, dry-mixed mortar is to blame for POCP and NP, 69% and 62%.

Conclusions

This study explored the rock wool board external thermal insulation on external walls, and calculated the life cycle environmental impact of $1m^2$ ETICS. The main conclusions can be drawn from this study are as follows:

(1) The most serious is AP, whose normalization result is 9.45E-12, which accounts for 76% in the total environmental impact. Then GWP and POCP are close behind, and the normalization result is 1.17E-12, 8.02E-13 respectively.

(2) Rock wool board, as the main component of ETICS, makes the most contribution in the environmental impact, which takes up 83% in the overall result. Environmental impact brought in dry-mixed mortar occupies 16%. The sum of glass fiber mesh and anchors only takes up less 1%,which can be neglected.

(3) The normalization result of ADP is 5.10E-13; almost all of it comes from dry-mixed mortar.

Acknowledgments

This work is supported by *National Key Technology Research and Development Program of China (Grant No. 2011BAJ04B06-02)*, *National High Technology Research and Development Program of China ("863" Program, Grant No. 2013AA031602)*, *The Project of Construction of Innovative Teams and Teacher Career Development for Universities and Colleges Under Beijing Municipality (No. 009000543113530)*. The authors thank the reviewer for the valuable comments.

References

[1] D. W. Long, G. Y. Bao, External Wall Thermal Insulating Technology and materials, J. Chinese and Overseas Architecture. 5 (2006) 193-194

[2] ISO International Standard 14040.Environmental management Life cycle assessment Principles and framework, S. Geneva: International Organization for Standardization (ISO). (2006)

[3] X.H. Di, Z. R. Nie, B. R. Yuan, et al. Life Cycle Inventory for Electricity Generation in China, J. Int J LCA. 12 (2007) 217-224

[4] B. R. Yuan, Measurement Method for Sustainable Development of Chemical Industry and Its Application, D. Ph.D. Dissertation of Beijing University of Technology. (2006) 93-94

[5] L. P. Ma, Z.H. Wang, X.Z. Gong, et al. Life Cycle Inventory Analysis of Two Types of Freight Transport on City Roads, J. Progress in Materials Science and Engineering 2006.

[6] H. M. Zhou. Life Cycle Assessment on Iron and Steel Processes, D. Ph.D. Dissertation of Beijing University of Technology. (2001) 242

[7] F. Gao, Z. R. NIE, Z. H. Wang, eta. Characterization and normalization factors of abiotic resource depletion for life cycle impact assessment in China. Science in China Series E: Technological Sciences. 52 (2009) 215-222

[8] Jeroen B, eta. Life cycle assessment An operational guide to the ISO standards, S. Dordrecht: Kluwer Academic Publishers. (2001)