

Life Cycle Assessment of IBS in Malaysia and Comparing Human Health on Timber and Concrete Pre-cast

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Abstract: The aim of this study is determining the life cycle assessment of IBS and compares the environmental impacts of building. There are two different kinds of structure has been assessed in this project namely: Timber prefabricate and concrete pre-cast. IBS is a prefabricated structure which component manufacturing in the factory and then transfer to site work for erect. Timbers prefabricate and concrete pre-cast is compared from the initial stage of extracting material to end of life. The method of LCIA in the project is Impact 2002. This project reveals that the total environmental impact of Timber prefabricated is lower than concrete pre-cast in both manufacturing and use phase 100 year life cycle of IBS. Secondly global warming and ozone layer depletion emissions from timber are also much lower than concrete.

Keywords: Concrete pre-cast, IBS, impact 2002, life cycle assessment, timber pre-cast

INTRODUCTION

IBS began in the early 1960s when ministry of local government visited several European countries and evaluate their housing development program, (Thanoon *et al.*, 2003). IBS was introduced as a construction system which components are manufactured in the factory and Assembled with minimal labor and site work. Lessing *et al.* (2005) defined IBS as an integrated manufacturing and construction process with well planned organization for efficient management, preparation and control over the resources used, activities and results supported by the used of highly developed components. Today, climate change and resource scarcity, combine with the need of cleaner environment to have an ever growing economy threaten our ability to reach this goal. To mitigate climate change, the world needs to reduce the CO₂ emission by 50% from the current level by 2050. For developed countries, this translates into a reduction of 80%, a factor five with respect to nowadays emissions to reach this goal, some authors have proposed to intensely reduce the energy consumption. As with the residential sector, the government has taken initiatives to reduce the energy intensity of commercial and residential buildings.

LCA is a relatively young method that became popular in the early nineties. Initially many people thought that LCA would be a good tool to support environmental claims that could directly be used in

marketing. Over the years, it has become clear that this is not the best application of LCA, although it is clearly important to communicate LCA results in a careful and well-balanced way. Life-cycle Assessment is a method for quantifying the environmental impact of the life-cycle of individual products or services from cradle to grave. LCA was developed in the early nineties and is, in contrast to IOA, a bottom up approach. LCA uses physical-chemical data at the process level. Life cycle assessment generally compares two products or system from cradle to grave, in this search focused from extract material from nature to demolish the product or reuse and in this study all waste which could be emission to air, emission to water and emission to soil will be considered.

According to Boyle (2004) the world's fossil energy consumption rate has reached 82%. The over use of fossil energy is the main contributor towards global climate change (USEPA (United States Environmental Protection Agency), 2010); the increasing of using fossil energy consumption contributes to global climate change consequently increasing CO₂ emission and more pollution. To eliminate of more CO₂ emission has to consider building more sustainability house and material which can result of less global warming. The Malaysian government has launched a few projects to act as a demonstration, educational and enhance public awareness programs (Ahmed, 2008). Malaysia Green Technology Corporation office building is one of the showcase projects that have high performance in its energy efficiency.

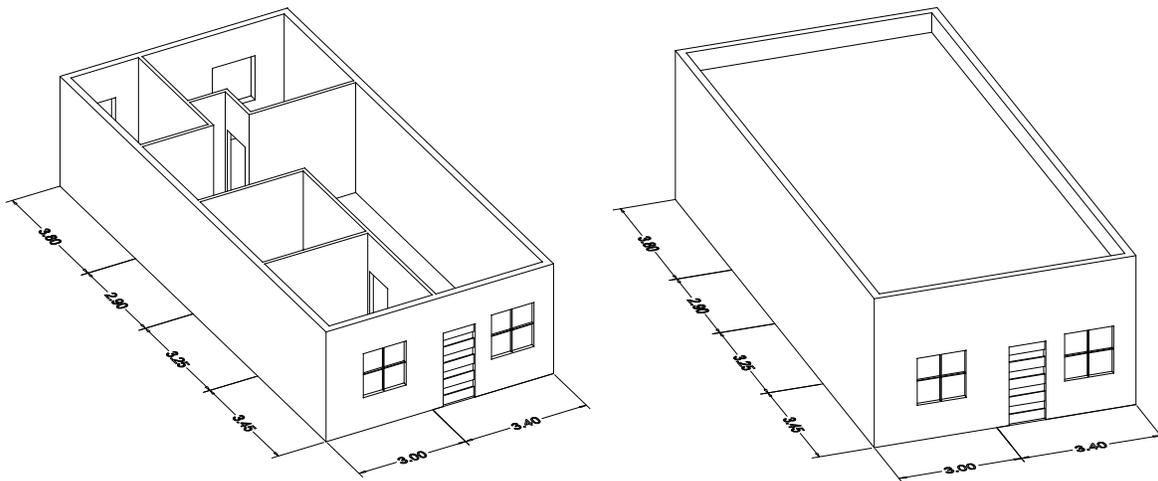


Fig. 1: Architectural model of the single-family house in Johor

Table 1: Description of concrete framing component

Building component	Area (m ²)
Roof-surface	293
Wall-surface	208
Wood-volum	1.34
Wood-mass	1.03E3
Concrete-mass	3.21E3

The development of human health in a building is important, because the increase of building non sustainable material contributes to the higher release of greenhouse gasses compared to other sectors. The collected data was conducted on a case study which is a house in Johor Bahru in Malaysia (Fig. 1).

The building has accumulated in this project is built round 25 years ago, the parameters which contributors are included Size and Shape, Orientation, Window systems and Construction detailing (Table 1) on the building.

Embodied energy represents the energy used for producing building materials (from the extraction of the raw materials to the manufacture of the final product, including transportation) and their implementations in the building. The total embodied energy comprises a direct component (the energy consumed directly at each phase) and an indirect component (the energy required indirectly to support the main process which is less obvious and more difficult to measure).

LITERATURE REVIEW

The Life Cycle Assessment (LCA) methodology is used in this project to assess the environmental impacts of two different IBS (Industrial Building System) frame over the 100 year life cycle in Malaysia. Determining the quantity of consumption of the energy and material resources during the life cycle of IBS building allows

the estimate the harmful emission on human health into the environment.

The basic concept and principles of the LCA are not new and in the 1970s the theory was used to analyze the life cycle of fuels. LCA studies conducted for building mainly focus on energy requirements and greenhouse gas emissions, just a small number of recent LCA have focused multiple environmental impact or even Life-Cycle Impact Assessment (LCIA) methods with non-comparable or inconsistent conclusions. Some research accomplished in different type of exterior wall to determine the one of those is more sustainable, for instance Helena and Fausto (2011) determine that the wood exterior wall is more sustainable friendly. Barbara *et al.* (2012) accomplished the Life-cycle assessment of residential buildings in three different European locations. Another study about LCA has accomplished by Iyer-Raniga and Wong (2012) about Evaluation of whole life cycle assessment for heritage buildings in Australia.

Werner and Richter (2007) found that wood products are believed to have a favorable environmental performance, especially with respect to energy consumption and also contributes to greenhouse gas emissions, than products having the same function but made out of other materials. Buchanan and Levine (1999), shows that the wood building requires much lower process energy and result in lower carbon emissions than building of other material such as brick.

System boundary: In this project avoided from human activity such as cooking and using water heaters on building through the use phase and also lighting because based on the assumption of this project these effects would be the same on both IBS frame and

there by only considering on extraction the raw material, transfer it to manufacturing and erected to site. The aim of this project is considering to life cycle of concrete frame and timber frame and find out which one is more environmentally friendly and also survey human health through the whole life cycle of a building. The objectives of this study are thus to examine the current situation of energy conservation of buildings and carbon dioxide emission in Malaysia.

Impact assessment methods: The impact assessment method structures comprising of four steps which consist of Characterization, Damage assessment, Normalization and Weighting and the last three steps are described and follow base on the ISO standard. Damage assessment is a proportionately new on impact assessment. The purpose of damage assessment is to combine a number of impact category indicators into a damage category. For example, in the Impact 2002 method, all impact categories that refer to Human health are expressed in DALY (Disability Adjusted Life Years). In this method it is allowed to add DALYs caused by carcinogenic substances to DALYs caused by climate change.

LCA METHODOLOGY AND LCIA METHOD

Life-Cycle Assessment (LCA) has four mutually dependent phases: goal and scope definition; Life-Cycle Inventory (LCI); Life-Cycle Impact Assessment (LCIA) and interpretation. The first step is the goal of life cycle assessment, any assess of environmental should have proper scope that clarifies why this assessment should be considered.

Life cycle inventory in Simapro is list of emissions to water, air and soil and raw materials which extract from nature for related purposes. The LCIA is aiming to calculate and evaluate the result from LCI. In the LCIA, inventory data is accumulated into specific environmental impact categories according to a method and Different LCIA methods will lead to a different result because any method has a different value, impact assessment and also unites. LCIA methods can be single-categorized and also multi-category.

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DALY: The project by De Schryver *et al.* (2009) tried to introduce human health damage in DALY's per unit

Table 2: Impact assessment category-table

Impact 2002	Unit
Carcinogens	DALY
Non-carcinogens	DALY
Respiratory in-organics	DALY
Ionizing radiation	DALY
Ozone layer depletion	DALY
Respiratory organics	DALY
Aquatic eco-toxicity	Under development
Terrestrial eco-toxicity	PDF * m ² * year
Terrestrial acid/Nutri	PDF * m ² * year
Land occupation	PDF * m ² * year
Global warming	(kgeq CO ₂ into air)
Non-renewable energy	MJ
Mineral extraction	MJ

GHG emissions related to some disease and unhealthiness such as malaria, diarrhea, malnutrition, drowning and cardio-vascular therefore DALY using to represent the emissions from materials to nature as a holistic unit. DALY expressed as the number of years of life lost (mortality and morbidity). This unit was used in recent research and Rosser (1987) was used it for decision support in the UK health system. This is the weighted sum of the years living disabled as a result of an illness and the years of life lost as a result of mortality. Life cycle assessments basically assess damage to human health by using the concept of 'Disability-Adjusted Life Years' (DALY). Hofstetter (1998) introduced this indicator to LCA. The DALY of a disease is extracted human health statistics on life years both lost and disabled. The range of disability-adjusted life years have been discussed in a wide range of diseases, including various cancer types, vector-borne diseases and non-communicable diseases.

DALY is represented as the sum of the Years of Life Lost which describe it by (YLL) and Years of Life Disabled that describe it by (YLD). The sum of those two units (YLL + YLD) will be introduced as DALY. If this unit shows higher means the damage to human health is higher. Table 2 represents the midpoint and emissions categories in the environment.

Goals and scope: The purpose of this project determines the quantity of emissions released from timber prefabricate and concrete pre-cast building meanwhile global warming, ozone layer depletion emission to environment by both structures. Secondly which of those building release less damage emissions on human health? The scope of study focused on IBS building in Malaysia and concentrate on human health issues, by comparing the emissions of the pre-cast frame. Table 1 shows the mass amounts of materials for building.

RESULTS AND DISCUSSION

The aim of doing LCA is to find the lowest environmental impact solution for building and also

Table 3: Damage assessment on human health by timber pre-cast

Substance	Compartment	Unit	Total	Timber	Paint	Nail	Sealing	Transport
Total		DALY	3.72E-5	1.47E-5	6.98E-6	6.155E-6	5.93E-6	3.41E-6
Remaining substance		DALY	6.29E-6	1.66E-6	9.59E-7	2.15E-6	7.27E-7	7.98E-7
Nitrogen oxides	Air	DALY	2.09E-5	1.24E-5	2.41E-6	2.26E-6	1.64E-6	2.19E-6
Particulates <2.5 um	Air	DALY	2.71E-6	-	1.24E-6	-	1.47E-6	-
Sulfur dioxide	Air	DALY	4.68E-6	2.15E-7	2.37E-6	-	2.09E-6	-
Sulfur oxides	Air	DALY	2.6E-6	4.27E-7	-	1.75E-6	-	4.26E-7

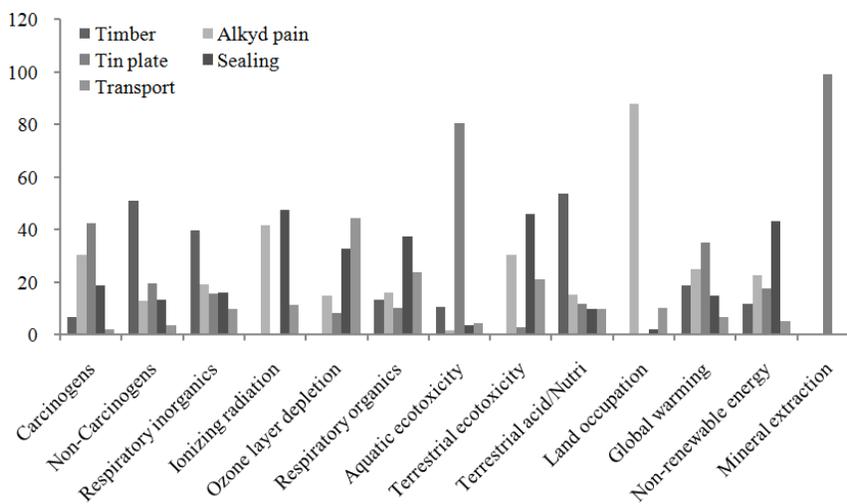


Fig. 2: Determined the life cycle inventory of timber pre-cast

lower emission on damage human health and for acquiring this aim LCA calculated the energy consumption and environmental emissions such as CO₂, NO₂, CFC-11 and etc.

Impact 2002: The life cycle impact assessment methodology IMPACT 2002+ suggested a possible implementation of midpoint/damage approach, connecting all types of life cycle inventory results via 14 midpoint categories to four damage categories. IMPACT 2002+ considered 14 midpoint categories, namely: human toxicity₁, respiratory effects (due to inorganics), ionizing radiation, ozone layer depletion, photochemical oxidation, aquatic eco-toxicity, terrestrial eco-toxicity, aquatic acidification, aquatic eutrophication, terrestrial acidification/nitrification, land occupation, global warming, non-renewable energy consumption and mineral extraction. All midpoints related to the four damage categories human health, ecosystem quality, climate change and resources which in this study only focus on human health.

Table 3 shows the damage assessment on human health by cut 5%. All the emissions released to air from manufacturing phase and total amount is 3.72E-5 DALY. The emissions consist of Remaining substance, Carbon dioxide, land transformation, Nitrogen oxides,

Particulates >2.5 and <10 um and Sulfur dioxide. Timber has a higher impact on human health by 1.47E-5 DALY in the construction phase.

Figure 2 illustrated the 14 midpoint categories, the first six impacts have an effect on human health which namely: Carcinogens, Non-Carcinogens, Respiratory inorganics, Ionizing radiation, Ozone layer depletion and Respiratory organics. The timber has effect on all categories except Ionizing radiation and Ozone layer, the highest effect on human health occurred on Non-Carcinogens 1.57E-6 DALY and the lower effect on Carcinogens by 7.81E-8. Figure 2 shows the effect of all components of a building such as nail, wood, painting transportation of timber frame and roof sealing. Painting also has a significant effect in all midpoint categories and has a high amount of Ionizing radiation by 5.02E-8 DALY while tin plate (nail to attach the timber frames) which used to attach timber plate to each other doesn't have any infection on human health in Ionizing radiation categories. The most damage emissions on human health occur on Non-Carcinogens by 3.08E-6 DALY and the lower damage on Respiratory organics 7.27E-8 DALY.

Table 4 shoes Damage assessment on human health by concrete pre-cast in the manufacturing phase of building and also transfer it to site. To accomplish the

Table 4: Damage assessment on human health by concrete pre-cast

Substance	Compartment	Unit	Total	Concrete	Alkyd	Transport
Total		DALY	0.000107	9.46E-5	9.98E-6	5.51E-6
Remaining substance		DALY	4.48E-6	2.87E-6	9.59E-7	6.46E-7
Nitrogen oxides	Air	DALY	8.27E-5	7.54E-5	2.41E-6	4.87E-6
Particulates, <2.5 um	Air	DALY	7.2E-6	5.95E-6	1.24E-6	-
Sulfur dioxide	Air	DALY	1.28E-6	1.04E-5	2.37E-6	-

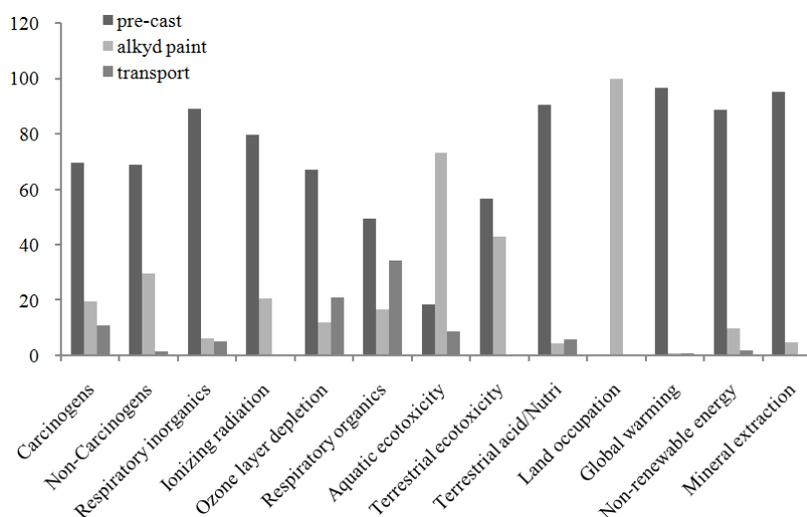


Fig. 3: Concrete pre-cast

Table 5: Comparison of construction phase

Substance	Compartment	Unit	Timber	Pre-cast concrete
Total		DALY	3.72E-5	0.000107
Remaining substance		DALY	8.89E-6	4.48E-6
Nitrogen oxides	Air	DALY	2.09E-5	8.27E-5
Particulates, <2.5 um	Air	DALY	2.71E-6	7.2E-6
Sulfur dioxide	Air	DALY	4.68E-6	1.28E-5

Table 6: Comparison of use phase

Substance	Compartment	Unit	Timber	Pre-cast concrete
Total		DALY	4.23E-5	0.00022
Remaining substance		DALY	1.08E-5	6.84E-6
Nitrogen oxides	Air	DALY	2.41E-5	0.000126
Particulates, <2.5 um	Air	DALY	2.73E-6	7.04E-5
Sulfur dioxide	Air	DALY	4.68E-6	1.64E-5

concrete pre-cast concrete paint and transport to site calculated. As can be seen, Concrete has a higher effect on human health damage by 9.46E-5 DALY and all the emissions of the building happened to air namely: Nitrogen oxides, Particulates, <2.5 um, and Sulfur dioxide this emission are nominated by the 5% cutoff to reveal most significant categories of emissions. Table 4 only presented the emission effect on human health on concrete pre-cast in construction phase.

Figure 3 shows present the environmental effect of concrete pre-cast in all 14 midpoint categories but only

the first six categories (as already mentioned) effected on human health which can see the concrete has a significant amount on human health the paint and transport relatively has a lower effect in the bellow graph on human health. The highest amount of bellow calculation occurred on Respiratory inorganics 0.000104 DALY and the lowest is on Ozone layer depletion 1.32E-8 DALY.

Compare timber and concrete: Table 5 present the comparison result between pre-cast timber and pre-cast concrete on Construction phase and effect emissions on human health. As can be seen, pre-cast concrete has a higher emission to air and damage environment impact. The highest effect on midpoint categories happened to Respiratory inorganics which is 3.27E-5 and 0.00104 DALY, respectively for pre-cast timber and pre-cast concrete and total amount on human health are respectively 3.72E-5 DALY 0.000107 DALY for pre-cast timber and pre-cast concrete.

Table 6 present that the both buildings in use phase after maintenance and reuse and retrofit of buildings which all needs energy and material to accomplish it. As can be seen, pre-cast concrete has a higher impact to temper and all emissions occurred in the air about 100 years of the life cycle of buildings. The same as

Construction phase the main damage on human health care on Respiratory inorganics midpoint by $3.62E-5$ and 0.000214 respectively for Timber and Concrete pre-cast. One point is the damage to the ozone layer in pre-cast and timber has a significantly high 44.8 and 448 kg CO_2 eq but this damage has not related to human health and just because this reason it's not mentioned in this study. To compare the Table 5 to 6 can easily find out that the emission on human health in Use phase has a slightly higher to Construction phase while in both table pre-cast concrete has most damage assessments on human health.

CONCLUSION

A life-cycle model has been implemented for a Malaysian single- family house with three bedrooms and by two different frame timber and concrete have been comparatively assessed in order to selection of more sustainability pre-cast material. To assess the building LC performance Impact 2002+ (Life-Cycle Impact Assessment (LCIA)) have been used. This study has been performed for hot and humid climate.

To compare the Fig. 2 and 3 reveals that the Timber has a lower emission to global warming and ozone layer depletion on timber then concrete pre-cast. Regarding the comparison of results from two pre-cast frame presents timber has lower damage on human health in both construction phase and use phase up to 100 years of the life cycle of a building. This research proves that timber is the solution to more environmental friendly to human and therefore would be the best choice of pre cast.

REFERENCES

Ahmed, A.Z., 2008. Integrating sustainable energy in buildings: A case study in Malaysia. Proceedings of the FAU Conference. Copenhagen, Denmark.
Barbara, R., M. Anne-Françoise, G. Mauritz and R. Sigrid, 2012. Life-cycle assessment of residential buildings in three different European locations, basic tool. *Build. Environ.*, 51(2012): 395e401.

Boyle, G., 2004. *Renewable Energy: Power for a Sustainable Future*. 2nd Edn., Oxford University, Press, Oxford (Chapter 1).
Buchanan, A.H. and S.B. Levine, 1999. Wood-based building materials and atmospheric carbon emissions. *Environ. Sci. Policy*, 2(6): 427-437.
De Schryver, A.M., K.W. Brakkee, M.J. Goedkoop and M.A.J. Huijbregts. 2009. Characterization factors for global warming in life cycle assessment based on damages to humans and ecosystems. *Environ. Sci. Technol.*, 43: 1689-1695.
Helena, M. and F. Fausto, 2011. Environmental life-cycle impacts of a single-family house in Portugal: Assessing alternative exterior walls with two methods. *GU J. Sci.*, 24(3): 527-534.
Hofstetter, P., 1998. *Perspectives in Life Cycle Impact Assessment: A Structured Approach to Combine Models of the Technosphere, Ecosphere and Valuesphere*. Kluwer Academic Publishers, Boston.
Iyer-Raniga, U. and J.P.C. Wong, 2012. Evaluation of whole life cycle assessment for heritage buildings in Australia. *Build. Environ.*, 47(2012): 138-149.
Lessing, J., L. Stehn and A. Ekholm, 2005. Industrialised housing: Definition and categorization of the concept. *Proceeding of 13th International Group of Lean Construction Conference (IGLCC, 2005)*. Sydney, Australia.
Rosser, R., 1987. A Health Index and Output Measure. In: Walker, S. and R. Rosser (Eds.), *Quality of Life: Assessment and Application*. MTP Press Ltd., Lancaster, England.
Thanoon, W.A.M., L.W. Peng, M.R. Abdul Kadir, M.S. Jaafar and M.S. Salit, 2003. The experiences of Malaysia and other countries in industrialised building system in Malaysia *Proceeding of International Conference on Industrialised Building Systems*. Kuala Lumpur, Malaysia, September 10-11.
USEPA (United States Environmental Protection Agency), 2010. *Climate Change: Greenhouse Gas Emissions*. Retrieved from: <http://www.epa.gov/climatechange/emissions/index.html#ggo>.
Werner, F. and K. Richter, 2007. Wooden building products in comparative LCA. *Int. J. Life Cycle Assessment*, 12(7): 470-479.